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

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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

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BACKGROUND

- **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

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BACKGROUND CONTINUED…

SO WHAT HAPPENS WHEN AVs ARE INTRODUCED TO OUR ROADS?

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...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.

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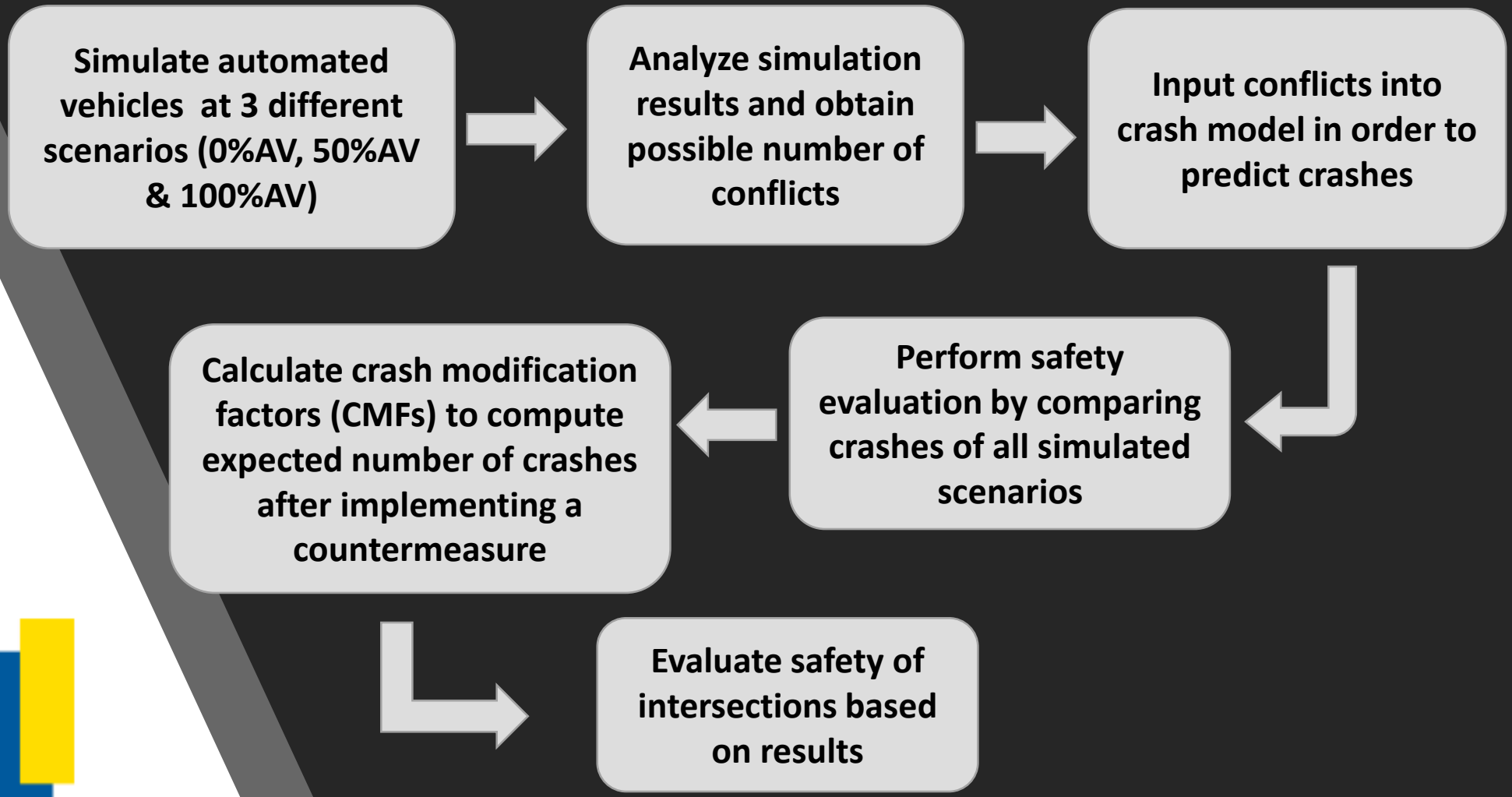
HOW WAS IT ACCOMPLISHED?



