Multimodal Level of Service (MMLOS) and the Highway Safety Manual (HSM)

Transportation Education Series

July 17, 2012

City of San Luis Obispo Council Chambers
Transportation Education Series Presenters
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Kamala Parks, Oakland
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Presentation Overview

- Introductions
- Design Flexibility and Performance Based Evaluation
- Multimodal Level of Service
- Highway Safety Manual
- Discussion
Presentation overview

- Introductions
- Design Flexibility and Performance Based Evaluation
  - A Guide for Achieving Flexibility in Highway Design
  - Designing Walkable Urban Thoroughfares: A Context Sensitive Approach
  - MMLOS (HCM 2010)
  - Highway Safety Manual
  - Caltrans Initiatives
- Multimodal Level of Service
- Highway Safety Manual
- Discussion
A Guide for Achieving Flexibility in Highway Design

- Institutionalizes CSS into transportation project development.
- Allows designers to think flexibly for the particular situation or context.
- Flexible design can be integrated into the existing transportation culture.
Designing Walkable Urban Thoroughfares: A Context Sensitive Approach

- Funded by EPA and FHWA in partnership with the Congress for the New Urbanism
- Guidance for walkable and bikeable communities, compact development, and mixed land uses
- Specific design criteria, and case studies
- ITE recommended practice
Caltrans: Flexibility in Design and Operations

Performance Measures

- Lower speeds & improved Level of Service
- Reduced congestion levels & reduction of motorist delay
- Improved pedestrian access and mobility
- Improved access to schools and businesses
- Improved safety
- Improved bicycle accessibility and mobility
- Protecting and preserving scenic and historic qualities and attributes
Why Complete Streets Matter to Caltrans

- SAFETY and risk management
- Commitment to the Three E’s: Environment, Economy, and Equity (AB 857, 2002)
- Help meet GHG reduction targets (AB 32, 2006)
- Help partners meet local complete streets requirements (AB 1358, 2008)
- Manage capacity and expand options for travel on the State Highway System
- Be proactive, avoid legislative mandates
- Support State policy to improve public health outcomes

Courtesy to Daniel Kopulsky
Caltrans, District 8
Performance Based Analysis Tools

- **HCM 2010 Multimodal Level of Service**
  - Facility operations from the traveler’s perspective
  - Provides LOS thresholds

- **Highway Safety Manual**
  - Safety prediction tools
  - Akin to the *Highway Capacity Manual*
  - Support planning and design decisions
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- Multimodal Level of Service
  - Introduction
  - Brief history of HCM multimodal analysis
  - Development of the HCM methodology
    - Bicyclist LOS model
    - Pedestrian LOS model
    - Transit Passenger LOS model
  - MMLOS Case Study – Lodi, CA
- Highway Safety Manual
- Discussion
Why Multimodal Level of Service (MMLOS)

- Vehicle LOS analysis methods
  - Often used as the only measure of effectiveness for roadway operations
    - Promote only improvements for vehicles
    - Encourage sprawl
  - Don’t reflect all operational or safety issues for roadways

Images Source: Google Earth Professional
Uses of MMLOS

- MMLOS can help:
  - Quantify the operational tradeoffs among modes for a given streetscape design feature or strategy
  - Help prioritize transit, bicycle, and pedestrian improvements
  - Assist and inform the public involvement process
  - Begin to document compliance with the California Complete Streets Act (AB 1358)

Images Source: Google Earth Professional
Sample Applications of MMLOS

- **Oakland**
  - Community-based transportation plan

- **Pasadena**
  - Traffic impact analysis and road diet

- **City of San Pablo**
  - General Plan and Specific Plan

- **City of Goleta**
  - Roadway redesign (Hollister Avenue)

- **SJCOG Regional CMP Update**
  - Designation of multimodal corridors and baseline analysis
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Brief History of Highway Capacity Manual (HCM) Multimodal Analysis

1950: Transit and pedestrian impacts on motor vehicle capacity

1965: Level of Service concept and bus transit chapter

1985: Expanded bus transit chapter, new pedestrian chapter (density), and new bicycle chapter (vehicle hindrance)

2000: 4 Transit LOS measures, expanded pedestrian and bicycle chapters
Brief History of Highway Capacity Manual (HCM) Multimodal Analysis

- **Issues with HCM 2000:**
  - Pedestrian and bicyclist LOS measures reflected a motorist perspective of density.
  - Transit measures reflected a traveler’s perspective, but the multiple LOS measures created issues with results interpretation.

