A Statistics and Reaction Time based Framework for Impact Prediction of Automated Vehicles on Road Safety of Vulnerable Road Users

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Unmotorized Vulnerable Road Users

- Consider pedestrians and cyclists.
- Difficult to cover their interactions with AVs in microsimulation.
- Suggest statistical approach, based on accident data with accident causes.

Accident Statistics and Implied Effects of AVs

- Consider urban accident data (car-pedestrian accidents).
- Accident types to be fully mitigated can be determined based on AV models.
- Ideally all causes (except VRU error) should be eliminated with AVs.

„Suspected Causes" upon registration:

1	Nonadjusted Speed	-16
2	Ignoring priority, Ignoring a red light	-262
3	overtaking	-7
4	distraction	-448
5	alcohol, medication	-23
6	fatigue	-0
7	Pedestrian error	-290
8	heart-/healthproblems	-0
9	lack of safety margin	-9
10	violation of road laws	-10
11	technical defect	-0
12	obstacles on the road	-5
no data		-264

Effect of AVs on not-fully mitigated accidents

- Even VRU error should be reduced, dependent on reaction times of AVs.
- Reports note the pedestrians to be „at-fault" in 30% of the cases.
- The „at-fault" percentage was at 30% for cyclist–car accidents as well .

Country/City	Pedestrian at-Fault	Cyclist at-Fault
Hungary	33%	30%
Vienna 2016	20%	18%
San Francisco	30%	44%
Hawaii	7%	Not stated
North Carolina	59%	Not stated
Israel (on "urban" roads)	30%	Not stated

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Impacts on „VRU at-fault“ Accidents

- Assume 30% of accidents with VRUs in an urban setting are not mitigated since the VRU was „at-fault“.

- Use braking distance formula and AV‘s reaction time to estimate further reductions:

$$\mathrm{d} = v\, RT + \frac{v^2}{2a}$$

v… Speed
RT… Reaction Time
a… Deceleration
d… braking distance

- Obtain „equivalent“ speed by equating braking distances:

$$v_{Human}\, RT_{AV} + \frac{v_{Human}^2}{2a_{AV}} = v_{AV} RT_{Human} + \frac{v_{AV}^2}{2a_{Human}}$$

- Use „power model(s)“ of accident numbers:

$$Number\ Accidents\ New = Number\ Accidents\ Old * \left(\frac{v_{AV}}{v_{Human}}\right)^2$$

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Parameters and Impact Estimate

- Made equation parameters coherent with microsimulation:

	Max Deceleration
Human	5 m/s^2
1st Generation AV	7 m/s^2
2nd Generation AV	9 m/s^2

	RT
Human	1.5 s
1st Generation AV	1.0 s
2nd Generation AV	0.5 s

- Consider first and second generation AVs separately.
- Final Formula:

$$prop_{new} = 0.7 * prop_{human} + 0.3 * (prop_{human} + prop_{1stGen} * \left(\frac{v_{1stGen}}{v_{Human}}\right)^2 + prop_{2ndGen} * \left(\frac{v_{2ndGen}}{v_{Human}}\right)^2)$$

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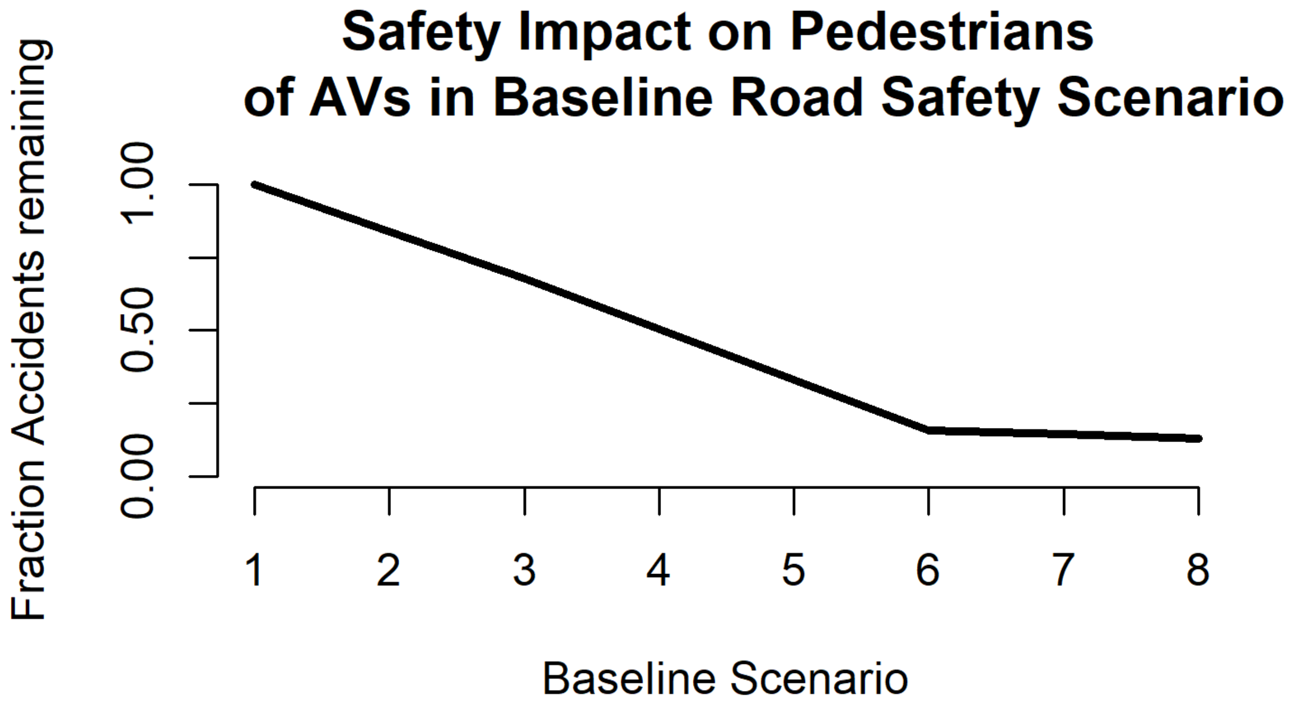
Impact on Road Safety Baseline Scenario



Baseline Step	1	2	3	4	5	6	7	8
Human	100%	80%	60%	40%	20%	0%	0%	0%
1st Gen AV	0%	20%	40%	40%	40%	40%	20%	0%
2nd Gen AV	0%	0%	0%	20%	40%	60%	80%	100%
Percentage remaining	100%	84%	68%	51%	33%	16%	14%	13%

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Combine Results with Microsimulation

- Fundamental connection: AV model parameters (RT, deceleration).
- Proportional decrease can be applied to absolute accident numbers or different types of relative accident numbers (per amount of vehicles or per kilometers driven in particular).
- Relative numbers can reflect results from microsimulation (changes in kilometers driven, changes in number of vehicles on road).

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Limitations - Future Work

- Usage restrictions of AVs could be reflected in the share of accidents they affect (weather conditions, time of day, area they can operate in -> data preparation).
- Additional risks for AV systems (failure to recognize object, system hacks) not included here.
- Connection between power model and RT based approach and classical risk models or surrogate safety measures to be investigated further.

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