Assessment of Speeding Profiles and Safety Margins from Tangent to Curve by means of Driving Simulation

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Background

- Design Consistency: critical element for road safety
  - “self-explaining” roads
  - avoidance of abrupt changes of successive alignment elements as to avoid erratic maneuvers
  - substantial differences between operational speeds or between design and operational speeds in successive design elements, indicate poor design consistency.

- Driver’s safety margin:
  - difference between design speed and driver’s speed
  - intended to express the degree of safe speeding behaviour at curves or from tangent-to-curve

Is Design Consistency Sufficiently Assessed?

ROAD SAFETY & SIMULATION INTERNATIONAL CONFERENCE 2017
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Along approach from tangent to curve:

Mostly linear speed profiles considered
- Spot speeds are utilized
- Acceleration/deceleration extracted assuming linear relationship between the spot speed data
- Or a linear correlation with the curvature

Need for non-linear speed profiles
- Drivers do not maintain constant speed
- acceleration on tangents
- deceleration before the curve
- "Breakpoint" - distance from curve entrance along the approach tangent where speed begins to decrease

Parameters affecting the speed profile

- Initial speed
- Tangent length
- Curve parameters
- Vehicle characteristics
- Driver characteristics
  - Safety margin
  - “Breakpoints”

Objectives

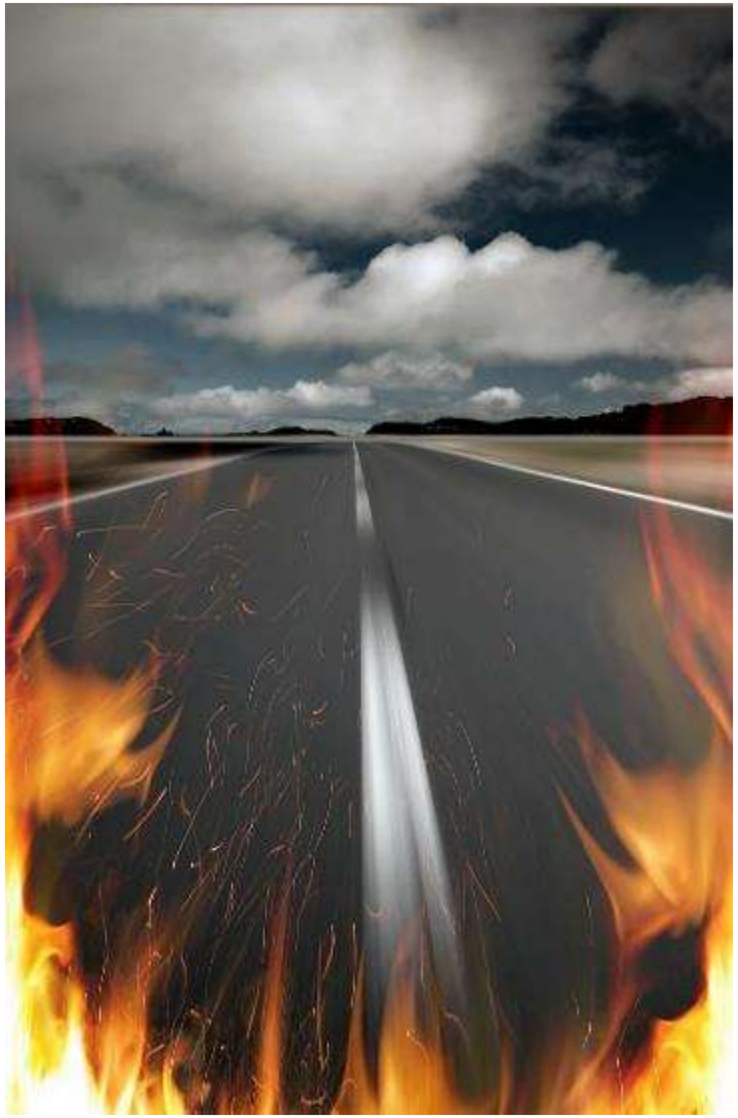
- Present and test a novel methodology of defining and assessing safety margins in speed variations on a tangent to curved road design.

- Combine data from a driving simulator experiment and a vehicle dynamics model to:
  - identify **speed profiles** corresponding to different ways of negotiating the approach from tangent to curve, and
  - estimate the related **safety margins** applied by drivers on the basis of the proposed methodology.

