INTRODUCTION

Jeff Jasper
Agenda

• Background/Overview
• Prequalification
• Resources
Traffic Engineering

• What is Traffic Engineering Design?

• Size Roadways, Intersections, Interchanges

• Develop Innovative Solutions
Purpose of Traffic Engineering

• Intended Use
  • Purpose and Need identifies Capacity and/or safety concerns
  • May be used in other instances
  • One of many inputs to decision making process

Inform & Document Decision Making Process
Kentucky’s Roadway System

- 4-Lane Roadways < 10,000 ADT
  - 741 miles

- 4-Lane Roadways < 5,000 ADT
  - 116 miles
Traffic Engineering Costs

• Typical Traffic Engineering Cost
  • $5,000-$10,000 per Intersection

• Approximate Cost for 1 Turn Lane
  • $25,000-$50,000

• 2-Lane Facility $7M; 4-Lane Facility $22M
Policies

- Design Memos
  - Design 03-11; Traffic Engineering Analysis
  - Design, Permits, Traffic 03-09; Auxiliary Turn Lane Policy
  - Design 03-10; Roundabout Analysis
Prequalification

Advanced Traffic Engineering Design and Modeling

Determine if a firm has the capability to perform advanced traffic engineering analysis for roadway design projects, including microsimulation and corridor signal analysis.

• The firm must have at least one full-time staff member registered as a Professional Traffic Operations Engineer (PTOE) or equivalent experience.

• Demonstrate experience in:
  • Signal Systems Operations
  • Microsimulation Modeling
TRAFFIC ENGINEERING
DESIGN PROCESS

Adam Kirk
Design Process

1. Determine Basic Number of Lanes
2. Determine Auxiliary Lanes
3. Intersection Type/Size (Signal, Stop, Roundabout)
4. Analyze/ Evaluate
Design Process

Determine Basic Number of Lanes

Determine Auxiliary Lanes

Intersection Type/Size (Signal, Stop, Roundabout)

Analyze/Evaluate
Basic Number of Lanes

Calculate Volume to Capacity Ratio (V/C)

- **Targeted** V/C
  - 1.0 Urban Areas
  - 0.9 Rural Areas

- Document if V/C less than
  - 0.8 Urban Areas
  - 0.7 Rural Areas
### Why V/C Ratio?

#### Exhibit 2-2

HCM Service Measures by System Element and Mode

<table>
<thead>
<tr>
<th>System Element</th>
<th>HCM Chapter</th>
<th>Service Measure(s)</th>
<th>Systems Analysis Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway facility</td>
<td>10</td>
<td>Automobile: Density</td>
<td>Speed</td>
</tr>
<tr>
<td>Basic freeway segment</td>
<td>11</td>
<td>Density</td>
<td>Speed</td>
</tr>
<tr>
<td>Freeway weaving segment</td>
<td>12</td>
<td>Density</td>
<td>Speed</td>
</tr>
<tr>
<td>Freeway merge and diverge segments</td>
<td>13</td>
<td>Density</td>
<td>Speed</td>
</tr>
<tr>
<td>Multilane highway</td>
<td>14</td>
<td>Density, LOS score&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Speed</td>
</tr>
<tr>
<td>Two-lane highway</td>
<td>15</td>
<td>Density,Percent time-spent-following speed, LOS score&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Speed</td>
</tr>
<tr>
<td>Urban street facility</td>
<td>16</td>
<td>Speed, LOS score&lt;sup&gt;a&lt;/sup&gt;, LOS score&lt;sup&gt;a&lt;/sup&gt;, LOS score&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Speed</td>
</tr>
<tr>
<td>Urban street segment</td>
<td>17</td>
<td>Speed, LOS score&lt;sup&gt;a&lt;/sup&gt;, LOS score&lt;sup&gt;a&lt;/sup&gt;, LOS score&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Speed</td>
</tr>
<tr>
<td>Signalized intersection</td>
<td>18</td>
<td>Delay, LOS score&lt;sup&gt;a&lt;/sup&gt;, LOS score&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Delay</td>
</tr>
<tr>
<td>Two-way stop</td>
<td>19</td>
<td>Delay, Delay</td>
<td>Delay</td>
</tr>
<tr>
<td>All-way stop</td>
<td>20</td>
<td>Delay, Delay</td>
<td>Delay</td>
</tr>
<tr>
<td>Roundabout</td>
<td>21</td>
<td>Delay, Delay</td>
<td>Delay</td>
</tr>
<tr>
<td>Interchange ramp terminal</td>
<td>22</td>
<td>Delay, Delay</td>
<td>Delay</td>
</tr>
<tr>
<td>Off-street pedestrian—bicycle facility</td>
<td>23</td>
<td>--, Space, events&lt;sup&gt;b&lt;/sup&gt;, LOS score&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Speed</td>
</tr>
</tbody>
</table>

