Evaluation of Freeway Work Zone Merge Concepts

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TxDOT Project: Reduction of Motorists’ Delay and Crash Potential Upstream of Highway Work Zone
Task Outline

Phase I: Foundation
- Task 1. Review of Lane Control Practices
- Task 2. Gather and Analyze Observational Data
- Task 3. Design Experiments

Phase II: Model
- Task 4. Network Performance
- Task 5. Driver Behavior and Operations
- Task 6. Impacts on Safety

Phase III: Synthesis
- Task 7. Decision Tree
- Task 8. Pilot Training Workshop
- Task 9. Final Reports

Schematic showing the logical relationships between tasks and phases
Introduction to Merge Concepts

• Three common families of merge concepts:
  – Early Merge
    • Ideal for low demand \((V/C < 1)\)
  – Late Merge
    • Ideal for low to moderate demand \((V/C = 1)\)
  – Signal Merge
    • Ideal for heavy demand \((V/C > 1)\)
Merge Concepts (1 of 4)

• Early Merge
  – Assumed effective with low traffic demand (V/C < 1)
    • Near capacity, queues would develop risk of high speed drivers coming in contact with queue
  – Implemented as either static or dynamic
  – Used to warn drivers in advance of work zone of upcoming closed lane(s)
    • Allows time for users to find gaps to merge and complete merging prior to closure
    • Reduces roadway capacity
  – Early merge guidance given at varying distances where work zone cannot be perceived
    • Merge ¼ mile from work zone (lane closure with ¼ mile buffer space)
Merge Concepts (2 of 4)

- **Traffic Space** allows traffic to pass through the activity area.
- **Work Space** is set aside for workers, equipment, and material storage.
- **Buffer Space (lateral)** provides protection for traffic and workers.
- **100' Downstream Taper**
- **Activity Area** is where work takes place.
- **Transition Area** moves traffic out of its normal path.
- **Advance Warning Area** tells traffic what to expect ahead.
Merge Concepts (3 of 4)

• Late Merge
  – Assumed effective with moderate traffic demand (V/C approximately 1.0)
  – Implemented as either static or dynamic
  – Encourages all lanes to be used until specified merging point (one-eighth mile buffer space)
    • Once vehicles reach merge point, users in closed lane(s) merge in an alternating pattern
    • Takes advantage of full capacity of highway to store queue and minimize queue length
• **Signalized Merge**
  – Assumed effective with heavily congested traffic demand (V/C > 1)
    • All vehicles treated equally by giving equal fractions of green times for all open lanes
      – Green provided to merging lane followed by equal green time for one or two through lanes
      – Minimizes queue jumping and driving in closed lanes, since there is no priority for any lanes
  – Simulations run for 30s, 60s, 90s, 120s cycle lengths
Data Collection Sites

• Houston site: IH-610E Loop Southbound at Clinton Drive to Lawndale
  – 1 main lane and left shoulder closed between 6/8/12-10/29/12

• 1st Austin site: Southbound IH-35 approaching 51st Street
  – Left-side lower deck exit lane closed between 4/23/12-4/24/12

• 2nd Austin site: Westbound Oltorf Road at IH-35
  – Westbound through lane closed between 7/24/12-7/26/12
Data Collection: Austin I-35 and 51st Street

Short term impacts-reaction of drivers to new work zone when there is not enough information to make strategic decisions
Data Collection: Austin Westbound
Oltorf Street and IH-35

[Graph showing volume of vehicles per 15 minutes by time of day for different days, including Normal and Workzone conditions.]
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Schematic showing the logical relationships between tasks and phases
Task 5 Product(s)

- Outcome: Technical memorandum
  - Describes how microscopic simulation is used to model each scenario
  - Discusses modeling results
    - How do traffic operations differ across scenarios?
    - What patterns emerge?
Introduction to VISSIM

- VISSIM is a microscopic, behavior-based simulation model.
  - Microsimulation used to determine optimal merge concept techniques
    - Simulation run for 2-to-1, 3-to-2, and 3-to-1 lane configuration
    - Varying per lane demand on remaining open lanes through the work zone for 1800, 2000, 2200, 2400, and 2600 pcphpl processed
    - For signal merge, ran 30s, 60s, 90s, 120s cycle lengths
Measures of Effectiveness

• **Delay**
  – Avg. delay per vehicle (s)
  – Avg. # of stops per vehicle
  – Avg. stopped delay per vehicle (s)

• **Speed**
  – Avg. speed (mph)
  – Avg. speed on link prior to closure (mph)

• **Queue**
  – Avg. queue length (ft)
  – Max queue length (ft)
  – # of stops within queue
## Weighted Rating System