A novel definition of safety margin

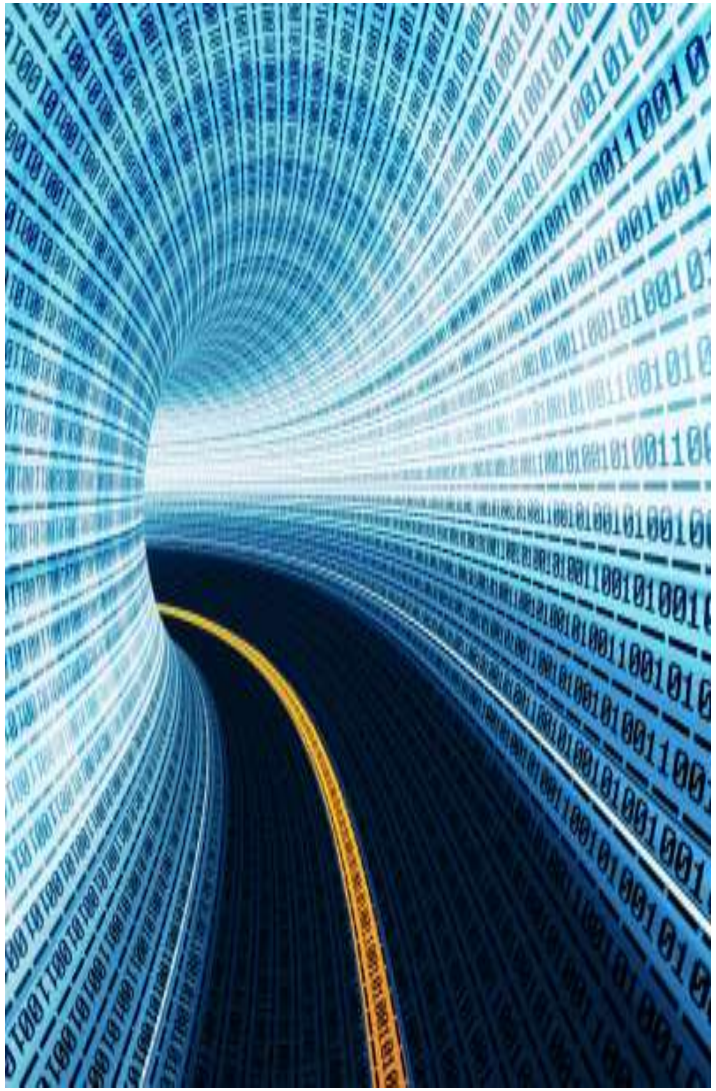
The driver's safety margin regarding speed variation on a tangent to curved road segment is defined as the difference between the utilized horse-power (hp) and the maximum available horse-power at impending skid conditions during the vehicle motion on tangent

- Estimated safety margin is based on objective reference
- Vehicle's speed / distance profile is more realistic through non-linear representation
- Allows various speed profiles during approach process



Methodology and data

- Estimation of speed – distance data
  - Driving Simulator (actual speed) vs.
  - Vehicle Dynamics Model (maximum attainable speed at impending skid conditions)
- Estimation of safety margins
- Analysis of speed -distance data
  - Identification of patterns
  - Grouping of drivers



Driving simulator experiment

Experimental route

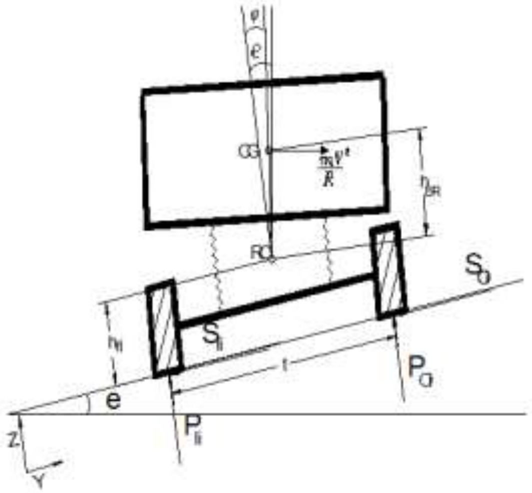
- Tangent (L=100m) to curve (R=133m)
- V_{limit} = 70km/h
- No visibility restrictions
- Low ambient traffic