Notes:

<sup>a</sup> See Exhibit 2-3 for the LOS score components.

<sup>b</sup> Events are situations where pedestrians meet bicyclists.
Basic Number of Lanes

Determined by Roadway Capacity

- **2-Lane Facility:**
  - 1700 vphpl; 3200 vphpl (both directions)

- **Multi-lane Facility**
  - 2000 vphpl

- **Interstate**
  - 2300 vphpl

- **Signalized Intersection**
  - 1900 vphplphg
Analysis Scenarios

- Design Year Analysis (20 Year)
  - Current Year analysis can be used to calibrate models
  - Interim Analysis may be useful (Incremental Improvements)

- AM and PM Peak Hours

- Requires Traffic Forecasting (Division of Planning)
Example

- Suburban Roadway Project
- 30,000 AADT Design Year Volume
- Peak Hour Factor \((K) = 0.09\)
- Directional Factor \((D) = 0.6\)
- PHF = 0.95

- How many lanes??
Example

- 30,000 ADT
- Peak Hour Factor (K) = 0.09
- Peak Hour Volume = 2700 vph
- Directional Factor (D) = 0.6
- Directional Volume = 1620/0.95 = 1705
- V/C (2-Lane) = 1705/1700 = 1.01

- V/C (4-Lane) = 1700/4000 = 0.425
AUXILIARY LANES
Design Process

1. Determine Basic Number of Lanes
2. Determine Auxiliary Lanes
3. Intersection Type/Size (Signal, Stop, Roundabout)
4. Analyze/Evaluate
LEFT-TURN LANE WARRANTS

• Uncontrolled Approaches
  • Left-turn lanes shall be provided at median openings on divided roadways
  • Left-turn lanes shall be provided if traffic volumes at the intersection meet the thresholds identified in Figures 1 and 2.
  • Left-turn lanes should be considered as a safety countermeasure, e.g. where sight distance of approaching traffic is limited.
LEFT-TURN LANE WARRANTS

- 2 Graphs measure probability of stopped vehicle blocking lane
  - ≤ 45 MPH (P = 0.02)
  - >45 MPH (P = 0.01)
LEFT-TURN LANE WARRANTS

• Inputs
  • \( L = \text{Percent Left-Turns} \)
  • Advancing Volume = Through + Left + Right-Turn Traffic
  • Opposing Volume = Through + Left + Right-Turn Opposing Traffic
LEFT-TURN LANE WARRANTS

\[ L = \text{Percent Left-Turns} \]
\[ = \frac{32 + 372 + 40}{32 + 372 + 40 + 40 + 500 + 71} \]
\[ = 0.07 \]

Advancing Traffic
\[ = 32 + 372 + 40 \]
\[ = 444 \]

Opposing Traffic
\[ = 40 + 500 + 71 \]
\[ = 611 \]
LEFT-TURN LANE WARRANTS

![Graph showing left-turn lane warrants with advancing and opposing volumes and various percentages labeled on the lines.](image-url)
LEFT-TURN LANE DESIGN

- Turn Lane Length
  - Deceleration Length
  - Storage Length
LEFT-TURN LANE DESIGN

