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Validation of an eyes-off-road crash causation model for virtual safety assessment

Jonas Bärgman (Chalmers)

Co-authors

Malin Svärd (Volvo Cars)

Simon Lundell (Volvo Cars)

Xiaomi Yang (Chalmers)

jonas.bargman@chalmers.se

Background

- Virtual simulations – used to assess advanced driver assistance systems (ADAS) and autonomous vehicles (AVs)
- …but, also possible to assess driver behavior impact on safety
- … and, a need to find better simple methods to assess DDI and countermeasures (e.g., for guidelines and NCAPs)

Aim and objectives

Aim

To validate a glance- and deceleration-based crash causation model + response model

Objectives

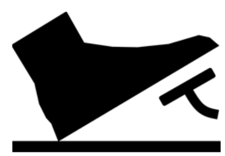
1. Comparing impact speed distributions: real crashes vs. generated with the proposed crash causation and response model
2. Comparing proposed model performance with traditional brake-light + reaction time + decel. model
3. Illustrate safety assessment of HMIs using the proposed models

Modeling crash causation

- Different model exist – most common a reaction time delay with some braking profile after brake-light onset

- In this study, two crash causation model component:
  - Off-road glances

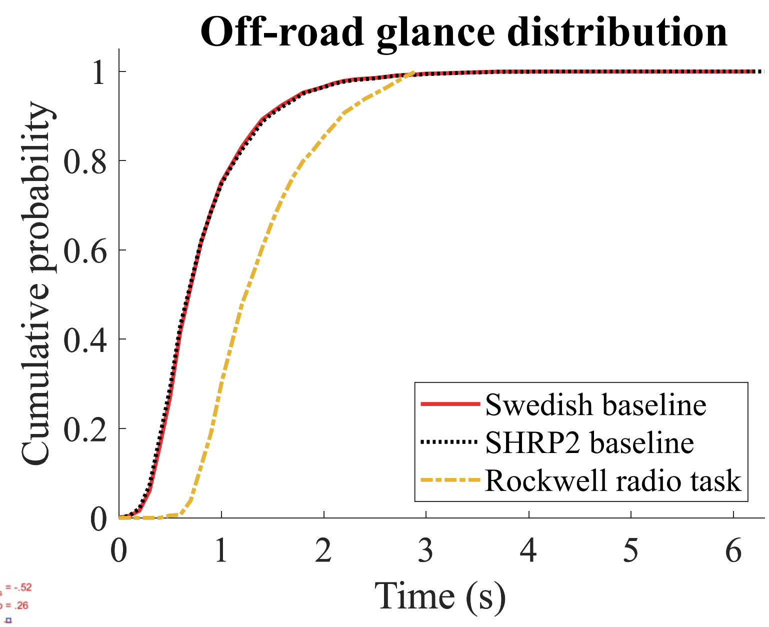
  - Less-than-maximum driver deceleration

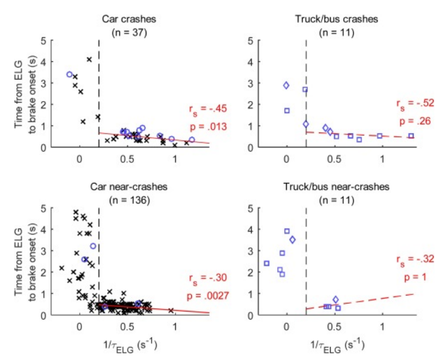


Modeling crash causation – off-road glances

- For rear-end crashes on highways, off-road glances identified as a main causation factor

- Models exist:
  - **how** drivers look away from the road
  - **when** it matters that they look away (timing)





Rockwell, T. H. (1988). Spare visual capacity in driving-revisited: New empirical results for an old idea. *In Vision in Vehicles II. Second International Conference on Vision in Vehicles.*