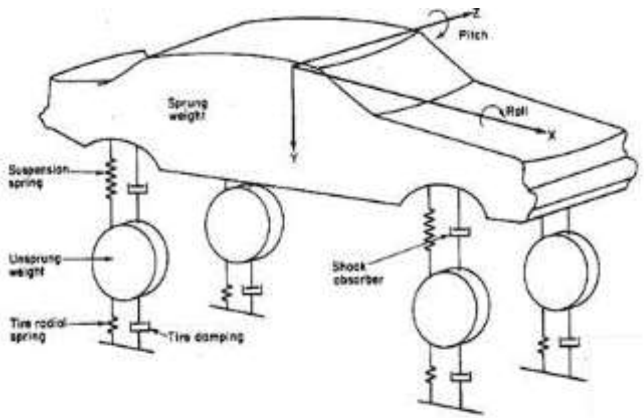
Sample

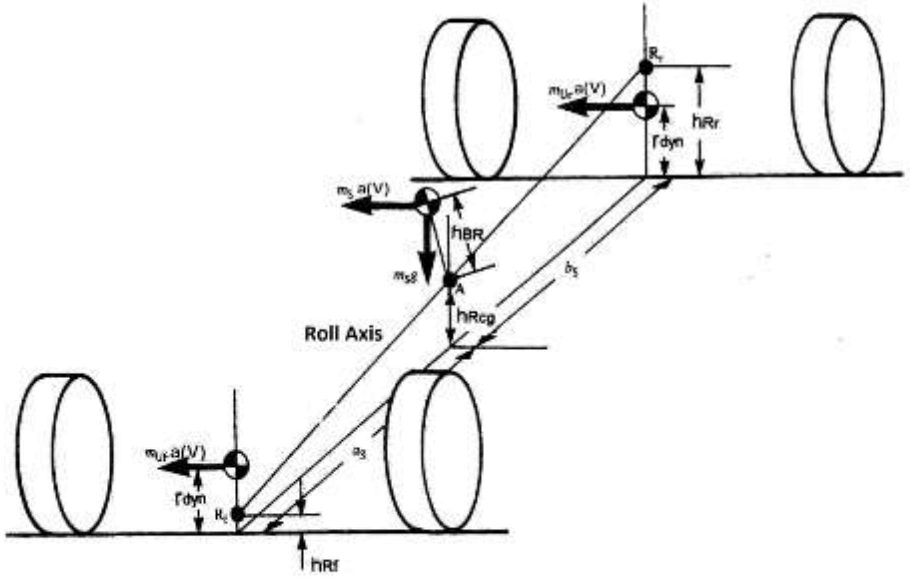
- 43 participants (22males, 23females)
- Aged from 22 to 87.
- 18 participants <35 years old, 16 participants 35-55 years old, and 9 participants >55 years (out of which 4 were >65 years)

Vehicle Dynamics Model

- Moving 3D coordinate system
- Parameters correlated
  - vehicle technical characteristics
  - road geometry
  - tire friction
- 4-wheel model
  - lateral load transfer
- Output data: vehicle speed variation
  - impending skid conditions
  - speed – distance performance
    under any desired hp utilization rate