• Turn Lane Length

<table>
<thead>
<tr>
<th>Approach Control</th>
<th>Turn Type</th>
<th>Turn Lane Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled</td>
<td>Left-Turn</td>
<td>Greater of Method 1&lt;sup&gt;A&lt;/sup&gt; or Method 2&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Stop Controlled</td>
<td>Left-Turn</td>
<td>Storage + Bay Taper</td>
</tr>
<tr>
<td>Signal Control&lt;sup&gt;B&lt;/sup&gt;</td>
<td>Left-Turn</td>
<td>Greater of Method 1 or Method 2</td>
</tr>
</tbody>
</table>

Notes:  
A: See Table 2 below.  
B: At signalized intersections the length of turn lanes should be extended so that it is not blocked by the queue of adjacent through traffic.
LEFT-TURN LANE DESIGN

• Turn Lane Length

<table>
<thead>
<tr>
<th>Speed (MPH)</th>
<th>Method 1: Deceleration Only</th>
<th>Method 2: Moderate Deceleration + Storage</th>
<th>Method 3: Full Deceleration + Storage (Rural Arterial ≥ 45 mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>125 ft</td>
<td>Storage + Bay-Taper</td>
<td>N/A</td>
</tr>
<tr>
<td>25</td>
<td>125 ft</td>
<td>Storage + Bay-Taper</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>125 ft</td>
<td>Storage + Bay-Taper</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>125 ft</td>
<td>Storage + Bay-Taper</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>170 ft</td>
<td>70 ft + Storage</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>220 ft</td>
<td>115 ft + Storage</td>
<td>340 ft + Storage</td>
</tr>
<tr>
<td>50</td>
<td>275 ft</td>
<td>170 ft + Storage</td>
<td>410 ft + Storage</td>
</tr>
<tr>
<td>55</td>
<td>340 ft</td>
<td>220 ft + Storage</td>
<td>485 ft + Storage</td>
</tr>
<tr>
<td>60</td>
<td>410 ft</td>
<td>275 ft + Storage</td>
<td>565 ft + Storage</td>
</tr>
<tr>
<td>65</td>
<td>485 ft</td>
<td>340 ft + Storage</td>
<td>645 ft + Storage</td>
</tr>
</tbody>
</table>

B: At signalized intersections the length of turn lanes should be extended so that it is not blocked by the queue of adjacent through traffic.
RIGHT-TURN LANE WARRANTS

- 1 Graph measures probability of turning vehicle blocking lane
- \( \leq 45 \text{ MPH} \ (P = 0.02) \)
- \( >45 \text{ MPH} \ (P = 0.01) \)
RIGHT-TURN LANE WARRANTS

Advancing Traffic
\[=40 + 500 + 71 = 611\]

Percent Right Turns
\[= \frac{40}{611} = 0.07\]
RIGHT-TURN LANE WARRANTS

The diagram illustrates the relationship between right-turn lane warrants and traffic conditions. The graph shows two curves:

- The lower curve represents conditions where a right-turn lane is required for V \leq 45 \text{ mph}.
- The upper curve represents conditions where a right-turn lane is required for V > 45 \text{ mph}.

The point (0.07, 611) indicates a situation where a right-turn lane is not required for advancing traffic conditions as indicated by the right-turn lane not being required in the lower part of the graph.
RIGHT-TURN LANE DESIGN

• Turn Lane Length
  • Deceleration Length
  • Storage Length
RIGHT-TURN LANE DESIGN

- **Turn Lane Length**

Table 1: Auxiliary Turn Lane Length by Turn Type and Intersection Control

<table>
<thead>
<tr>
<th>Approach Control</th>
<th>Turn Type</th>
<th>Turn Lane Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled</td>
<td>Right-Turn</td>
<td>Method 1(^A)</td>
</tr>
<tr>
<td>Stop Controlled</td>
<td>Right-Turn</td>
<td>Storage + Bay taper</td>
</tr>
<tr>
<td>Signal Control(^B)</td>
<td>Right-Turn</td>
<td>Greater of Method 1(^A) or Method 2(^A)</td>
</tr>
</tbody>
</table>

**Notes:**

- A. See Table 2 below.
- B. At signalized intersections the length of turn lanes should be extended so that it is not blocked by the queue of adjacent through traffic.