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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

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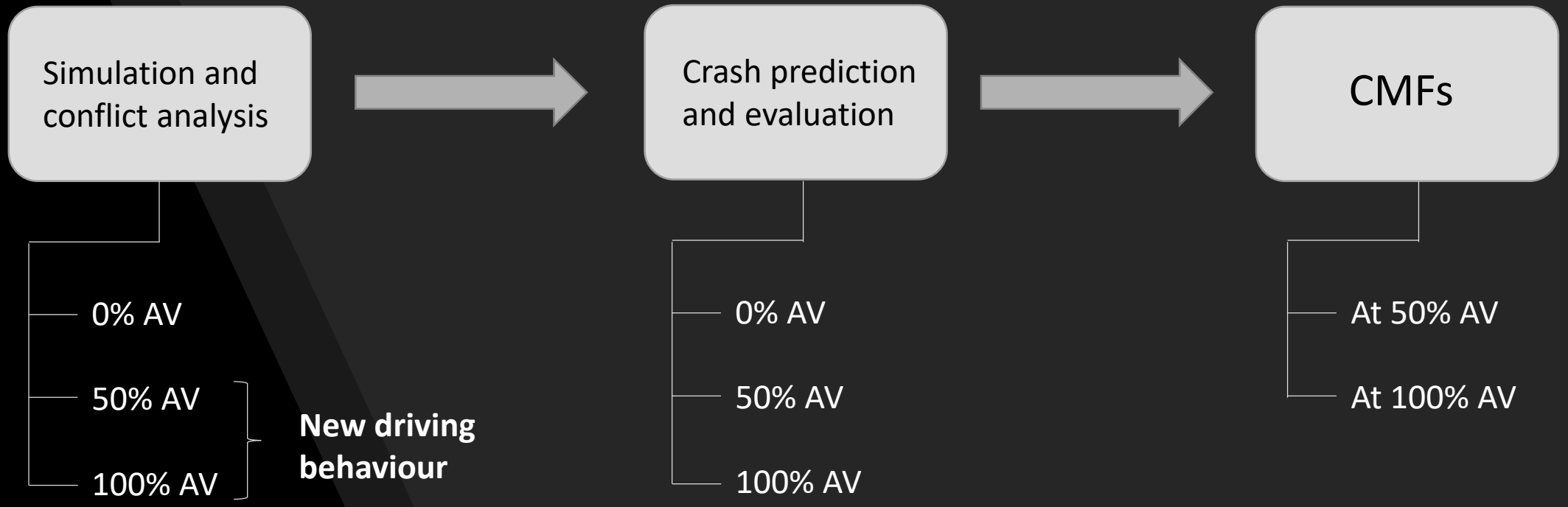
CRASH MODIFICATION FACTORS FOR INTRODUCING AVs



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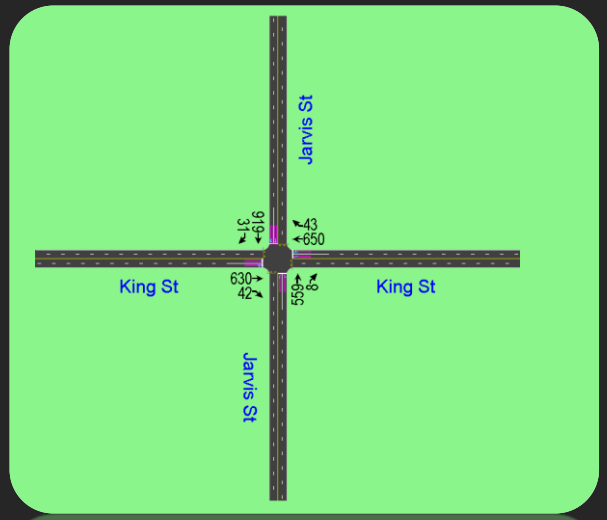
TRAFFIC SIMULATION

- 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)