HCM 2000: Ped LOS A

HCM 2000: Ped LOS D
HCM 2010 Multimodal Philosophy

- Integrate multimodal analysis methods into appropriate chapters
  - Road user perspective
  - No separate bicyclist, pedestrian, or transit passenger chapters
    - Methodologies for all modes presented together and intertwined
  - Encourage software developers to add multimodal analysis features
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Highway Safety Manual

Discussion
Methodology Selection

- **NCHRP Report 616 method**
  - Designed specifically for the HCM
  - LOS measures based on traveler perceptions
  - Modal LOS scores can be directly compared to each other and reflect average traveler satisfaction by mode
  - Model developed and tested based on national conditions
Methodology Development

- Pedestrian, bicyclist, and motorist:
  - 90 typical street segments recorded
  - Video labs in four cities around the U.S.
  - 120 Participants rated conditions on a 1–6 scale,
Methodology Development

- **Transit passenger:**
  - Video lab not feasible
  - On-board surveys conducted in 4 cities
    - However, results showed too wide a range to fit a model to
  - Final model was based on national traveler response data to changes in transit service quality
    - For example, when service frequency or travel time is improved, ridership increases
Methodology

Characteristics

- All models generated a perception score that was generally in the range of 1 to 6
- All models had multiple service quality factors as inputs
  - Traditional HCM service measures are based on a single factor (e.g., delay)
- LOS thresholds were the same for all modes
### LOS Score Interpretation

- **Adopted in the 2010 HCM**
  - LOS models developed in the NCHRP report for pedestrians, bicyclists, and transit passengers

<table>
<thead>
<tr>
<th>LOS</th>
<th>LOS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≤2.00</td>
</tr>
<tr>
<td>B</td>
<td>&gt;2.00–2.75</td>
</tr>
<tr>
<td>C</td>
<td>&gt;2.75–3.50</td>
</tr>
<tr>
<td>D</td>
<td>&gt;3.50–4.25</td>
</tr>
<tr>
<td>E</td>
<td>&gt;4.25–5.00</td>
</tr>
<tr>
<td>F</td>
<td>&gt;5.00</td>
</tr>
</tbody>
</table>
## LOS Score Interpretation

### Changes to motorist LOS on arterials

- Based on percent of free-flow speed

<table>
<thead>
<tr>
<th>Travel Speed / Base Free Flow Speed</th>
<th>LOS by Critical V/C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 1.0</td>
</tr>
<tr>
<td>&gt; 85%</td>
<td>A</td>
</tr>
<tr>
<td>68% to 85%</td>
<td>B</td>
</tr>
<tr>
<td>51% to 67%</td>
<td>C</td>
</tr>
<tr>
<td>41% to 50%</td>
<td>D</td>
</tr>
<tr>
<td>31% to 40%</td>
<td>E</td>
</tr>
<tr>
<td>≤ 30%</td>
<td>F</td>
</tr>
</tbody>
</table>

The critical volume-to-capacity ratio is based on the through movement in the analysis direction at the downstream intersection.
LOS Score Interpretation

- LOS is reported individually by mode and is directional
- No combined LOS for the street
  - Auto volumes would typically dominate an LOS weighted by number of travelers
  - Combined LOS would potentially mask important deficiencies for a given mode
- Measures the degree to which urban streets meet the need of all users
Treatment of Safety in Multimodal LOS

- HCM 2010 does not explicitly include safety in LOS calculations
  - Crash history does not affect LOS

- However, HCM 2010 does include Traveler Perceived Safety elements
  - Speed of traffic
  - % heavy vehicles
  - Sidewalk buffers
  - Lateral separation of bicyclists and pedestrians from the traffic stream
Urban Street System Elements: Link

- Between two signalized intersections
  - Roundabout or all-way stop could also be an end point
- Perception score for bicyclists and pedestrians
Signalized intersection, roundabout, or all-way stop that terminates a link

Perception score for bicyclists and pedestrians
Segment = link + downstream intersection

Perception scores for all modes

- Pedestrian & bicyclist scores based on combination of link, intersection, and additional factors
Urban Street System Elements: Facility

- Facility = 2 or more consecutive segments
- Perception scores available for all modes
  - Length-weighted average of the segment scores
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Bicycle LOS: Links Model Factors

- Factors included:
  - Vehicle traffic in outside travel lane (–)
    - Volume
    - Speed
  - Heavy vehicle percentage (–)
  - Pavement condition (+)
  - Bicycle lane presence (+)
  - Bicycle lane, shoulder, and outside lane widths (+)
  - On-street parking utilization (–)
Bicycle LOS: Signalized Intersections
Bicycle LOS: Signalized Intersections
Model Factors

- Factors included:
  - Width of lanes (+)
    - Outside through vehicle lane
    - Bicycle lane
  - Cross-street width (−)
  - Motor vehicle traffic volume in the outside lane (−)
Bicycle LOS: Segments
Bicycle LOS: Segments Model Factors

- Factors included:
  - Bicycle link LOS (+)
  - Bicycle intersection LOS, if signalized (+)
  - Number of access points on right side (−)
    - Includes driveways and unsignalized street intersections
    - Judgment required on how low-volume residential driveways are treated
Bicycle LOS: Segments Model Form

\[ I_{b,seg} = 0.160 \ I_{b,link} + 0.011 \ F_{bi} \ e^{I_{b,int}} + 0.035 \ \frac{N_{ap,s}}{(L/5280)} + 2.85 \]