Table 2: Turn Lane Length by Speed

<table>
<thead>
<tr>
<th>Speed (MPH)</th>
<th>Method 1: Deceleration Only</th>
<th>Method 2: Moderate Deceleration + Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>100 ft</td>
<td>Storage + Bay Taper</td>
</tr>
<tr>
<td>25</td>
<td>100 ft</td>
<td>Storage + Bay Taper</td>
</tr>
<tr>
<td>30</td>
<td>100 ft</td>
<td>Storage + Bay Taper</td>
</tr>
<tr>
<td>35</td>
<td>100 ft</td>
<td>Storage + Bay Taper</td>
</tr>
<tr>
<td>40</td>
<td>170 ft</td>
<td>70 ft + Storage</td>
</tr>
<tr>
<td>45</td>
<td>220 ft</td>
<td>115 ft + Storage</td>
</tr>
<tr>
<td>50</td>
<td>275 ft</td>
<td>170 ft + Storage</td>
</tr>
<tr>
<td>55</td>
<td>340 ft</td>
<td>220 ft + Storage</td>
</tr>
<tr>
<td>60</td>
<td>410 ft</td>
<td>275 ft + Storage</td>
</tr>
<tr>
<td>65</td>
<td>485 ft</td>
<td>340 ft + Storage</td>
</tr>
</tbody>
</table>
INTERSECTION TYPE & SIZE
Design Process

- Determine Basic Number of Lanes
- Determine Auxiliary Lanes
- Intersection Type/Size (Signal, Stop, Roundabout)
- Analyze/Evaluate
Determine Intersection Type

• Warrant Analysis – MUTCD

• Alternative Analysis
Warrants

• Traffic Signal Control
• 4-Way Stop Control
• Roundabout
HCS Signals
Input Screen
### HCS Signals Phasing Design

<table>
<thead>
<tr>
<th>Phase</th>
<th>Traffic Light Signals</th>
<th>Pedestrian Signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R G 15.0 R</td>
<td>Ped R</td>
</tr>
<tr>
<td>2</td>
<td>L G 4.0 T</td>
<td>T L</td>
</tr>
<tr>
<td>3</td>
<td>R R 0.0 L</td>
<td>R L</td>
</tr>
<tr>
<td>4</td>
<td>L G 15.0 R</td>
<td>Ped R</td>
</tr>
<tr>
<td>5</td>
<td>P e d G 35.0 R</td>
<td>L R</td>
</tr>
<tr>
<td>6</td>
<td>R Y 4.0 Y</td>
<td>Y L</td>
</tr>
<tr>
<td>7</td>
<td>R R 0.0 L</td>
<td>R L</td>
</tr>
<tr>
<td>8</td>
<td>Ped G 35.0 R</td>
<td>L R</td>
</tr>
</tbody>
</table>

**Cycle Length:** 60.0

**Estimation/Optimization**
## HCS Signals Output

<table>
<thead>
<tr>
<th></th>
<th>Eastbound</th>
<th></th>
<th>Westbound</th>
<th></th>
<th>Northbound</th>
<th></th>
<th>Southbound</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L TR</td>
<td></td>
<td>L TR</td>
<td></td>
<td>L TR</td>
<td></td>
<td>L TR</td>
<td></td>
</tr>
<tr>
<td>Lane Group Adjusted Volume, (vph)</td>
<td>67 207 0</td>
<td>73 274 0</td>
<td>41 543 0</td>
<td>27 743 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Group Capacity, (vph)</td>
<td>223 438</td>
<td>282 432</td>
<td>272 1088</td>
<td>427 1059</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Group v/c Ratio</td>
<td>0.30 0.47</td>
<td>0.26 0.63</td>
<td>0.15 0.50</td>
<td>0.06 0.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Lane Group</td>
<td>#</td>
<td></td>
<td>#</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Group Delay, (sec/veh)</td>
<td>21.7 22.8</td>
<td>20.3 27.0</td>
<td>6.9 9.0</td>
<td>5.7 12.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Group Level of Service</td>
<td>C C</td>
<td>C C</td>
<td>A A</td>
<td>A B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Unmet Demand, (v)</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach Delay, (sec/veh)</td>
<td>22.5</td>
<td>25.6</td>
<td>8.8</td>
<td>12.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach Level of Service</td>
<td>C C</td>
<td></td>
<td>A</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle Length</td>
<td>60.0 sec</td>
<td></td>
<td>Intersection Delay</td>
<td>15.1 sec/veh</td>
<td>Intersection LOS</td>
<td>B</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Output: Conceptual Layout
Innovative Designs
Innovative Designs