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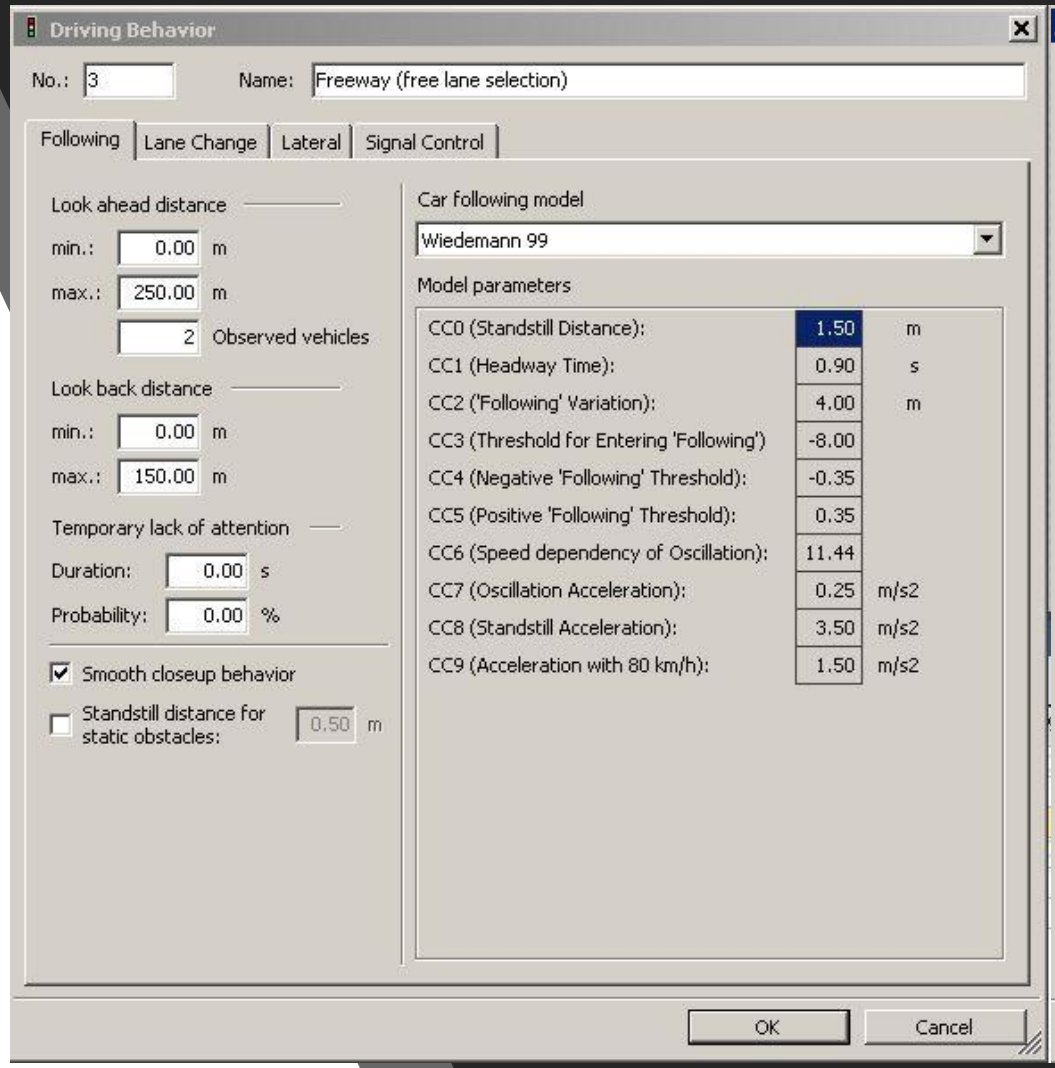