<table>
<thead>
<tr>
<th>Bike Segment LOS Score</th>
<th>Bike Link LOS Score</th>
<th>Indicator Variable</th>
<th>Bike Intersection LOS Score</th>
<th>Segment length (mi)</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_{bi} = 1 ) if signalized</td>
<td>( F_{bi} = 0 ) if unsignalized</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Number of access points on right side
Bicycle LOS: Facility

- Length-weighted average of segment LOS scores
  - Can mask deficiencies in individual segments
  - Consider also reporting segment LOS score for the worst segment in the facility
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Pedestrian LOS: Links
Pedestrian LOS: Links Model Factors

- **Factors included:**
  - Outside travel lane width (+)
  - Bicycle lane/shoulder width (+)
  - Buffer presence (e.g., on-street parking, street trees) (+)
  - Sidewalk presence and width (+)
  - Volume and speed of motor vehicle traffic in outside travel lane (−)

- **Pedestrian density considered separately**
  - Worse of (density LOS, link LOS score) used in determining overall link LOS
Pedestrian LOS: Signalized Intersections
Pedestrian LOS: Signalized Intersections

Model Factors

- Factors included:
  - Permitted left turn and right-turn-on-red volumes (−)
  - Cross-street motor vehicle volumes and speeds (−)
  - Crossing length (−)
  - Average pedestrian delay (−)
  - Right-turn channelizing island presence (+)
Pedestrian LOS: Segments
Pedestrian LOS: Segments
Model Factors

- Factors included:
  - Pedestrian link LOS (+)
  - Pedestrian intersection LOS (+)
  - Street-crossing difficulty (−/+)
    - Delay diverting to signalized crossing
    - Delay crossing street at legal unsignalized location
Pedestrian LOS: Facility

- Length-weighted average of segment LOS scores
  - Can mask deficiencies in individual segments
  - Consider also reporting segment LOS score for the worst segment in the facility
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  - **Transit Passenger LOS model**
  - MMLOS Case Study – Lodi, CA

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Transit LOS: Overview

- Only segment and facility LOS models
- Transit facility LOS is a length-weighted average of segment LOS
- “Transit” includes buses, streetcars, and street-running light rail
- Three main model components:
  - Access to transit (pedestrian link LOS)
  - Wait for transit (frequency)
  - Riding transit (perceived travel time rate)
Transit LOS: Perceived Travel Time Components

- Factors included:
  - Actual bus travel speed (+)
  - Bus stop amenities (+)
  - Excess wait time due to late bus/train arrival (−)
  - On-board crowding (−)

- Default value of time data and average passenger trip lengths used to convert actual times into perceived times
  - For example, the trip seems to take longer when one has to stand
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MMLOS Case Study
SR-12 Kettleman Lane, Lodi

- State Highway is Main Street
  - Pedestrian, transit and bicycle use
  - Mostly commercial uses
  - Provides access to residential areas
  - Congestion Management Program System
Case Study
SR-12 Kettleman Lane, Lodi

- Data Collection
  - March 2012 in AM and PM
  - Mostly infrastructure

- Roadway Conditions
  - 4 to 5 through lanes
  - 35 MPH posted speed
  - Raised median

- Hourly vehicle volumes (from counts)

<table>
<thead>
<tr>
<th>Peak-Hour Vehicles</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastbound</td>
<td>1,000 to 1,850</td>
<td>1,700 to 2,600</td>
</tr>
<tr>
<td>Westbound</td>
<td>745 to 1,600</td>
<td>1,300 to 2,500</td>
</tr>
</tbody>
</table>
Case Study
SR-12 Kettleman Lane, Lodi

- Existing Conditions - Pedestrian
  - 4 to 8 foot wide sidewalks
  - Lack of sidewalk buffers
  - Some shoulders / parking lanes
  - Low on-street parking occupancies
    - Eastbound 0% to 3%
    - Westbound 0% to 14%

Source: Recordnet.com
Case Study
SR-12 Kettleman Lane, Lodi

- Existing Conditions - Bicyclist
  - 5 to 6 foot bike lanes through most of corridor
  - Some shoulders / parking lanes
  - Low on-street parking occupancies
    - Eastbound 0% to 3%
    - Westbound 0% to 14%

Source: Lodinews.com
Case Study
SR-12 Kettleman Lane, Lodi

▪ Existing Conditions – Transit Passenger
  ▪ Variety of bus service on corridor
    ▪ Lodi Grape Line
    ▪ San Joaquin Regional Transit District
  ▪ Multiple routes
  ▪ Long headways
  ▪ Lack of bus stop amenities
    ▪ Benches only on 3 segments in westbound direction
    ▪ No shelters