<table>
<thead>
<tr>
<th>Tier</th>
<th>Assigned Points</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>• Avg. delay time&lt;br&gt;• Avg. speed</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>• Avg. number of stops / vehicle&lt;br&gt;• Avg. stopped delay / vehicle&lt;br&gt;• Avg. queue length</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>• Avg. speed on link prior to closure&lt;br&gt;• Max. queue length&lt;br&gt;• Number of stops within queue</td>
</tr>
</tbody>
</table>

Showed no difference for signal merge

- Points assigned to merge concept for the output with the most efficient operations
### Optimal Merge Concepts

#### Optimal Merge Concept Techniques based on Lane Configuration and Demand

<table>
<thead>
<tr>
<th>User Demand</th>
<th>V &lt; C</th>
<th>V &lt; C</th>
<th>V = C</th>
<th>V &gt; C</th>
<th>V &gt; C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-to-1</td>
<td>EM</td>
<td>EM</td>
<td>LM</td>
<td>SM-90s</td>
<td>SM-90s</td>
</tr>
<tr>
<td>3-to-2</td>
<td>EM</td>
<td>EM</td>
<td>EM</td>
<td>EM</td>
<td>SM-120s</td>
</tr>
<tr>
<td>3-to-1</td>
<td>EM</td>
<td>EM</td>
<td>EM</td>
<td>SM-60s</td>
<td>SM-60s</td>
</tr>
</tbody>
</table>

#### Optimal Signalized Merge by Cycle Length

<table>
<thead>
<tr>
<th>User Demand</th>
<th>V &lt; C</th>
<th>V &lt; C</th>
<th>V = C</th>
<th>V &gt; C</th>
<th>V &gt; C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-to-1</td>
<td>60 sec</td>
<td>90 sec</td>
<td>90 sec</td>
<td>90 sec</td>
<td>90 sec</td>
</tr>
<tr>
<td>3-to-2</td>
<td>60 sec</td>
<td>60 sec</td>
<td>60 sec</td>
<td>60 sec</td>
<td>120 sec</td>
</tr>
<tr>
<td>3-to-1</td>
<td>60 sec</td>
<td>60 sec</td>
<td>60 sec</td>
<td>60 sec</td>
<td>60 sec</td>
</tr>
</tbody>
</table>
Safety Analysis

• Vehicle trajectory files are generated by running VISSIM, then used as an input into Surrogate Safety Assessment Model (SSAM) to produce traffic conflicts.

• SSAM combines microsimulation and automated conflict analysis, which analyzes frequency and character of vehicle-to-vehicle collisions in traffic.
SSAM Result Analysis

• Conflicts Related to Work Zone Closures:
  (a) Rear-end conflict   (b) Lane-change conflict
Implementing Fixed Cycle Work Zone Traffic Signal Control (FCWZTSC) could significantly reduce the lane-change conflicts for all cycle lengths and all demands, except 1800VPHPL with a 30 second cycle length, when compared to the baseline (early merge) strategy.

Implementation of FCWZSC increases rear-end conflicts for all volume conditions, especially when the cycle length is 30 seconds.
SSAM Result: 3-to-2 Lane Configuration

- For light traffic demands of 1800 vphpl or 2000 vphpl, the baseline lane control strategy works well and has the least lane-change and rear-end conflicts.

- For heavy traffic condition, FCWZTSC can reduce both lane-change and rear-end conflicts.
SSAM Result: 3-to-1 Lane Configuration

- FCWZTSC can significantly reduce lane-change conflicts, especially when the traffic volume is high.
- When the traffic volume reaches 2400 vphpl, FCWZTSC starts to work well and reduces rear-end conflicts.
Procedure

Assess Before Condition (Capacity & Volume Profile)

Traffic Control Plan Data

Assess After Condition (Capacity & Volume Profile)

Approve Plan? No

Choose Merge Concept

Analyze VMS Placement

Done

Yes
Choose Merge Concept

- **Early Merge**: preferred, less queuing, and less user cost
  - Static or Dynamic

- **Late Merge**: If Demand approaches capacity and queuing expected
  - Static or Dynamic

- **Signalized Merge**: If Demand exceeds capacity

![Diagram showing the process of choosing a merge concept](Dynamic_Late_Merge_(ITE).png)
Conclusions

• Assumptions of different merge concept applications proved by VISSIM
  – Early merge: V/C < 1
  – Late merge: V/C = 1
  – Signal merge: V/C > 1

• Signal merge can reduce lane-change conflicts as demand exceeds 2,200 vphpl
  – should have minimum cycle length of 60s
Recommendations

• Analysis assumed no truck volume
  – 10% of traffic as trucks could impact outputs

• For signal merge, simulation assumes equal demand in all lanes and thus, equal green times
  – If drivers perceive work zone, demand may be unequal

• No horizontal or vertical grade

• Application of joint merge

• Analysis will be applied to various sites across Texas
  – TxDOT suggested using simulation with no entrance or exit ramps within two miles before or after work zone
References


Questions?