ZIPPER MERGE

Applicability of Zipper Merge versus Early Merge in Kentucky Work Zones

Erin Lammers
Kentucky Transportation Center University of Kentucky
on behalf of
The Kentucky Transportation Cabinet
BACKGROUND

• Increased highway maintenance activities need for better traffic flow management within work zones
• KYTC’s goal: provide safe environment, ensure minimum delay to traveling public
TRADITIONAL MERGE

- Often result in unsatisfactory driver behavior
  - Unsafe for drivers and construction workers
- Traditional early merge: drivers are notified of lane closure and merge at earliest opportunity
  - Leaves one lane unused longer than necessary
  - Excessively long queue in open lane
  - May negatively affect safety, travel times, and highway operations
ZIPPER MERGE

• A form of late merging: potentially safer and more efficient
• Drivers encouraged to use both lanes up until the merge point and then take turns merging at the close point

• Advantages:
  • Road capacity is more fully realized
  • Reduces potential interference with entrance/exit ramps
  • Better flow management, decreased queue length, and safety improvements
OBJECTIVES

• Previous work: simulations show zipper merge is best, but real-world situations have shown more complexity
  • Importance of driver behavior
• 2 case studies at work zones
  • Both considered qualitative and quantitative indicators
  • Interstate 275 (Carroll Cropper Bridge) – comprehensive study
  • Kentucky 9 (Taylor Southgate Bridge) – less detailed, more emphasis on public
CASE STUDY 1: INTERSTATE 275

- Fall of 2015
- Carroll Cropper Bridge spans Ohio River from Kentucky to Indiana, under Kentucky’s jurisdiction.
- Project scope: public awareness campaign, testing traffic control devices, investigating and implementing methods of data collection, and analyzing the data to determine the effect of the zipper merge.
PUBLIC AWARENESS CAMPAIGN

- On KYTC website:
  - Write-up of concept
  - Video highlighting location and guidance
  - Brief radio announcement
  - Facebook page, open to public input too

MERGE LIKE A ZIPPER
Alternate When Merging
TRAFFIC CONTROL

- Advise drivers of upcoming lane closure and how to utilize the system
- Text reads “Use both lanes during backup”
- “Take turns” at merge point
DATA COLLECTION

• In-field data collection (floating car) to measure vehicle speeds and queue lengths
  • Early merge: August 1 – October 18
    • Control data
  • Zipper merge: October 19 – December 2
    • Experimental data
  • Data collected during a.m. and p.m. peak hours
    • Quantitative data: GPS created text file every second with information about vehicle’s spatial position
    • Observational data: notes on driver behavior and traffic circumstances
Data Processing: Excel

- Text file data included lat/long, time, direction, distance along route
- To determine speed at single point:

\[
\text{Speed} = \cos^{-1}\left(\cos(90 - lat_p) \times \cos(90 - lat_c) + \sin(90 - lat_p) \times \sin(90 - lat_c) \times \cos(long_p - long_c) \times 3958.756 \times 3600\right)
\]

where:
- \(lat_p\) = latitude of previous point
- \(lat_c\) = latitude of current point
- \(long_p\) = longitude of previous point
- \(long_c\) = longitude of current point

- Speeds binned into 3 groups: <15mph, 15-30mph, >30mph
- Added column for these speed categories; helped for GIS mapping in next step
DATA PROCESSING: GIS

• Excel files created for each trip, loaded into ArcGIS
• Each point was geographically referenced and surrogate values for queue speed displayed by color
• By this process, developed series of maps: half early merge, half zipper merge
• Representative (although somewhat idealized) examples…
DATA ANALYSIS: TRAFFIC FLOW INDICATORS

- Maps alone not enough to draw conclusions, so combined them with quantitative information from Excel documents
- Traffic flow indicators: average time to make a pass, average queue time, average queue length, average speed through a queue, average length of pass, and average speed through a pass.
- Most important: queue parameters, both to travelling public and construction workers
- Separated by direction of travel and time of day
## Data Analysis: Traffic Flow Indicators, Morning