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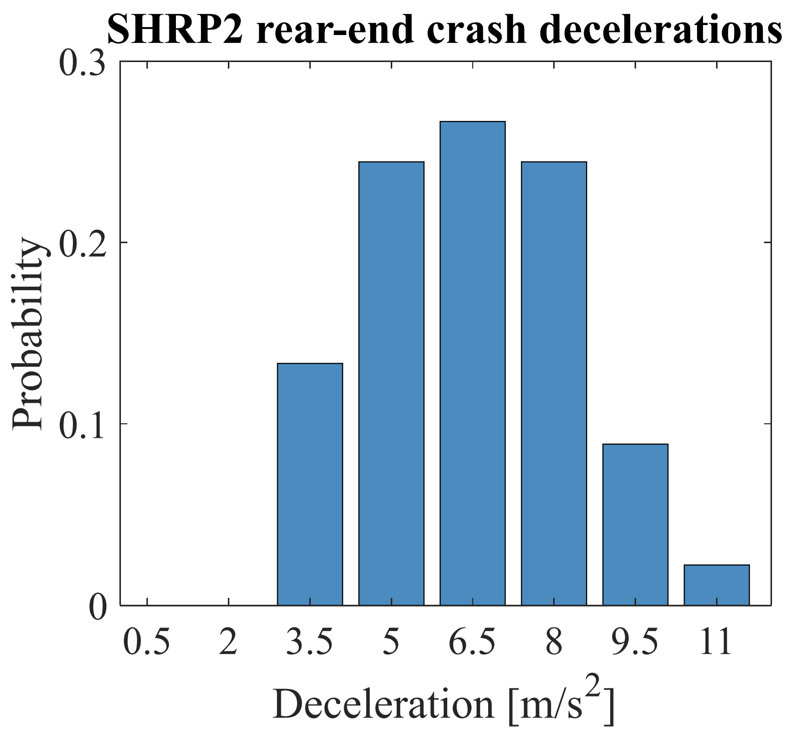
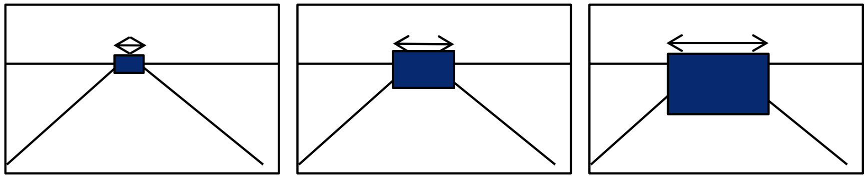
Modeling crash causation – limited driver deceleration

- Driver do not brake fully **even in crash situations**
- Distributions of driver pre-crash braking in crashes ➔ crash causation model