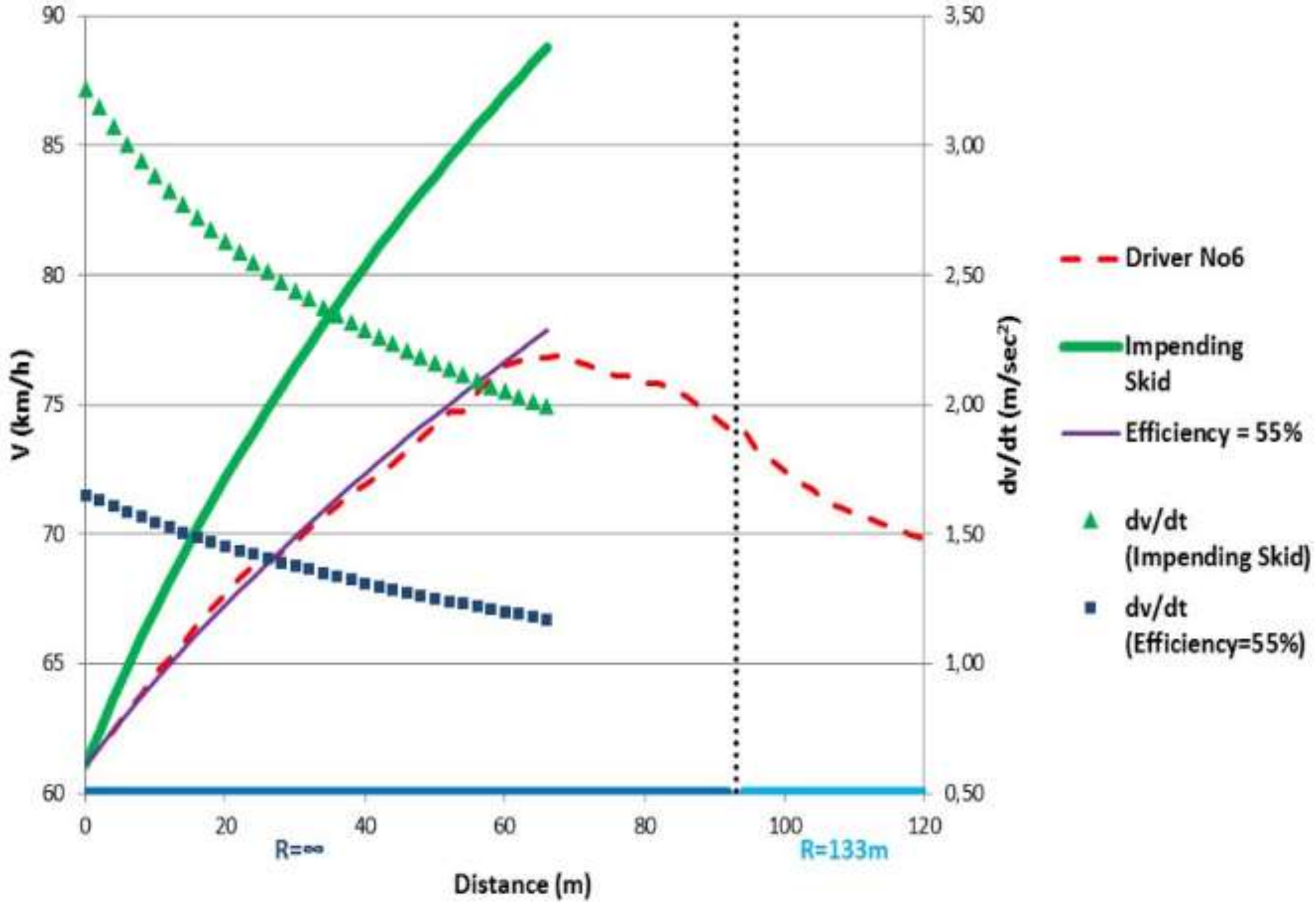
Estimation of safety margins

Driving Simulator

- speed - distance data per participant

Vehicle Dynamics Model

- 2 different speed - distance and acceleration - distance data sets per participant
    - vehicle under impending skid (max hp utilization)
    - “best fit” of actual driver performance (55% of hp for the present graph)



