Safety Evaluation of Signalized Intersections with Automated Vehicles at Various Penetration Levels Based on Conflict Analysis of Simulated Traffic

Maria Espinosa
M.A.Sc

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OUTLINE

- Background
- Objective & Methodology
- Assumptions & Limitations
- Crash Modification Factors for Introducing AVs
  - Traffic Simulation, Conflict Analysis and Crash Prediction at:
    - 0% AV
    - 50% AV
    - 100% AV
- Crash Modification Factors for a Safety Treatment in the Presence of AVs
- Conclusions & Future Work
AUTOMATED VEHICLES

“...operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking. They are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode.” (NHTSA, 2013)

Leading causes of crashes:
- Impaired driving
- Speeding
- Human error
BACKGROUND CONTINUED...

SO WHAT HAPPENS WHEN AVs ARE INTRODUCED TO OUR ROADS?
...SO WHAT WERE WE TRYING TO ACCOMPLISH?

To perform a safety evaluation based on CONFLICTS from simulated traffic.

Near – collision. When one or both involved entities brakes or swerves within 2 seconds in order to avoid the crash.
HOW WAS IT ACCOMPLISHED?

- Simulate automated vehicles at 3 different scenarios (0%AV, 50%AV & 100%AV)
- Analyze simulation results and obtain possible number of conflicts
- Input conflicts into crash model in order to predict crashes
- Calculate crash modification factors (CMFs) to compute expected number of crashes after implementing a countermeasure
- Perform safety evaluation by comparing crashes of all simulated scenarios
- Evaluate safety of intersections based on results

Ryerson University
ASSUMPTIONS & LIMITATIONS

• Simulations are assumed to have normal road and weather conditions
• Pedestrians were not included in the analysis
• All vehicles have the same automation level: Level 3
• Driving behaviour values were based on previous research (For AVs and no AVs)
• No calibration is possible due to the lack of data
CRASH MODIFICATION FACTORS FOR INTRODUCING AVs

Simulation and conflict analysis
- 0% AV
- 50% AV
- 100% AV

New driving behaviour

Crash prediction and evaluation
- 0% AV
- 50% AV
- 100% AV

CMFs
- At 50% AV
- At 100% AV
TRAFFIC SIMULATION

• 78 signalized intersections were coded in Synchro

• Synchro files were imported into VISSIM

• Once in VISSIM, new vehicle types were created (AV Car & AV Truck)
TRAFFIC SIMULATION CONTINUED...
CONFLICT ANALYSIS

- Software: Surrogate Safety Assessment Model (SSAM)

<table>
<thead>
<tr>
<th>Summary Gr.</th>
<th>Total</th>
<th>Unclassified</th>
<th>Crossing</th>
<th>RearEnd</th>
<th>LaneChange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmerged</td>
<td>353</td>
<td>0</td>
<td>30</td>
<td>1235</td>
<td>233</td>
</tr>
<tr>
<td>RearEnd</td>
<td>309</td>
<td>0</td>
<td>24</td>
<td>1784</td>
<td>290</td>
</tr>
<tr>
<td>LaneChange</td>
<td>564</td>
<td>0</td>
<td>56</td>
<td>100</td>
<td>115</td>
</tr>
</tbody>
</table>

50%AV

100%AV

0%AV

Rear End

Crossing

Lane change
CRASH PREDICTION MODEL USING CONFLICTS

• Crash Model

\[
\text{crashes per year} = e^{\alpha} \times \text{conflicts}^{\beta_1} \times \text{peak hour ratio}^{\beta_2}
\]

where \( \alpha \) and \( \beta \) are regression estimates.