Source: Transitunlimited.com
### Case Study
**SR-12 Kettleman Lane, Lodi**

<table>
<thead>
<tr>
<th>Segment</th>
<th>From</th>
<th>To</th>
<th>Auto Segment</th>
<th>Transit Segment</th>
<th>Bicycle Segment</th>
<th>Pedestrian Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HWY-99 SB Ramps</td>
<td>Cherokee Lane</td>
<td>29.0% (F)</td>
<td>4.94 (E)</td>
<td>4.09 (D)</td>
<td>4.52 (E)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.08 (D)</td>
<td></td>
<td></td>
<td>2.66 (B)</td>
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<tr>
<td>2</td>
<td>Cherokee Lane</td>
<td>Central Avenue</td>
<td>47.2% (D)</td>
<td>3.21 (C)</td>
<td>0.93 (A)</td>
<td>2.80 (C)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-0.46 (A)</td>
<td></td>
<td></td>
<td>2.14 (B)</td>
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<tr>
<td>3</td>
<td>Central Avenue</td>
<td>Stockton Street</td>
<td>41.6% (D)</td>
<td>3.75 (D)</td>
<td>2.42 (B)</td>
<td>1.88 (A)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.32 (B)</td>
</tr>
<tr>
<td>4</td>
<td>Stockton Street</td>
<td>Church Street</td>
<td>50.7% (C)</td>
<td>4.84 (E)</td>
<td>1.83 (A)</td>
<td>3.33 (C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.95 (A)</td>
</tr>
<tr>
<td>5</td>
<td>Church Street</td>
<td>Hutchins Street</td>
<td>36.0% (E)</td>
<td>5.23 (F)</td>
<td>1.12 (A)</td>
<td>-0.27 (A)</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>2.40 (B)</td>
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<tr>
<td>6</td>
<td>Hutchins Street</td>
<td>Crescent Avenue</td>
<td>43.2% (D)</td>
<td>4.87 (E)</td>
<td>2.07 (B)</td>
<td>1.47 (A)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>1.95 (A)</td>
</tr>
<tr>
<td>7</td>
<td>Crescent Avenue</td>
<td>Ham Lane</td>
<td>56.1% (C)</td>
<td>5.25 (F)</td>
<td>2.75 (C)</td>
<td>2.13 (B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.62 (D)</td>
</tr>
<tr>
<td>8</td>
<td>Ham Lane</td>
<td>Mills Avenue</td>
<td>68.5% (B)</td>
<td>2.61 (B)</td>
<td>0.88 (A)</td>
<td>2.86 (C)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>2.12 (B)</td>
</tr>
<tr>
<td>9</td>
<td>Mills Avenue</td>
<td>Tienda Drive</td>
<td>61.5% (C)</td>
<td>2.07 (B)</td>
<td>-0.17 (A)</td>
<td>2.07 (B)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>2.29 (B)</td>
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<tr>
<td>10</td>
<td>Tienda Drive</td>
<td>Lower Sacramento Road</td>
<td>49.5% (D)</td>
<td>2.21 (B)</td>
<td>0.82 (A)</td>
<td>-3.89 (A)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.96 (C)</td>
</tr>
</tbody>
</table>
## Case Study
**SR-12 Kettleman Lane, Lodi**