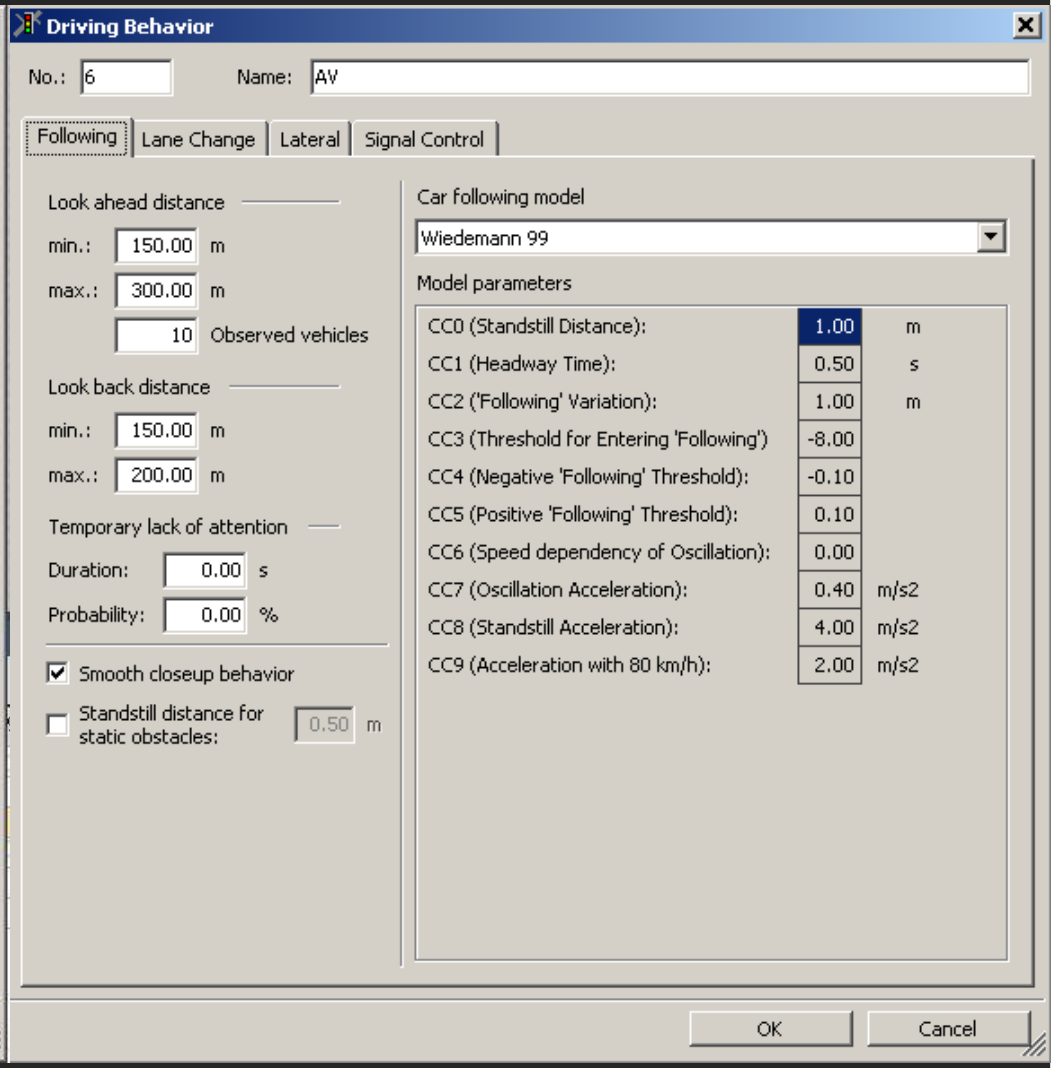
TRAFFIC SIMULATION CONTINUED...