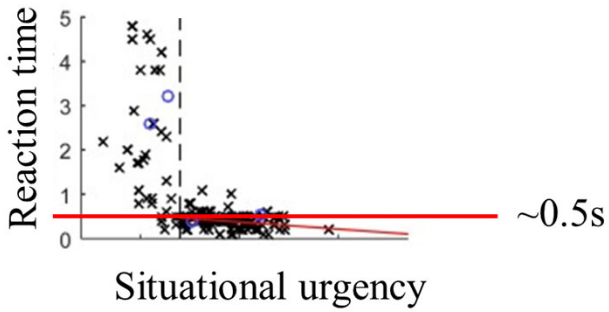


Driver response model

- Urgency (looming threshold) based



- + 0.5s response time



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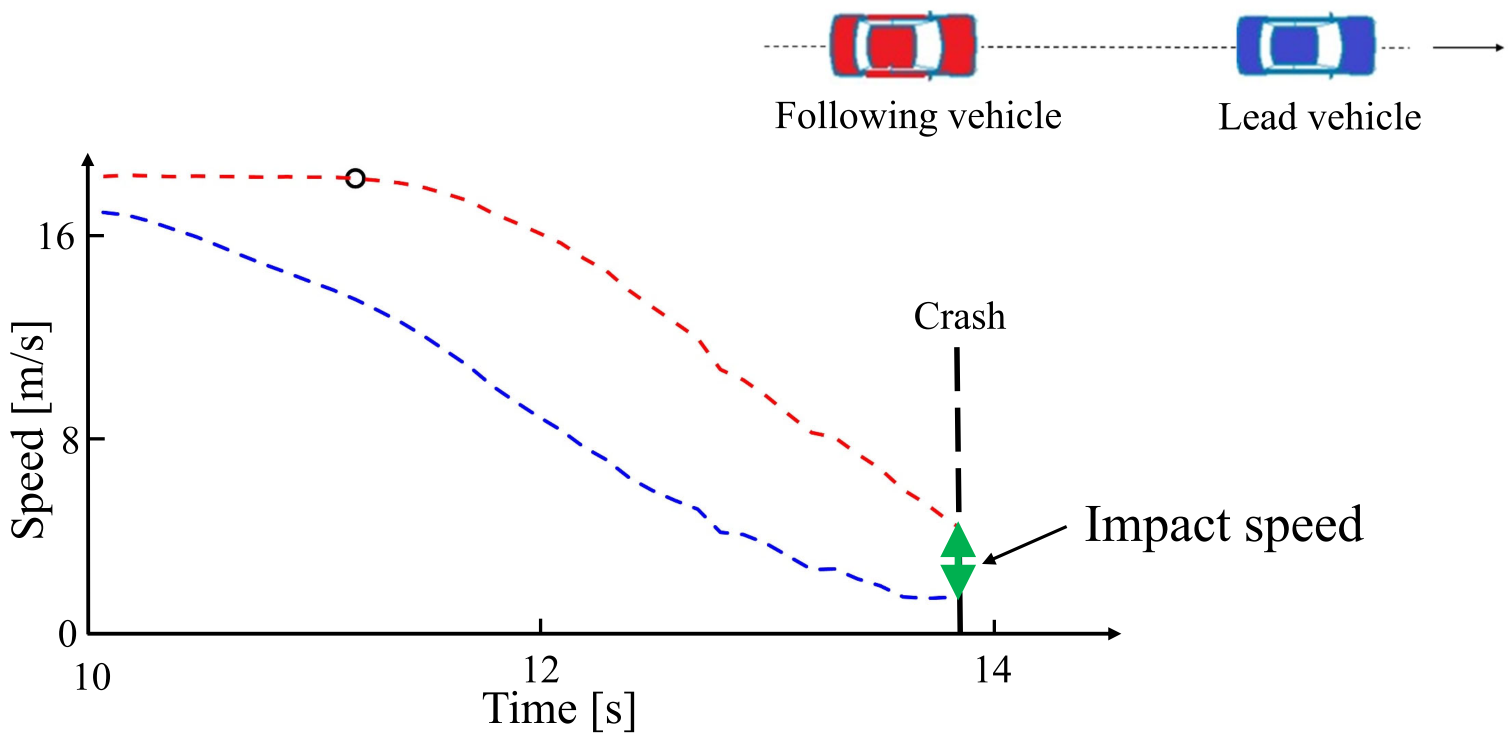
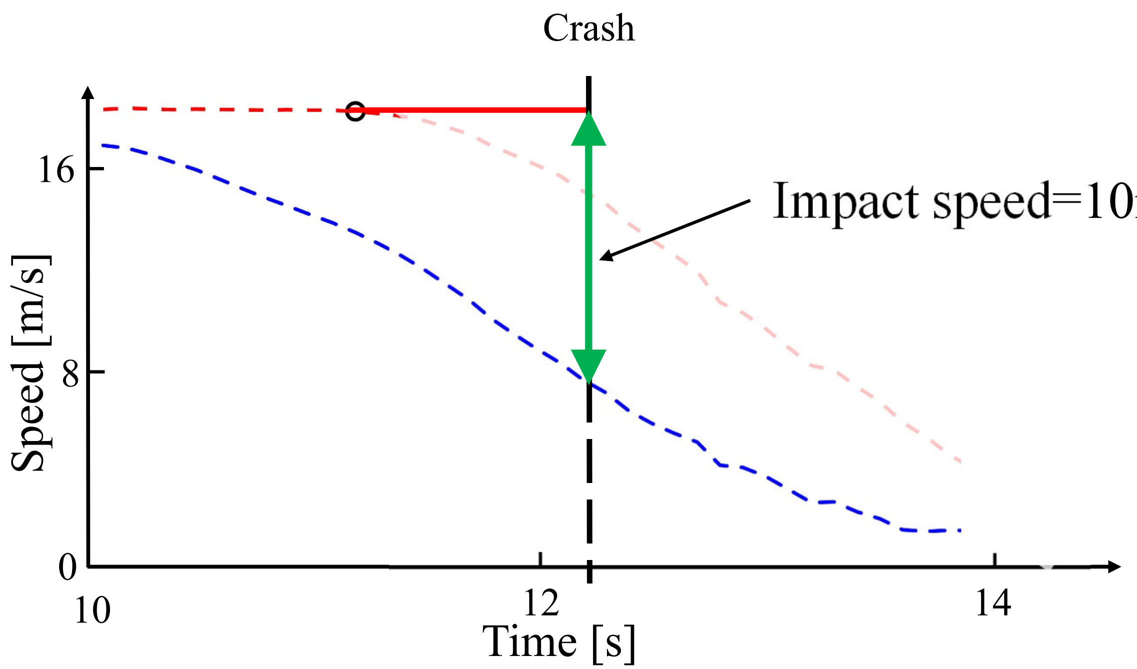
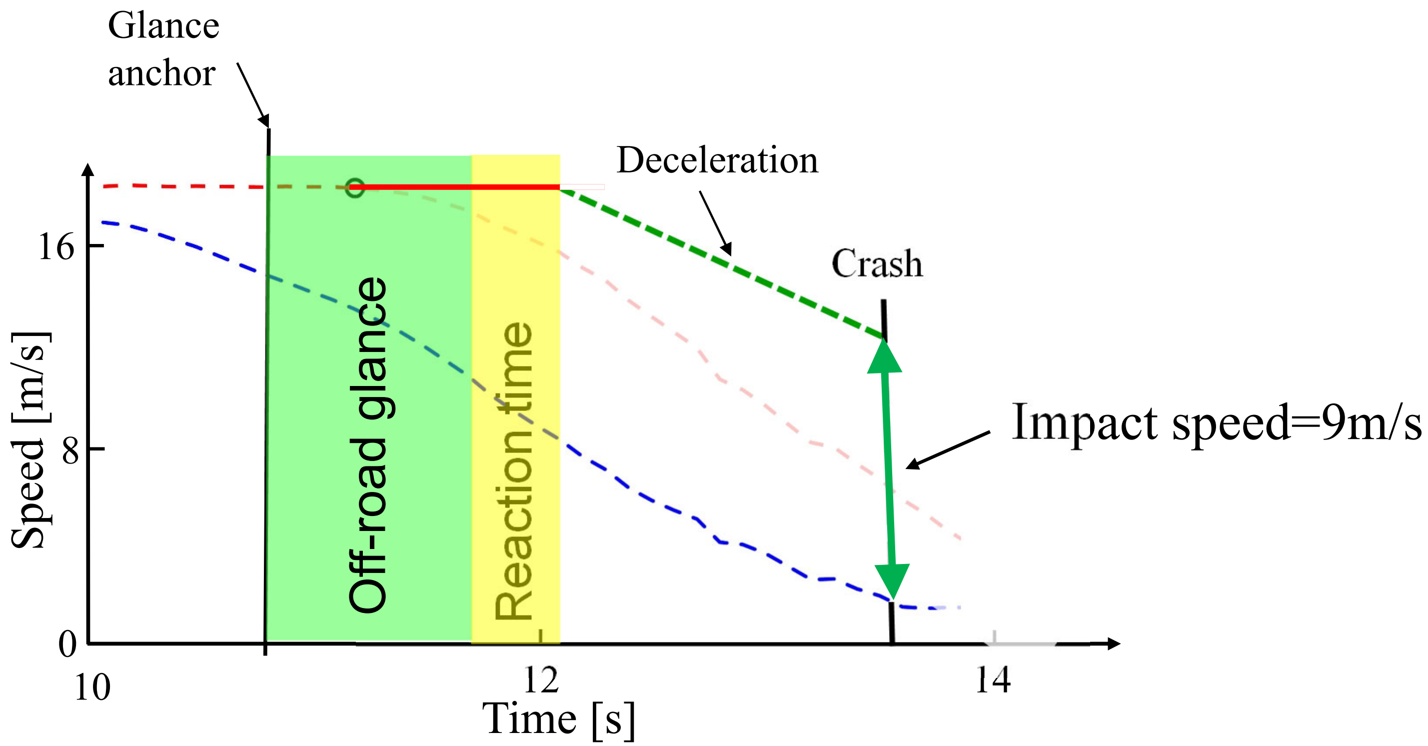
Consider pre-crash kinematics of a rear-end crash