Safety Margin: 45%

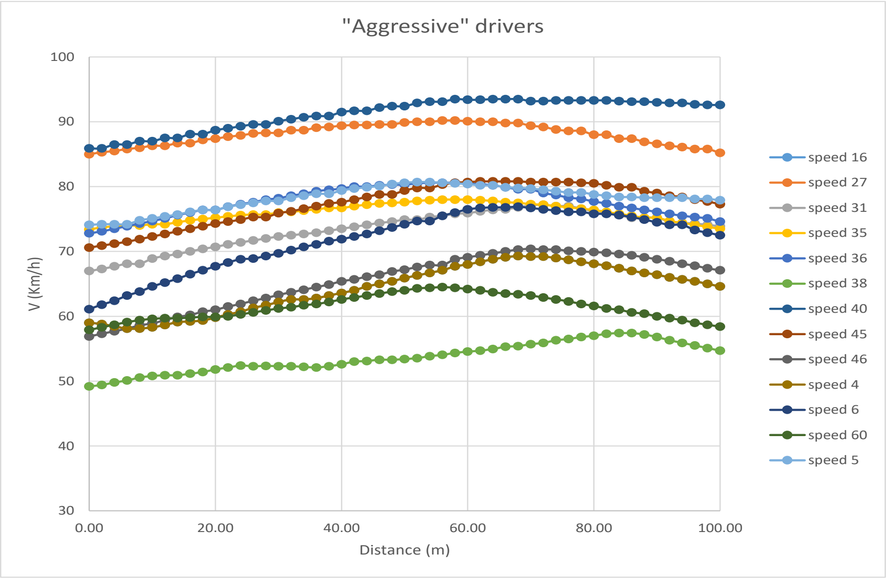
Exploratory analysis

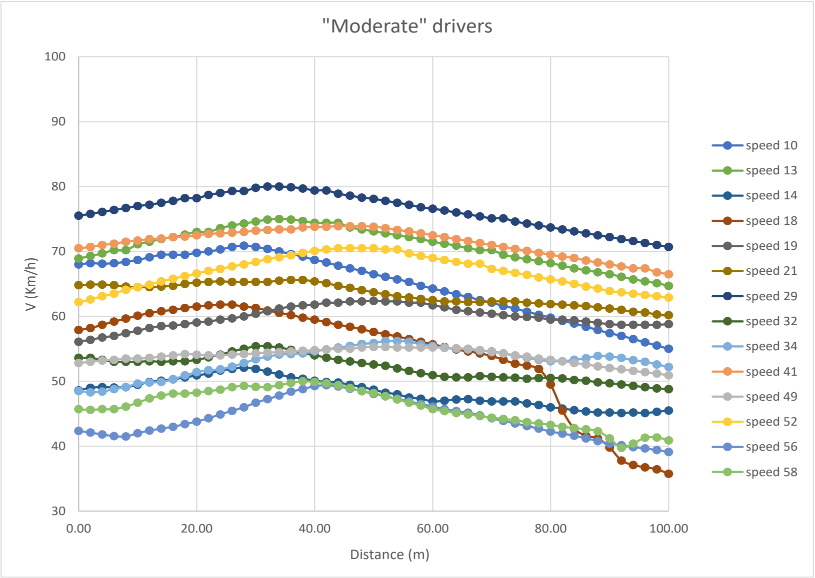
- Large variations in drivers' speeding behaviour and the related safety margins

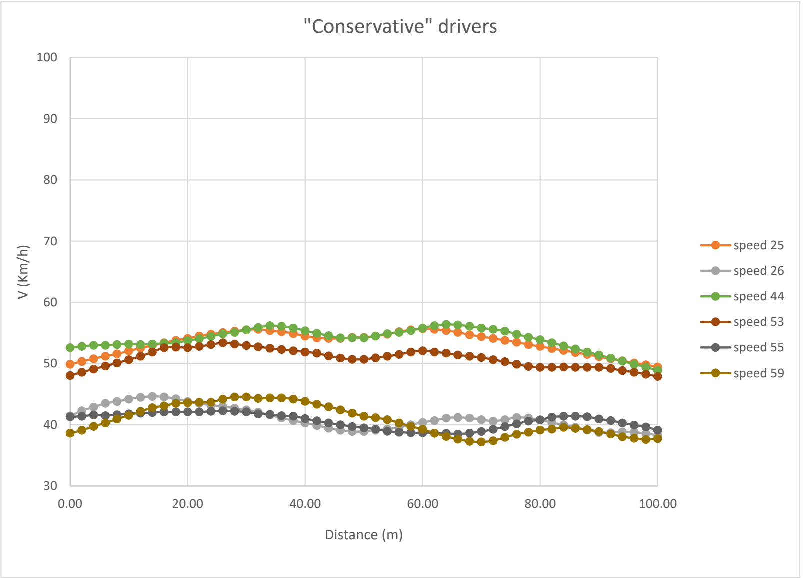
  (min: 45%, max: 92%, mean: 72.6, stdev: 13)
- Drivers use a minor share of the available horse power on the examined curve
- Examined profiles of drivers exhibiting similar speeding behaviour:
  - Initial speed
  - Number of breakpoints
  - Location of breakpoints

Three patterns of speed profiles

- **“Aggressive” drivers**: high initial speed (>50 km/h), “breakpoint” close to the curve entrance (<50m), clear acceleration / deceleration pattern, efficient speeding behaviour.
- **“Moderate drivers”**: moderate to high initial speed (>40 km/h, maximum 75 km/h), “breakpoint” quite earlier than the previous group.
- **“Conservative”** drivers: significantly low initial speed (<55km/h), a “plateau” shaped profile.