### Eastbound AM

<table>
<thead>
<tr>
<th>Segment</th>
<th>From</th>
<th>To</th>
<th>Auto Segment</th>
<th>Auto Transit Segment</th>
<th>Bicycle Intersection</th>
<th>Bicycle Link</th>
<th>Pedestrian Segment</th>
<th>Pedestrian Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lower Sacramento Road</td>
<td>Tienda Drive</td>
<td>50.9% (C)</td>
<td>2.19 (B)</td>
<td>0.04 (A)</td>
<td>-2.52 (A)</td>
<td>2.63 (B)</td>
<td>1.99 (A)</td>
</tr>
<tr>
<td>2</td>
<td>Tienda Drive</td>
<td>Mills Avenue</td>
<td>60.2% (C)</td>
<td>2.57 (B)</td>
<td>-0.64 (A)</td>
<td>-6.46 (A)</td>
<td>1.93 (A)</td>
<td>1.94 (A)</td>
</tr>
<tr>
<td>3</td>
<td>Mills Avenue</td>
<td>Ham Lane</td>
<td>67.9% (B)</td>
<td>2.61 (B)</td>
<td>0.44 (A)</td>
<td>-4.17 (A)</td>
<td>2.35 (B)</td>
<td>2.71 (B)</td>
</tr>
<tr>
<td>4</td>
<td>Ham Lane</td>
<td>Crescent Avenue</td>
<td>55.6% (C)</td>
<td>5.04 (F)</td>
<td>0.55 (A)</td>
<td>-1.13 (A)</td>
<td>2.94 (C)</td>
<td>2.47 (B)</td>
</tr>
<tr>
<td>5</td>
<td>Crescent Avenue</td>
<td>Hutchins Street</td>
<td>38.5% (E)</td>
<td>5.12 (F)</td>
<td>1.41 (A)</td>
<td>-0.88 (A)</td>
<td>2.92 (C)</td>
<td>2.64 (B)</td>
</tr>
<tr>
<td>6</td>
<td>Hutchins Street</td>
<td>Church Street</td>
<td>32.5% (E)</td>
<td>4.90 (E)</td>
<td>0.94 (A)</td>
<td>-0.44 (A)</td>
<td>3.03 (C)</td>
<td>1.96 (A)</td>
</tr>
<tr>
<td>7</td>
<td>Church Street</td>
<td>Stockton Street</td>
<td>50.2% (C)</td>
<td>5.10 (F)</td>
<td>2.25 (B)</td>
<td>3.01 (C)</td>
<td>3.54 (D)</td>
<td>2.53 (B)</td>
</tr>
<tr>
<td>8</td>
<td>Stockton Street</td>
<td>Central Avenue</td>
<td>43.5% (D)</td>
<td>3.79 (D)</td>
<td>1.35 (A)</td>
<td>-0.04 (A)</td>
<td>3.02 (C)</td>
<td>1.96 (A)</td>
</tr>
<tr>
<td>9</td>
<td>Central Avenue</td>
<td>Cherokee Lane</td>
<td>44.7% (D)</td>
<td>5.14 (F)</td>
<td>3.47 (C)</td>
<td>1.62 (A)</td>
<td>3.74 (D)</td>
<td>2.61 (B)</td>
</tr>
<tr>
<td>10</td>
<td>Cherokee Lane</td>
<td>HWY-99 SB Ramps</td>
<td>35.1% (E)</td>
<td>4.97 (E)</td>
<td>2.63 (B)</td>
<td>4.00 (D)</td>
<td>3.96 (D)</td>
<td>1.85 (A)</td>
</tr>
</tbody>
</table>
### Case Study
**SR-12 Kettleman Lane, Lodi**

- **Eastbound AM – Transit Passenger LOS**

#### 3. Compute Transit Level of Service

<table>
<thead>
<tr>
<th>Segment</th>
<th>Headway Factor</th>
<th>Travel Time Factor</th>
<th>Transit Wait-Ride Score</th>
<th>Pedestrian Link LOS Score</th>
<th>Transit LOS Score</th>
<th>Transit LOS</th>
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**Average**

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<th>Segment</th>
<th>Headway Factor</th>
<th>Travel Time Factor</th>
<th>Transit Wait-Ride Score</th>
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<th>Transit LOS Score</th>
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</table>
Case Study
SR-12 Kettleman Lane, Lodi

- Eastbound AM
  - Improvements between Ham Ln and Crescent Ave
    - Reduce Ham Lane width from 108 feet to 80 feet
    - Install 7-foot sidewalk buffer
    - Install bus shelter
Case Study
SR-12 Kettleman Lane, Lodi

- Eastbound AM – Ham Ln to Crescent Ave
  - Compare Existing to Improved for Transit

<table>
<thead>
<tr>
<th></th>
<th>Headway Factor</th>
<th>Perceived Travel Time Factor</th>
<th>Transit Wait Ride Score</th>
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- All Modes

<table>
<thead>
<tr>
<th></th>
<th>Auto Segment</th>
<th>Transit Segment</th>
<th>Bicycle Intersection</th>
<th>Pedestrian Link Segment</th>
<th>Pedestrian Intersection</th>
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<tr>
<td>Existing</td>
<td>55.6% (C)</td>
<td>5.04 (F)</td>
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<td>-1.13 (A)</td>
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<tr>
<td>Improved</td>
<td>55.6% (C)</td>
<td>4.98 (E)</td>
<td>0.65 (A)</td>
<td>-1.13 (A)</td>
<td>2.94 (C)</td>
<td>1.94 (A)</td>
<td>2.33 (B)</td>
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</table>
Presentation Overview

• Introductions
• Design Flexibility and Performance Based Evaluation
• Multimodal Level of Service
• **Highway Safety Manual**
  – What is the HSM? & How can it be used
  – Example Applications of the HSM
  – Example Application of HSM and MMLOS
• Discussion
What is the HSM?

• **Safety prediction tools** developed through research

• Akin to the Highway Capacity Manual:
  – Definitive
  – Widely-accepted
  – Science-based

• From qualitative descriptive-based analysis to quantitative prediction
What is the HSM?