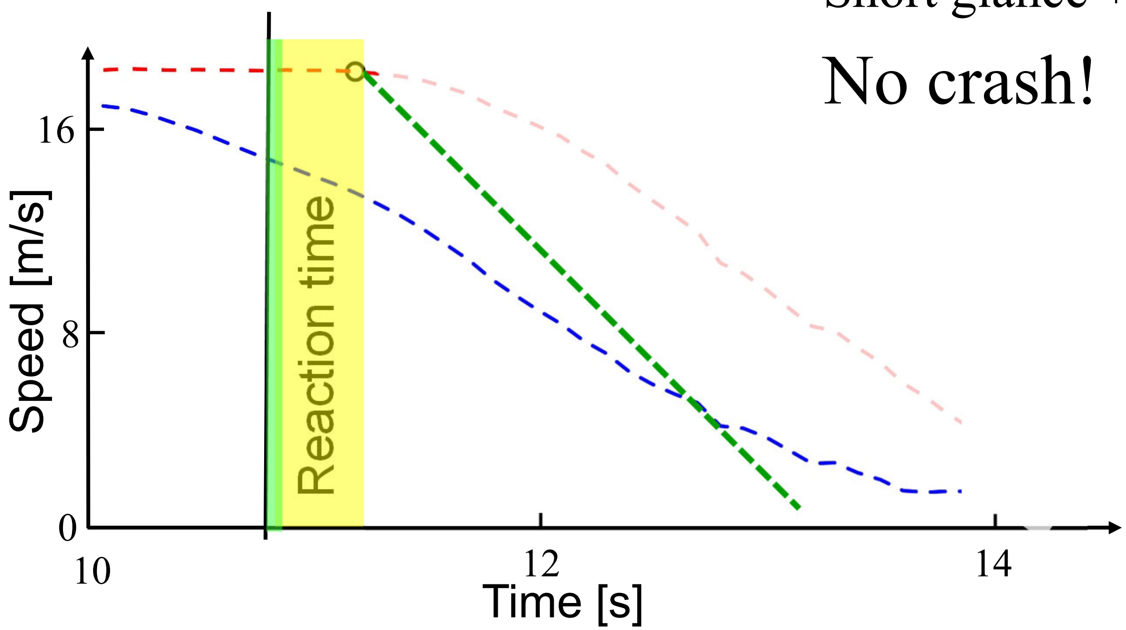
Remove the evasive maneuver of the following vehicle ...basically a sleeping driver