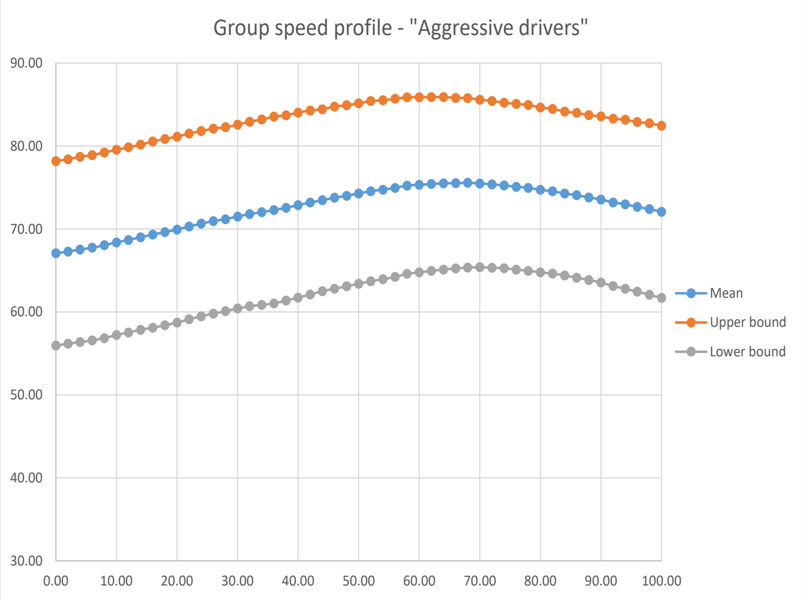


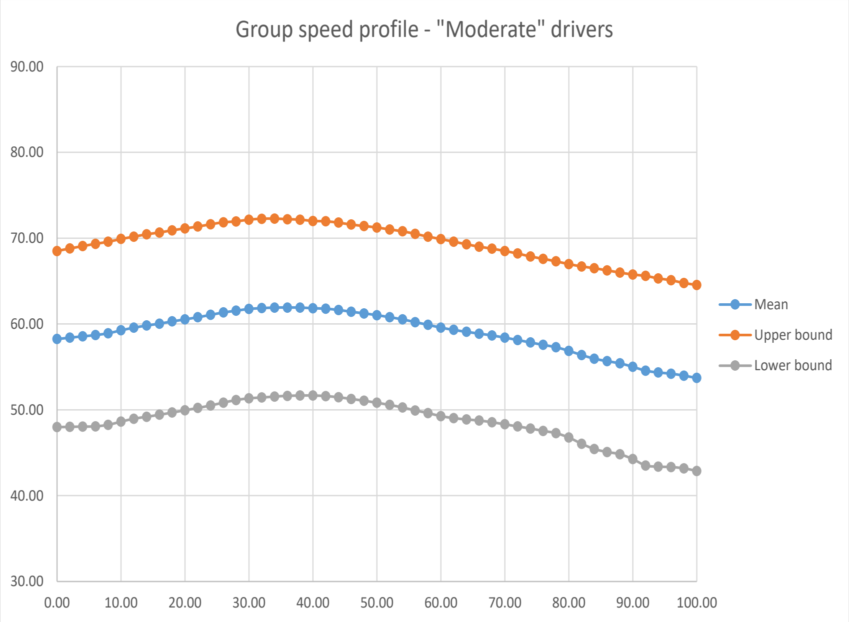


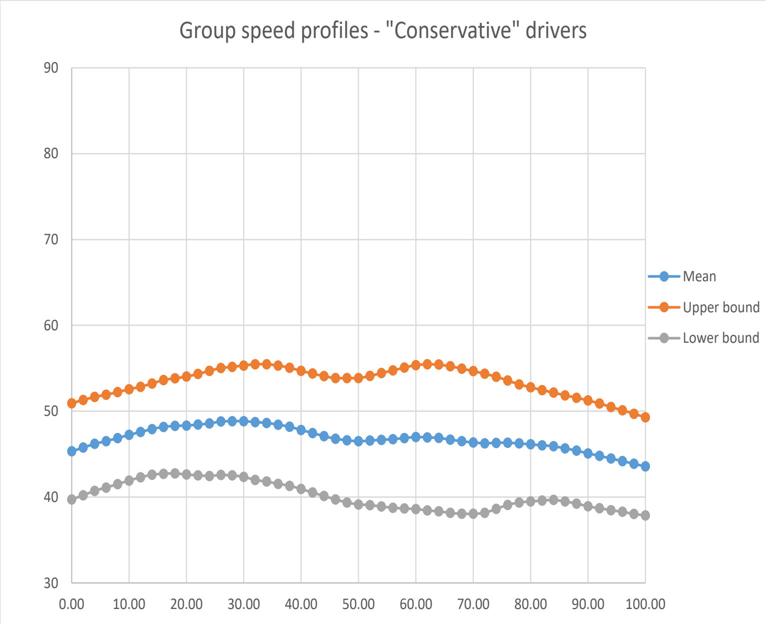


Aggregate speed profiles

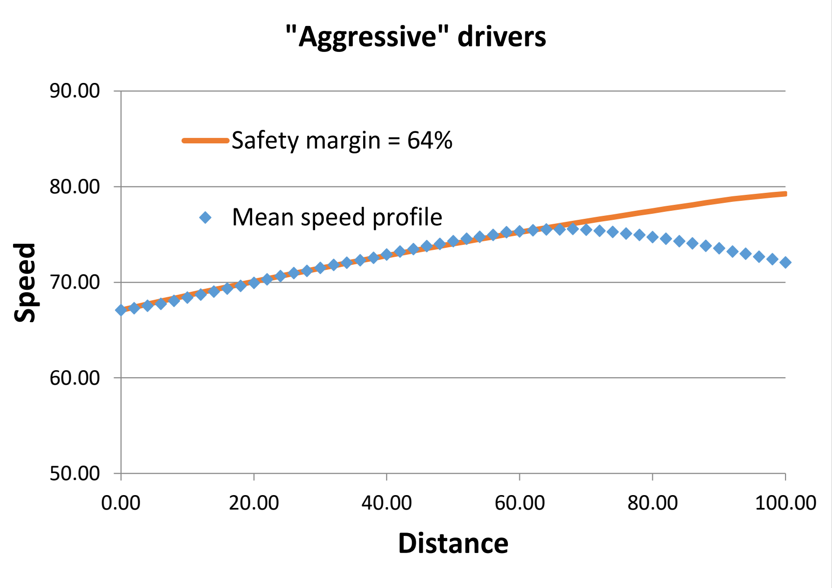
- A **mean speed profile:** average speed of all drivers in the group;
- An **upper bound speed profile**: average speed plus one standard deviation;
- A **lower bound speed profile**: average speed plus one standard deviation.