- **Part A Introduction and Fundamentals**
  - 1: Introduction
  - 2: Human Factors
  - 3: Fundamentals

- **Part B Roadway Safety Management Process**
  - 4: Network Screening
  - 5: Diagnosis
  - 6: Select Countermeasures
  - 7: Economic Evaluation
  - 8: Prioritization
  - 9: Safety Effectiveness Evaluation

- **Part C Predictive Method**
  - 10: Rural Two-Lane Highways
  - 11: Rural Multilane Highways
  - 12: Urban and Suburban Arterials

- **Part D Crash Modification Factors**
  - 13: Roadway Segments
  - 14: Intersections
  - 15: Interchanges
  - 16: Special Facilities
  - 17: Networks

- Glossary
How can the HSM be used?

• Estimate Crashes per Year for Today and Future

Condition 1

Photo Courtesy of Yolanda Takesian

Condition 2
Why use the HSM?

• Able to measure safety objectively (i.e., quantitatively)
• New tools build on and enhance current practice
  – Improve reliability
  – Provide new capabilities (e.g., predicting crashes)
  – Able to quantify safety and compare with other project
    advantages and disadvantages
• Opportunities to incorporate new tools and methods
  in the near-term and plan for further integrating them
  in the long-term
  – No need to do everything at once
  – New tools/methods can provide value to decision making
    now
Part A – Review of Key HSM Concepts

• Driver Factors Influencing Crashes
• Nominal vs. Substantive Safety
• Objective vs. Subjective Safety
• Randomness of Crashes
Driver Factors Influencing Crashes

Source: Treat 1979
Nominal vs. Substantive Safety

Crash Risk vs. Design Dimensions

Nominal Safety is an Absolute
Substantive Safety is a Continuum

Source: NCHRP 480
Objective and Subjective Safety

- Objective – Measured
- Subjective - Perceived

**SUBJECTIVE**

“Downtown is difficult as it is without having a roundabout death trap in it.” - Chico Enterprise - Record Posted: 03/08/2011

**OBJECTIVE**

Converting a traffic signal in an urban area to a roundabout reduces injury/fatal crashes by about 60%. – HSM 2010
Preferred Measure of Safety: Long Term Expected Average Crashes

- Considered more reliable measure – minimizing influence of the randomness of crashes
Crashes are Rare and Random Events

Relative Proportion of Crash Events

- Low Risk of Crash
- Situation with Potential Risk of Crash
- Risk of a Crash
- Crash occurs
Crashes are Rare and Random Events

- Crashes, as rare random events, tend to regress to long-term average
- Looking at short-term crash frequencies can be misleading
Crashes are Rare and Random

Site selected for treatment due to short-term trend (treatment implemented)

Expected Average Crash Frequency (without treatment)

Expected Average Crash Frequency (with treatment)

RTM Reduction

Percieved effectiveness of treatment

Actual reduction due to treatment

Crash Data Before Treatment
Crash Data After Treatment
Expected Number of Crashes Before
Expected Number of Crashes After
How is the randomness compensated for?

- **Safety Performance Functions (SPFs)**
  - Predicts the average number of crashes per year
  - It is generally a nonlinear regression equation

![Graph](attachment:image.png)
How to compensated for randomness?

- Empirical Bayes
  - A process to develop a *weighting between observed and predicted crashes*
  - A means to calculate a refined prediction called the *expected number of crashes*
Part B – Content Highlights

• Part A Introduction and Fundamentals
  – 1: Introduction
  – 2: Human Factors
  – 3: Fundamentals

• Part B Roadway Safety Management Process
  – 4: Network Screening
  – 5: Diagnosis
  – 6: Select Countermeasures
  – 7: Economic Evaluation
  – 8: Prioritization
  – 9: Safety Effectiveness Evaluation

• Part C Predictive Method
  – 10: Rural Two-Lane Highways
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  – 12: Urban and Suburban Arterials

• Part D Crash Modification Factors
  – 13: Roadway Segments
  – 14: Intersections
  – 15: Interchanges
  – 16: Special Facilities
  – 17: Networks

• Glossary
Part B – Content Highlights

Network Screening
What sites have potential for improvement?

Safety Effectiveness Evaluation
How effective were countermeasures?

Diagnosis
What pattern do crashes follow?

Select Countermeasures
What factors contribute to crashes?

Prioritize Projects
What projects meet program objectives?

Economic Appraisal
What countermeasures are cost-effective?
Part B – Content Highlights

• Chapter 4
  Network Screening

• Safety Analyst Software Implements
  Part B Chapters including Network Screening
Part C – Content and Application

- Part A Introduction and Fundamentals
  - 1: Introduction
  - 2: Human Factors
  - 3: Fundamentals

- Part B Roadway Safety Management Process
  - 4: Network Screening
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  - 13: Roadway Segments
  - 14: Intersections
  - 15: Interchanges
  - 16: Special Facilities
  - 17: Networks

- Glossary
## Part C - Content and Application

<table>
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<tr>
<th>HSM Chapter</th>
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</table>
Part C - Content and Application

• Method to predict safety performance of alternative designs

\[ n_{predicted} = SPF \times (CMF_1 \times CMF_2) \times C \]

\[ N_{expected} = w \times N_{predicted} + (1 - w) \times N_{observed} \]