- Cost Savings:
  - $4.5M
- LOS B
- Target LOS D/E
ANALYZE / EVALUATE
Design Process

- Determine Basic Number of Lanes
- Determine Auxiliary Lanes
- Intersection Type/Size (Signal, Stop, Roundabout)
- Analyze/Evaluate
Measures of Effectiveness

- V/C
- Level of Service (LOS)
- Queuing
- Travel Time
- Delay

Other MOEs. Additional MOEs required by project type, such as interchange justification studies, or defined by the project Purpose and Need Statement, e.g., emissions, queues, etc. for CMAQ projects, may be analyzed, and documented as needed.
Traffic Analysis

- Validates Proposed Design
- Alternative Analysis and Evaluation
- Refine Design
  - Passing Sight Distance
  - Auxiliary Climbing Lanes
  - Additional Turn Lanes
  - Lane Widths/Shoulder Widths
Innovative Approach
## Current Design Guidelines

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Section</td>
<td>No Cable Barrier. Rumble Strips in 4’ striped median. 4-6ft shoulders, with or without shoulder rumbles</td>
</tr>
<tr>
<td>Length of Passing Lanes</td>
<td>0.5 – 1.5 mile spacing (1-2.5km, and 0.8-1.1 mi)</td>
</tr>
<tr>
<td>Widen Direction</td>
<td>Symmetrical, Asymmetrical, Non-Continuous</td>
</tr>
<tr>
<td>LOS Capacity (C)</td>
<td>Up to 2800pc/hr if one directional 1700pc/hr max.</td>
</tr>
</tbody>
</table>
Traffic Analysis

- Highway Capacity Manual/Software (HCM/HCS)

- Microsimulation
  - TSIS/CORSIM
  - VISSIM
  - HCM 2010 Urban Streets??
Micro Simulation
Micro-Simulation
Micro Simulation

Micro-simulation may be considered on corridors that:
• Operate within coordinated signal systems,
• Have multiple signalized intersections where queuing may impact adjacent intersections,
• Operate interdependently, such as at interchanges, or
• When deemed necessary by the project team for operational or other reasons such as for use in public involvement activities.
DESIGN CONSIDERATIONS
Example 1
Design Considerations

Critical issues to the proper operation of a facility may be identified and documented in a technical memorandum if deemed necessary by the project team

- Alignment of opposing left turn lanes
- Number of receiving lanes
- Turn restrictions
- Passing sight distance
REVIEW AND APPROVAL
Review and Approval

- Scoping Meeting
  - assumptions
  - description of alternatives
  - modeling limits
  - analysis time periods (AM, PM peak periods)
  - design year
  - calibration factors
  - micro-simulation program
Review and Approval

- Coordination
  - Planning: Traffic Forecast
- Traffic Operations: Proposed traffic signal or lighting
- Location Engineers: DES Approval; Other Resources
Documentation

• Documentation
• provide sufficient information to allow a thorough review of the analysis and analytical results,
• document reasoning behind operational assumptions and
• provide enough information to duplicate the results.
• At a minimum this includes:
  • assumptions (input)
  • calibration method and results
  • conceptual layout
  • MOE summary
  • design considerations
  • output
  • electronic input and output files