The proposed crash causation model: Application of off-road glance + reaction time + deceleration



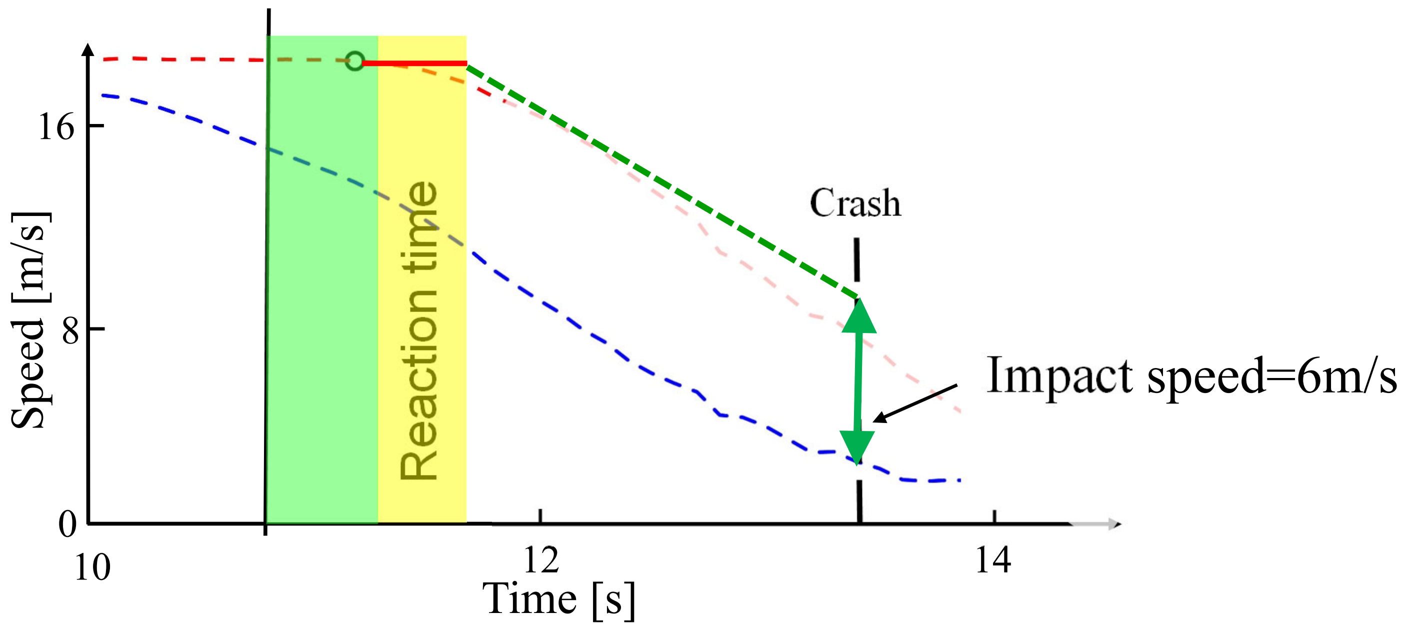
Different combinations of off-road glances and decelerations result in different crashes (or not)