<table>
<thead>
<tr>
<th>Crash Type for Dependent Variable</th>
<th>Conflict Type for Independent Variable</th>
<th>( \alpha ) Estimate (Pr &gt; ( \chi^2 ))</th>
<th>( \beta_1 ) Estimate (Pr &gt; ( \chi^2 ))</th>
<th>( \beta_2 ) Estimate (Pr &gt; ( \chi^2 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>Total</td>
<td>-0.9722 (.2771)</td>
<td>0.3461 (&lt;.0001)</td>
<td>-1.0775 (.0023)</td>
</tr>
<tr>
<td>Injury</td>
<td>Total</td>
<td>-1.7527 (.0543)</td>
<td>0.3030 (&lt;.0001)</td>
<td>-0.8498 (.0164)</td>
</tr>
<tr>
<td>Angle</td>
<td>Crossing</td>
<td>-0.8015 (.2791)</td>
<td>0.2549 (.0020)</td>
<td>-0.7117 (.0485)</td>
</tr>
<tr>
<td>Rear end</td>
<td>Rear end</td>
<td>-1.2676 (.2341)</td>
<td>0.3423 (&lt;.0001)</td>
<td>-0.6609 (.1264)</td>
</tr>
</tbody>
</table>

4 models
78 intersections
3 scenarios (0%AV, 50%AV & 100%AV)

Source: (Saleem, Persaud, Shalaby, & Ariza, 2012)
CRASH MODIFICATION FACTORS FOR INTRODUCING AVs

<table>
<thead>
<tr>
<th>MODEL</th>
<th>CMF at 50%AV</th>
<th>CMF at 100%AV</th>
<th>Reduction in crashes for 50%AV</th>
<th>Reduction in crashes for 100%AV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Crashes using Total Conflicts</td>
<td>0.76</td>
<td>0.73</td>
<td>24.4%</td>
<td>27.1%</td>
</tr>
<tr>
<td>Injury Crashes using Total Crashes</td>
<td>0.78</td>
<td>0.76</td>
<td>21.7%</td>
<td>24.2%</td>
</tr>
<tr>
<td>Angles Crashes using Crossing Conflicts</td>
<td>0.99</td>
<td>1.00</td>
<td>1.2%</td>
<td>0%</td>
</tr>
<tr>
<td>Rear-end Crashes using Rear-end Conflicts</td>
<td>0.72</td>
<td>0.68</td>
<td>27.9%</td>
<td>31.8%</td>
</tr>
</tbody>
</table>

- Implementing AVs at signalized intersections will potentially reduce crashes.
- Marginal change in reduction of crashes from 50%AV to 100%AV.
  - Indication of a change in driving behaviour from the non-automated vehicles when AVs are present
  - No V2I present in the simulation
CRASH MODIFICATION FACTORS (CMFs) FOR A SAFETY TREATMENT IN THE PRESENCE OF AVs

• To explore the effects on signalized intersections when changing a permissive left turn phasing to permissive-protected.

• Performed to 13 of the 78 signalized intersections.

Source: www.safety.fhwa.dot.gov
### SAFETY TREATMENT CONTINUED...

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>0% AV Penetration</th>
<th>50% AV Penetration</th>
<th>100% AV Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Predicted Crashes/year</td>
<td>Average CMF</td>
<td>Total Predicted Crashes/year</td>
</tr>
<tr>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Total</td>
<td>478.01</td>
<td>340.66</td>
<td>0.71</td>
</tr>
<tr>
<td>Angle</td>
<td>71.09</td>
<td>62.93</td>
<td>0.89</td>
</tr>
<tr>
<td>Rear End</td>
<td>150.78</td>
<td>104.72</td>
<td>0.69</td>
</tr>
<tr>
<td>Side Swipe</td>
<td>56.52</td>
<td>45.76</td>
<td>0.81</td>
</tr>
<tr>
<td>Turning</td>
<td>72.16</td>
<td>62.38</td>
<td>0.86</td>
</tr>
<tr>
<td>Injury</td>
<td>103.86</td>
<td>77.21</td>
<td>0.74</td>
</tr>
</tbody>
</table>
CONCLUSIONS

• Introduction of automated vehicles to signalized intersections will potentially reduce crashes.

• Difference in crash reduction from having 50%AV penetration to 100%AV is marginal.

• SAFETY TREATMENT:
  ▪ At 0%AV, crashes will be potentially reduced.
  ▪ CMF values for 50%AV and 100%AV diminish considerably compared to 0%AV.
  ▪ AVs can be considered a safety treatment by itself. Additionally, these results could be due to randomness in the simulation process.
FUTURE WORK

• Use VISSIM Add On Tool to compare results and develop a more accurate simulation.
• Perform different safety treatments under the presence of AVs.
• Use more penetration levels of AVs.
THANK YOU