<table>
<thead>
<tr>
<th></th>
<th>Queue Time</th>
<th>Queue Length</th>
<th>Queue Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 1 Morning Queue Data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Early Merge</strong></td>
<td>Average</td>
<td>4.80</td>
<td>0.57</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>7.07</td>
<td>0.45</td>
<td>14.15</td>
</tr>
<tr>
<td>Sample Size</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>Zipper Merge</strong></td>
<td>Average</td>
<td>6.51</td>
<td>0.49</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>9.93</td>
<td>0.38</td>
<td>26.17</td>
</tr>
<tr>
<td>Sample Size</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>
## Data Analysis:
### Traffic Flow Indicators, Evening

<table>
<thead>
<tr>
<th></th>
<th>Early Merge</th>
<th>Zipper Merge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Queue Data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Queue time</strong></td>
<td>6.47</td>
<td>7.56</td>
</tr>
<tr>
<td><strong>Queue length</strong></td>
<td>0.76</td>
<td>0.86</td>
</tr>
<tr>
<td><strong>Queue speed</strong></td>
<td>8.94</td>
<td>9.07</td>
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<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>9.40</td>
<td>10.45</td>
</tr>
<tr>
<td><strong>Sample size</strong></td>
<td>30</td>
<td>56</td>
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</table>
DATA ANALYSIS:
TRAFFIC INDICATORS

• Queue data are the most useful indicators to analyze
• No statistically significant changes in performance metrics
• Traffic quality indicators operate independently: some parameters improved while others did not.
  • May be valuable to traffic planners
DATA ANALYSIS: SAFETY

<table>
<thead>
<tr>
<th></th>
<th>Early merge</th>
<th>Zipper merge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of crashes</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Number of injuries</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Crash type (majority)</td>
<td>Rear-ends</td>
<td>Sideswipes</td>
</tr>
<tr>
<td>Report mentions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>construction as</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>contributing factor</td>
<td>0</td>
<td>2</td>
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<tr>
<td>Report mentions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>merge as contributing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>factor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Limited crash data for relatively short time period
• Main conclusion: no quantifiable difference between early merge and zipper merge.
• Public awareness is important for safety
RESULTS FOR INTERSTATE 275

- Raw data: some positive changes
- Statistically analyzed data: no significant changes
- Safety analysis inconclusive
- Overall, this case study failed to provide any substantial evidence in favor of one merge system over the other
- However, finding meaningful method of data collection and analysis was invaluable. Further studies can expand upon these methodologies.
- Additionally, this case study highlighted the importance of collecting qualitative data in addition to quantitative data.
CASE STUDY 2: KY 9

- June/July 2018
- KY 9: Taylor Southgate Bridge crosses Ohio River between Covington, Kentucky and Cincinnati, Ohio
  - Short length: 0.4 mile
  - Mostly regular commuters
- Zipper merge implemented from the start
  - Facilitated driver understanding, but prevented thorough before-and-after analysis
  - Instead, focused more on qualitative indicators
DATA COLLECTION & ANALYSIS

• Speed data collection and mapping modeled after first case study
  • Drivers maintained a steady pace leading up the bridge, but quickly slowed down once they were on it.
  • Zipper merge located halfway across, but construction affected entire length of bridge and more
DATA COLLECTION & ANALYSIS

- Mounted GoPro camera
QUALITATIVE ANALYSIS

• For this case study, qualitative indicators just as important as quantitative indicators

• Community feedback: letter from commuting citizen, concerned with safety of early merge system, suggested zipper merge.

• Transportation workers and construction personnel: zipper merge noticeably shortened backups, worked well.

• Public-facing transportation officials: zipper merge helped move traffic and calm motorists. Equalized drivers by eliminating the idea of the “good” driver waiting their turn and the “bad” driver racing through traffic.

• Researchers, data collectors: zipper merge worked very well here
  • Noted difference from first case study: no trucks!
OVER AND OVER AGAIN…

I’m not letting any of those jerks past.
RESULTS FOR KY 9

• Researchers concluded that this bridge was a judicious location to implement the zipper merge and that doing so improved the flow of traffic.
CONCLUSIONS & RECOMMENDATIONS

• Limited conclusions and minimal support for zipper merge
• However, enough potential that they should continue to be implemented and studied when possible.
• Traffic data parameters + photos/videos = complete picture of zipper merge effectiveness
• Agencies must decide what factors are important to them and choose their merging system accordingly.
• Biggest lessons: public awareness and truck drivers!!
• Erin Lammers
  Kentucky Transportation Center, University of Kentucky
  email: erin.lammers@uky.edu
  phone: (859) 218-0379