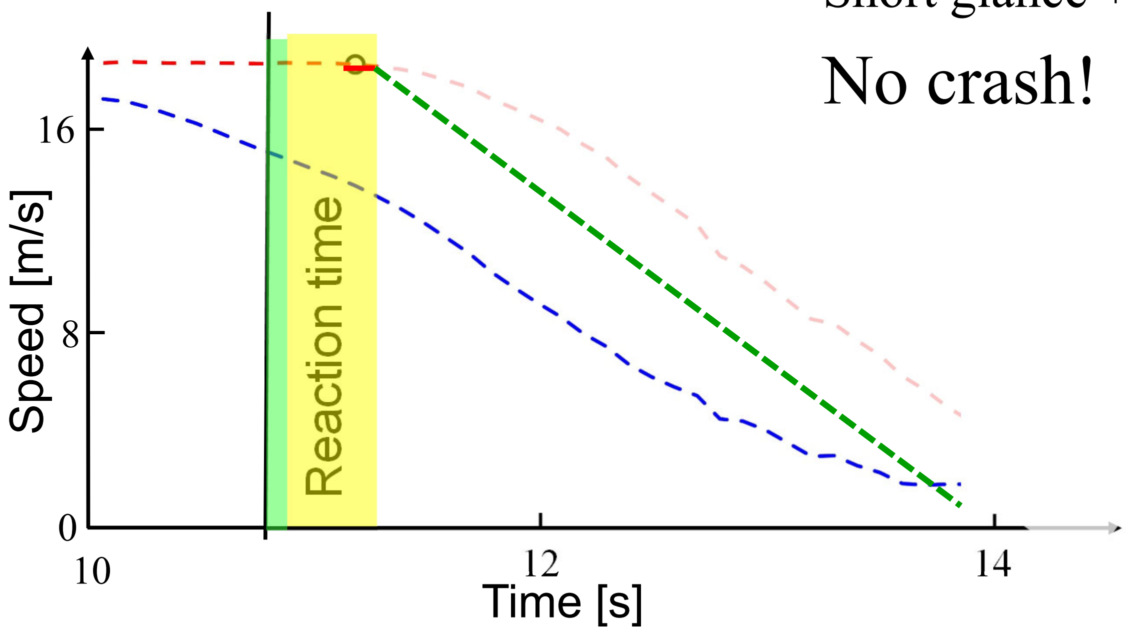
Short glance + hard decel ➔

No crash!

Different combinations of off-road glances and decelerations result in different crashes (or not)



Now a longer off-road glance at a more problematic time…

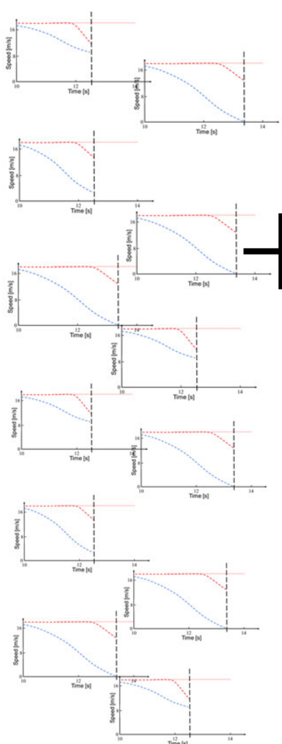


Short glance + hard decel ➔

No crash!

Counterfactual simulations for validation of crash causation model

A set of pre-crash kinematics of crashes (Volvo)



+

Remove driver evasive maneuver

and

Implement crash causation model(s)

+

Models of vehicle + environment

and

Driver response model

- How/when the driver start braking
- How the driver brakes
- Driver variability through distribution – stochastic simulations

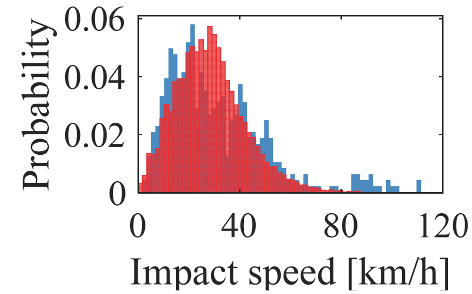
+

Virtual simulations

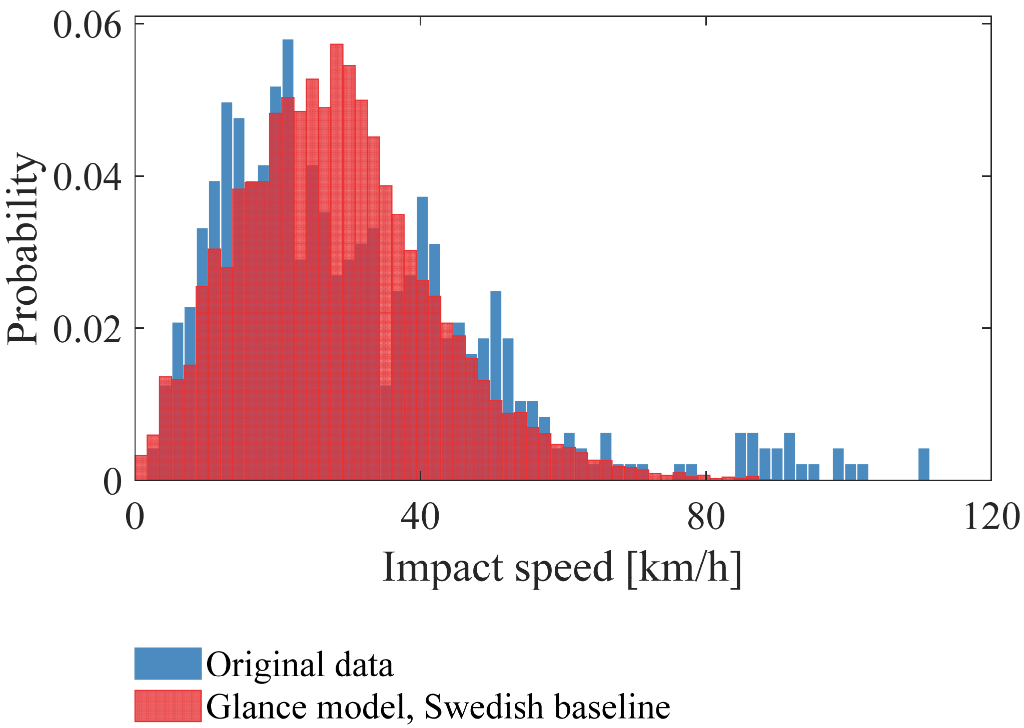
➡

Compare original-crash outcomes with generated crashes:

- Distribution of impact speeds



Results:
Crashes generated with proposed model vs. original



- Similar to original-crash impact speeds
- Underestimates medium and very high impact speeds
  - ?➔High impact speed different may be due to no "sleeping" drivers

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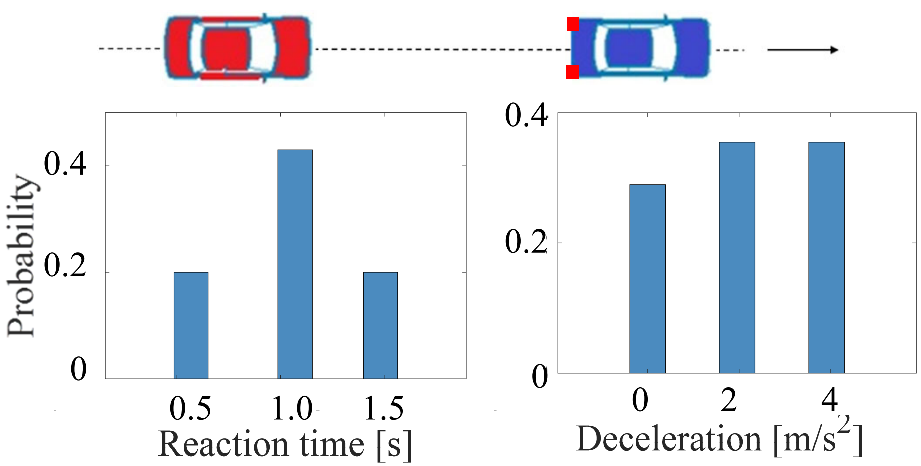
Traditional brake-light model

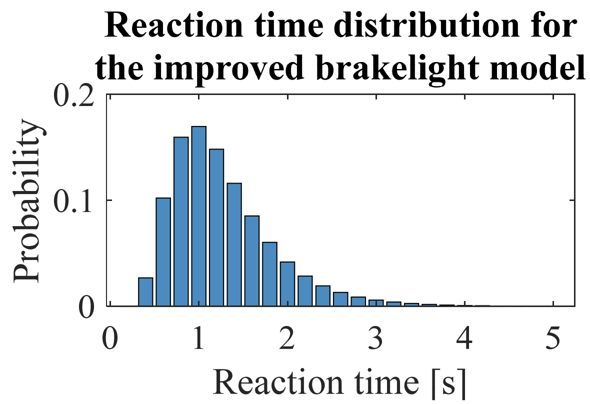
Simple reaction time + decel.

- Constant deceleration after “simple” reaction time, starting at brake-light onset



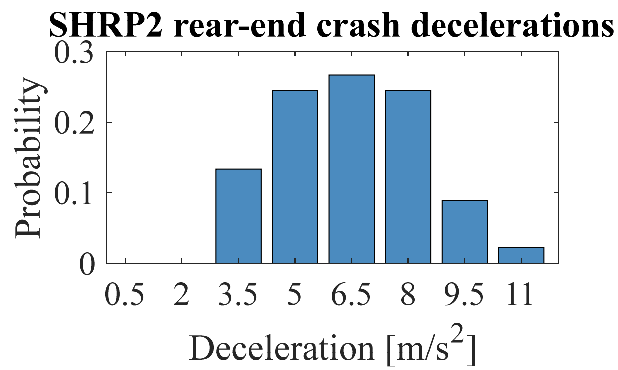
Kusano, K. D., & Gabler, H. C. (2012). Safety benefits of forward collision warning, brake assist, and autonomous braking systems in rear-end collisions. *IEEE Transactions on Intelligent Transportation Systems*

Improved (full distributions)