• Predict Expected Safety Performance
  – Select homogeneous analysis segments
  – Select SPF and estimate base conditions for each analysis segment
  – Apply CMFs to modify base conditions to site specific conditions
  – Apply calibration factor
  – Apply EB when appropriate
Overview of Steps

1. Categorize Homogenous Sites
2. Estimate base prediction
3. Modify to reflect local conditions
4. Apply Calibration Factor
5. Apply EB, if appropriate
Categorize Homogenous Sites

• Categorize facilities by intersection and segment
  • Intersections
    – Signalized
    – Unsignalized
    – Number of Approaches
  • Segments
    – Divided
    – Undivided
    – Number of lanes
Part D – Content and Application

• Part A Introduction and Fundamentals
  – 1: Introduction
  – 2: Human Factors
  – 3: Fundamentals

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  – 13: Roadway Segments
  – 14: Intersections
  – 15: Interchanges
  – 16: Special Facilities
  – 17: Networks

• Glossary
What is a Part D CMF?

- Ratio showing the change in the number of crashes between two conditions
- Usually a comparison of a proposed condition to an existing condition
  - Existing Traffic Signal Control
  - Proposed Single Lane Roundabout

\[
CMF = \frac{\text{Crash frequency for proposed condition } 'p'}{\text{Crash frequency for existing condition } 'e'} = \frac{E_p}{E_e}
\]
Sources of Crash Modification Factors

- Part C contains CMFs applied in the predictive method
- Part D presents CMFs for:
  - Chapter 13: Roadway Segments
  - Chapter 14: Intersections
  - Chapter 15: Interchanges
  - Chapter 16: Special Facilities and Geometric Situations
  - Chapter 17: Road Networks
- FHWA CMF Clearinghouse
  - [http://www.cmfclearinghouse.org/](http://www.cmfclearinghouse.org/)
Russell Street Corridor Study

• Project Context
  – Update of traffic analysis for widening of 1.5-mile long corridor in Missoula, MT
  – Public opposition to original corridor study
    • One advocacy group formed specifically to fight this project
    • Bike/pedestrian groups uneasy
    • Opinion that safety was not sufficiently quantified in the initial study
Russell Street Corridor Study

• Basic Project Question
  – Which alternative best accommodates projected traffic volumes without compromising the safety of roadway users?

• Project Activities
  – Conducted Safety and MMLOS evaluations
  – Quantified predicted safety trade-offs between concepts
Russell Street Corridor Study

- One of five river crossings
- Two and three-lane cross-section
- Important route for bicycle commuters
- AADT of 20,000 to 25,000
Russell Street Corridor Study

- Six alternatives (Alternative 1 is no build)
- Mixture of cross-sections and traffic control

<table>
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<th>Intersection / Segment</th>
<th>DEIS Alternatives</th>
<th>Option 6</th>
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<td>S. 14\textsuperscript{th}-Mount</td>
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</table>
Russell Street Corridor Study

| Percentage of Crashes Compared to No-Build Scenario (Alternative 1) | 3-Lane Volume Scenario | 5-Lane Volume Scenario |
|---|---|---|---|
| Alt 1 | Alt 2 | Alt 3 | Option 6 | Alt 1 | Alt 4 | Alt 5-R | Option 7 |
| 100% | 67% | 65% | 85% | 100% | 70% | 63% | 73% |

- **Good Performance**
  - Alternative 2
  - Alternative 3
  - Alternative 5R

- **Fair Performance**
  - Alternative 4
  - Alternative 6
  - Alternative 7

- **Poor Performance**
  - Alternative 1 – No Build Condition
Russell Street Corridor Study

• Key Characteristics of Well-Performing Alternatives
  – Raised Medians
  – Roundabouts
  – Left-turn Lanes at Intersections
Russell Street Corridor Study

• Value of Analysis
  – Allowed City and State to consider quantified safety information in selection process.
  – Comprehensive assessment of alternatives created a better understanding of tradeoffs.
  – Allowed City and State staff to communicate to the public and elected officials that the preferred alternative is an improvement over existing conditions.
US 97 Study – Bend, Oregon

• Corridor Study
  – Access Management Considerations
  – Traffic Operations Considerations

• Long term solutions are a long way out but near term development goals remain

• Use safety evaluation criteria to specifically measure the relative merits of various project considerations

• Identify strategic improvements to improve safety performance that buy time until long range solutions are in place
US 97 Study

Library of Potential Improvements

- Improved Intersections
- Enhanced Railroad Crossing
- Pedestrian, Bike & Transit Improvements
- Non-motorized Connectivity

- Gateway Features
- Speed Management Techniques
- Transition Zone
- Defined Urban Features

[Diagram showing various improvements and treatments along US 97]
US 97/Cooley Intersection Safety

• Current annual crashes
  – ~ 6 crashes/year (2 injury, 4 PDO)

• Predicted crashes 2020 no improvements
  – ~ 8 crashes/year (3 injury, 5 PDO)
Potential Targeted Countermeasures

• Need for detailed review of crash type, location, approach, severity, time of day, etc.