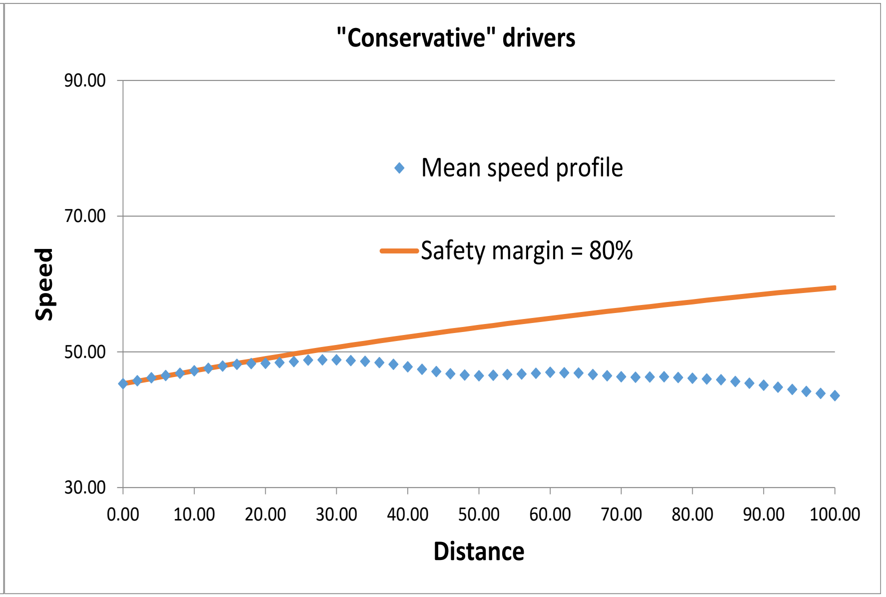






Group mean safety margins

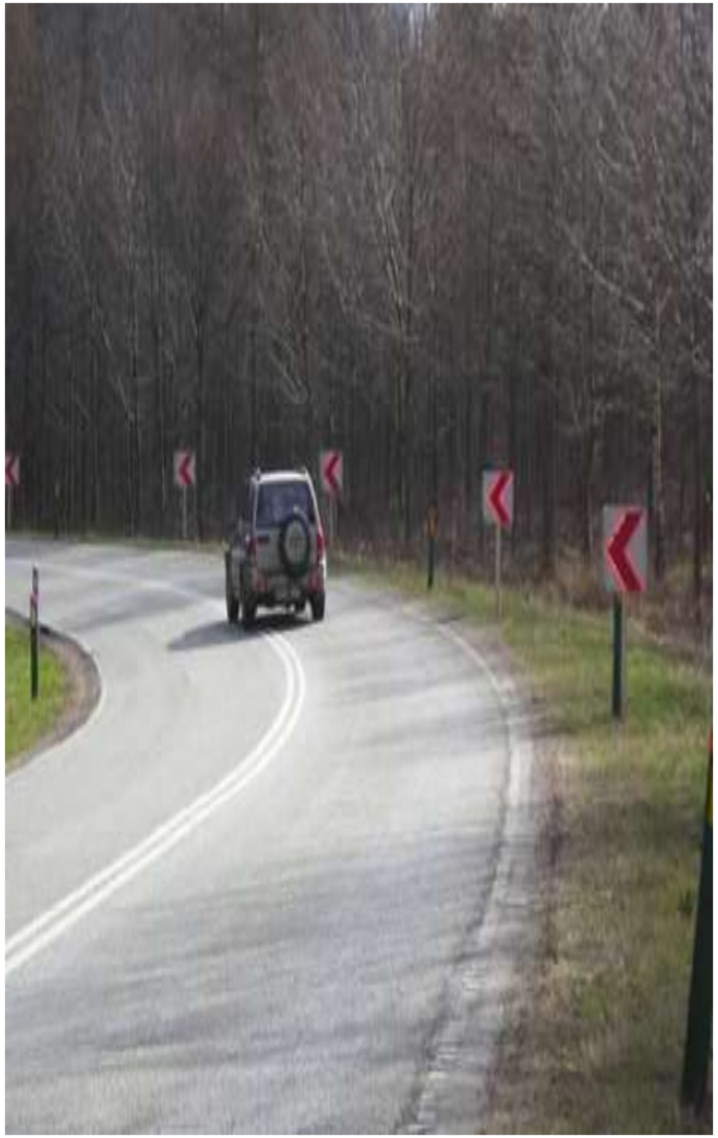




- Even the most “aggressive” drivers utilise less than 50% of the available horse power and the respective maximum speed that can be safely attainable.
- “Moderate” and “conservative” drivers have different initial speeds and accelerations before the “breakpoint”, but both groups have a similar safety margin in terms of maximum attainable safe speed.
- Keep in mind the singnificant within-group variation!

Conclusions

- A vehicle dynamics model for the estimation of the safety margin, defined as the difference in percent between the maximum available hp utilization at impeding skid conditions and actual hp utilized by the driver.
- Advantageous approach: a potentially varying speed profile, assessed against an objective calculation
- Three distinct patterns identified (initial speed, number and location of breakpoints)
  - “aggressive” drivers
  - “moderate drivers”
  - “conservative” drivers



Further Research

- Limitations
  - single curve examined
  - one vehicle type simulated
  - small sample of drivers
  - driving simulator environment

- Large variation suggests numerous unobserved human factors affect the examined speeding behavior

- Further research to substantiate the present exploratory analysis
  - varying alignments (curves, grades, tangents)
  - different friction values
  - other driver characteristics

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