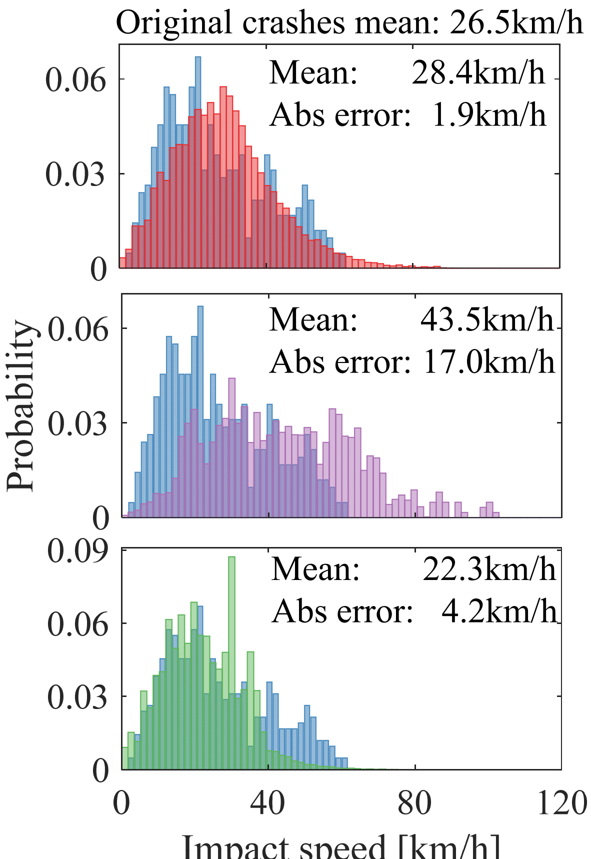
Reaction time (log normal)

Green, M. (2000). "How long does it take to stop?" Methodological analysis of driver perception-brake times. *Transportation Human Factors*



SHRP2 crash decelerations (same as in proposed model)

Results: Comparison with traditional crash causation model



Proposed
(glance behavior +
deceleration)

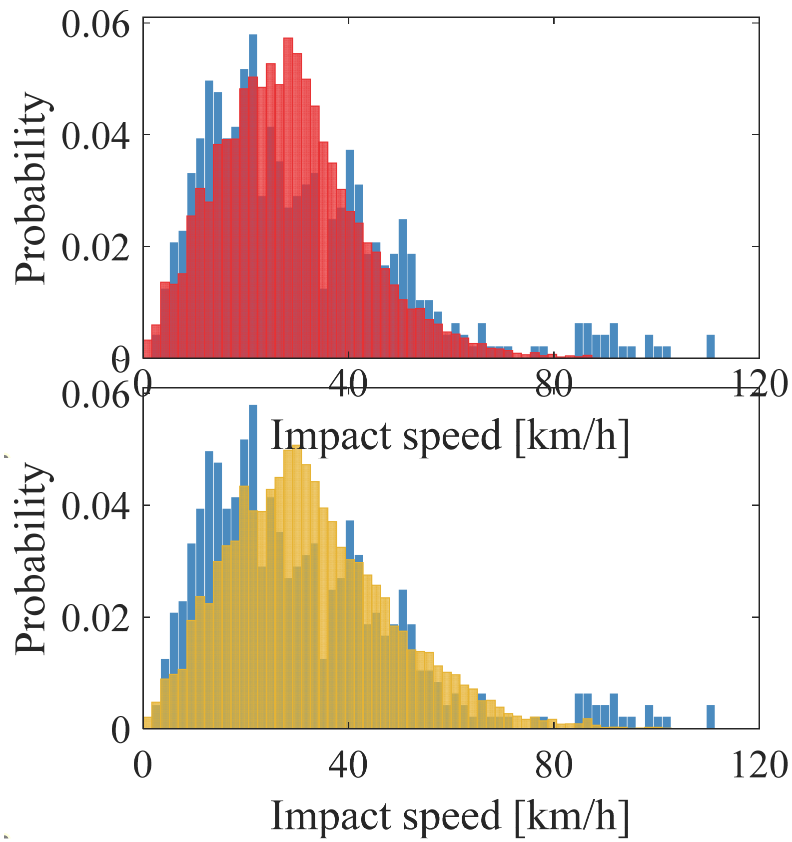
Traditional
(brake-light + simple
reaction time + simple
deceleration)

Improved Traditional
(brake-light + full
reaction time + full
deceleration
distribution)

- Proposed much better than traditional brake-light model
- Traditional brake-light model much overestimate higher impact speeds
- Improved traditional brake-light better, but not as good – underestimates high impact speeds + larger mean error

Original data
Glance model, Swedish baseline

Results – What about Rockwell radio tuning?



Original data
Glance model, Swedish baseline

- Rockwell radio tuning considered "safe enough"
- Results as expected ➔ higher mean + right-shifted distribution

➔ Method can also be used to assess "HMIs" (actually without simulations)

Swedish baseline mean	28.37	km/h
Rockwell mean	32.41	km/h
Difference	4.04	km/h

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Summary and conclusions

- Proposed model similar to real crash data in both mean and distribution
- … but do not capture some very-high-impact-speed crashes

- Traditional model much worse
- … but improvements can be made. Still much worse than proposed model

- Proposed model can be used to assess driver (visual) distraction and inattention ➔ to assess HMIs in a simplified way
  - Full method need: % eyes-on-road + total task time + glance-off-road distrib.

- Note: Proposed model can handle lead-vehicle non-braking scenarios
  - … traditional do not

The end

Thank you:

- Volvo Cars Corporation
- FFI funding agency
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- European Commission

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