• Example options
  – Intersection Control (e.g., modern roundabout)
  – Reduction of Conflict Points (e.g., grade separation)
  – Additional design elements (e.g., add right-turn lanes on US 97)
  – Warning treatments (e.g., flashing beacons, stop ahead signals)
## Potential Safety Benefits

<table>
<thead>
<tr>
<th>Countermeasure Options</th>
<th>Potential Annual Crash Reduction</th>
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<tr>
<td>Multilane Roundabout</td>
<td>0 (all crashes)</td>
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<tr>
<td></td>
<td>2 (injury crashes)</td>
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<td>Mid-Term (2 intersections with fewer conflict points)</td>
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<tr>
<td>Right Turn Lanes on US 97</td>
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<td>Advanced Warning</td>
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<td>Stop Ahead Warning Signs</td>
<td>4 (all crashes)</td>
</tr>
<tr>
<td></td>
<td>1-2 (injury crash)</td>
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</table>
US 97 Study

• Value of Analysis
  – Identify near term solutions that could address existing crash experience concerns
  – Consider near term improvements that are within reasonable City budget ranges
  – Create ways for economic development to continue versus being stunted by uncertainty about long term solutions
US 26 Corridor Study – Portland, Oregon

• Corridor considering cross section changes
  – Access management study
  – Pedestrian/bike facilities
  – Rural roadway evolving to urbanized features
  – Basic corridor capacity improvement

• Project where traffic operations are not clear differentiators
  – High volume considerations
  – Low volume considerations

• Safety and Multi Modal Level of Service are supplemental performance measures to traditional vehicular operational evaluations
US 26 (Powell Boulevard) Context
US 26 (Powell Boulevard) Corridor Study

- Originally had 22 specific alternatives
- Organized alternatives into five primary groups
- Tested alternatives using the HSM predictive method

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Access Management and Intersection Modifications at 122nd</td>
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<tr>
<td>2</td>
<td>Different locations of left-turn lanes along SE Powell Boulevard</td>
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<tr>
<td>3</td>
<td>Three-lane (TWLTL) roadway with different roadway element widths</td>
</tr>
<tr>
<td>4</td>
<td>Three-lane (raised median) roadway with different roadway elements</td>
</tr>
<tr>
<td>5</td>
<td>Existing conditions with different pedestrian features</td>
</tr>
</tbody>
</table>
US 26 (Powell Boulevard) Corridor Study Safety Analysis Results

- Two groups of alternatives emerged with clear safety benefits

<table>
<thead>
<tr>
<th>Alt Group</th>
<th>Description</th>
<th>% Crash Reduction</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Access management and intersection modifications near 122nd</td>
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<tr>
<td>2</td>
<td>Varying locations of left-turn lanes along US 26</td>
<td>1-3%</td>
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<tr>
<td>3</td>
<td>Three-lane (TWLTL) roadway with varying roadway element widths</td>
<td>21%</td>
</tr>
<tr>
<td>4</td>
<td>Three-lane (raised median) roadway with varying roadway elements</td>
<td>19-27%</td>
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<td>5</td>
<td>Existing conditions with different pedestrian features</td>
<td>0%</td>
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</table>
US 26 (Powell Boulevard) Corridor Study
MMLOS Analysis Results

- Similar performance relative to no-build

<table>
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<tr>
<th>Alternative Group</th>
<th>Bicycle Facility LOS</th>
<th>Pedestrian Facility LOS</th>
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<tbody>
<tr>
<td></td>
<td>Eastbound</td>
<td>Westbound</td>
</tr>
<tr>
<td>Existing/No Build</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
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</tr>
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<td>E/F</td>
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<tr>
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</tbody>
</table>

Alternative focused on Pedestrian Treatments
What else could be done to improve MMLOS performance?

- Landscape buffer between roadway and sidewalk improves Pedestrian LOS to C

- Rectangular Rapid Flashing Beacons at uncontrolled pedestrian crossings (improve yield rate) AND refuge island

- Greater consolidation of driveways and wider bicycle lanes are needed to improve Bicycle LOS
US 26 (Powell Boulevard) Corridor Study

• Value of Analysis
  – Allowed ODOT to consider quantified safety information in their selection process.
  – Comprehensive assessment of alternatives created a better understanding of tradeoffs.
  – Allowed ODOT to communicate to the public the benefit of doing more than sidewalks.
Presentation Overview

- Introductions
- Design Flexibility and Performance Based Evaluation
- Multimodal Level of Service
- Highway Safety Manual
- Discussion
Questions/Comments

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- Kamala Parks kparks@kittelson.com
- Brian Ray bray@kittelson.com