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CONFLICT ANALYSIS

- Software : Surrogate Safety Assessment Model (SSAM)

353

Summary Gr...	Total	Unclassified	Crossing	RearEnd	LaneChange
Unfiltered-All	1857	0	99	1325	233
Filtered-AllFiles	353	0	91	230	32
Filtered E:\R...	46	0	5	34	7
Filtered E:\R...	44	0	9	33	2
Filtered E:\R...	32	0	7	23	2
Filtered E:\R...	36	0	13	22	1
Filtered E:\R...	36	0	14	21	1
Filtered E:\R...	30	0	8	18	4
Filtered E:\R...	32	0	10	19	3
Filtered E:\R...	38	0	10	25	3
Filtered E:\R...	25	0	6	15	4
Filtered E:\R...	34	0	9	20	5

50%AV

309

Summary Gr...	Total	Unclassified	Crossing	RearEnd	LaneChange
Unfiltered-All	1600	0	94	1249	257
Filtered-AllFiles	309	0	87	184	38
Filtered Z:\R...	37	0	14	22	1
Filtered Z:\R...	29	0	10	14	5
Filtered Z:\R...	35	0	8	20	7
Filtered Z:\R...	34	0	3	26	5
Filtered Z:\R...	22	0	7	13	2
Filtered Z:\R...	39	0	12	24	3
Filtered Z:\R...	28	0	6	17	5
Filtered Z:\R...	22	0	7	13	2
Filtered Z:\R...	32	0	9	17	6
Filtered Z:\R...	31	0	11	18	2

100%AV

564

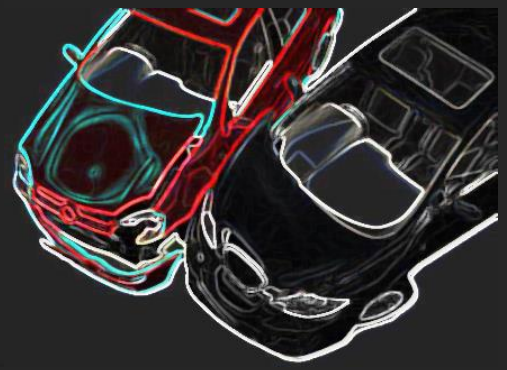
Summary Gr...	Total	Unclassified	Crossing	RearEnd	LaneChang
Unfiltered-All	1738	0	70	764	204
Filtered-AllFiles	564	0	46	483	35
Filtered C:\D...	52	0	7	42	3
Filtered C:\D...	49	0	8	38	3
Filtered C:\D...	67	0	6	57	4
Filtered C:\D...	51	0	5	41	5
Filtered C:\D...	50	0	1	45	4
Filtered C:\D...	68	0	3	62	3
Filtered C:\D...	58	0	4	51	3
Filtered C:\D...	65	0	5	58	2
Filtered C:\D...	61	0	4	52	5
Filtered C:\D...	43	0	3	37	3

0%AV

Rear End

Crossing

Lane change



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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 α and β are regression estimates.

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

TABLE 3 Parameter Estimates for Crash Models Based on VISSIM Simulated Conflicts

Crash Type for Dependent Variable	Conflict Type for Independent Variable	α Estimate ($Pr > \chi^2$)	β_1 Estimate ($Pr > \chi^2$)	β_2 Estimate ($Pr > \chi^2$)
Total	Total	–0.9722 (.2771)	0.3461 (<.0001)	–1.0775 (.0023)
Injury	Total	–1.7527 (.0543)	0.3030 (<.0001)	–0.8498 (.0164)
Angle	Crossing	–0.8015 (.2791)	0.2549 (.0020)	–0.7117 (.0485)
Rear end	Rear end	–1.2676 (.2341)	0.3423 (<.0001)	–0.6609 (.1264)

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Source: (Saleem, Persaud, Shalaby, & Ariza, 2012)

CRASH MODIFICATION FACTORS FOR INTRODUCING AVs

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

- 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

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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.

Source: www.safety.fhwa.dot.gov

- Performed to 13 of the 78 signalized intersections.

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SAFETY TREATMENT CONTINUED…

	0% AV Penetration			50% AV Penetration			100% AV Penetration		
Crash Type	Total Predicted Crashes/year		Average CMF	Total Predicted Crashes/year		Average CMF	Total Predicted Crashes/year		Average CMF
	Before	After		Before	After		Before	After	
Total	478.01	340.66	0.71	335.58	324.85	0.97	302.66	280.38	0.93
Angle	71.09	62.93	0.89	63.62	64.36	1.01	64.72	65.4	1.01
Rear End	150.78	104.72	0.69	102.2	98.94	0.97	89.19	81.37	0.91
Side Swipe	56.52	45.76	0.81	47.38	43.42	0.92	45.46	40.77	0.90
Turning	72.16	62.38	0.86	63.06	64.11	1.02	64.50	65.4	1.01
Injury	103.86	77.21	0.74	76.19	74.07	0.97	69.57	65.08	0.94

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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.

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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.

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Source: www.autoevolution.com

THANK YOU