What drives speed on rural roads?
Exploratory study using floating car data

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Introduction: speed

- A key element in road design, linked to safety: speeding is the most frequent cause of road deaths on Czech roads.

- What influences speed choice (and can be treated in order to manage speed)?
  - alignment (curvature, radius…)
  - cross section (shoulders, number of lanes…)
  - roadside, signing/marking, vegetation…

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Introduction: speed measurement

- Traditionally: spot speed
  - roadside traffic counters
  - hand-held speed guns
  - loops, tubes, etc.

- New approach: floating car data
  - GPS positions of vehicle fleet units
  - not limited in time and space

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Background/motivation

- Ideal (safe) driving = without unexpected changes, reflected in speed differences
- Speed consistency = speed_{curve} – speed_{tangent}
- Negative value = unexpected braking?
- Identified inconsistent curves can be treated (warning signs, speed limits, re-design…)
- Consistent design will lead to consistent speeds… and self-explaining roads
The study

- „What drives speed on rural roads?“
- Floating car data $\Rightarrow$ speeds in tangents and curves
- Road environment data on potential speed choice factors
- The data were used to build multivariate models (factors $\Rightarrow$ speed $\Rightarrow$ accidents)
Data: speed

- Floating car data (FCD) from company fleets
- ~1000 vehicles, 8 months, frequency 4 Hz
- Selection of rural sections of national roads
- Segmentation into tangents and curves, discarding segments < 200 m and < 100 vehicles in each direction
- Detection of „uninfluenced“ speeds ⇒ 85th percentile ⇒ weighted average

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Data: potential risk factors

From databases, own measurement, GoogleMaps...

TRAFFIC:
- AADT

ROAD GEOMETRY:
- Curvature change rate
- Curve radius
- Segment length
- Vertical grade (Y/N)
- Visibility (Y/N)

CROSS SECTION:
- Climbing lane (Y/N)
- Road width (3 cat.)
- Shoulder width (3 cat.)
- Cross slope/superelevation
- Overtaking (Y/N)

ROADSIDE:
- Guardrails (Y/N)
- Delineator posts (Y/N)
- Vegetation (3 cat.)
<table>
<thead>
<tr>
<th></th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>2268,5</td>
<td>8846,5</td>
<td>5023,8</td>
</tr>
<tr>
<td>length</td>
<td>201,32</td>
<td>3193,22</td>
<td>642,83</td>
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<td>CCR</td>
<td>0,25</td>
<td>122,78</td>
<td>13,72</td>
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<tr>
<td>cross_slope</td>
<td>-1,7</td>
<td>3,5</td>
<td>1,3</td>
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<tr>
<th></th>
<th>Min.</th>
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<th>Mean</th>
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</thead>
<tbody>
<tr>
<td>AADT</td>
<td>2268,5</td>
<td>8846,5</td>
<td>5054,4</td>
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<tr>
<td>length</td>
<td>204,46</td>
<td>1477,32</td>
<td>407,57</td>
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<tr>
<td>CCR</td>
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<td>454,81</td>
<td>75,85</td>
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<td>superelevation</td>
<td>0,3</td>
<td>4,4</td>
<td>1,5</td>
</tr>
<tr>
<td>radius</td>
<td>106,72</td>
<td>2068,64</td>
<td>975,66</td>
</tr>
</tbody>
</table>

**TANGENTS / CURVES**

- **Climbing lane**
  - Absent: 91%
  - Present: 9%

- **Guardrails**
  - Absent: 40%
  - Present: 60%

- **Overtaking**
  - Prohibited: 64%
  - Possible: 36%

- **Road width**
  - <= 9.5 m: 12%
  - 9.6 - 11.5 m: 23%
  - > 11.5 m: 42%

- **Shoulderwidth**
  - <= 0.75 m: 32%
  - 0.76 - 1.5 m: 33%
  - > 1.5 m: 35%

- **Vegetation**
  - None/bushes: 38%
  - Single trees: 25%
  - Alley/forest: 37%

- **Vertical grade**
  - Flat: 53%
  - Slope: 47%

- **Visibility**
  - No: 76%
  - Yes: 24%
- 509 pairs of curves and preceding tangents
- Discarded urban, divided, multilane… ⇒ sample of ~100 two-lane rural undivided road segments (not a complete network)
- Added geo-located accidents

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Why models?

- The objective is application for a road agency (all national roads), without additional field measurements… but our sample cover a part only

- From collected data we build prediction models for future network-wide application

\[ \Delta V = V_c - V_t \]

\[ \text{Model of tangent speeds } \Rightarrow V_t \]

\[ \text{Model of curve speeds (incl. } V_t \text{) } \Rightarrow V_c \]
Modelling

1. Exploratory analysis ⇒ discarding categorical variables with one of categories < 10%

2. Checking correlations between predictors ⇒ not using highly correlated pairs (> 0.5)

3. Multivariate linear regression: backward stepwise, keeping the variables with significance level < 5%
Results: tangent speeds

- Length, width, overtaking/climbing, visibility *increase* speed
- AADT, curvature, cross slope *reduce* speed
- Strongest effects: overtaking/climbing, length

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Results: curve speeds

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>1  (Constant)</td>
<td>32.957</td>
<td>15.567</td>
</tr>
<tr>
<td>tangent_speed_prediction</td>
<td>.642</td>
<td>.158</td>
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<tr>
<td>radius</td>
<td>.003</td>
<td>.001</td>
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<tr>
<td>superelevation</td>
<td>-1.835</td>
<td>.910</td>
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<tr>
<td>climbing_lane</td>
<td>4.272</td>
<td>1.992</td>
</tr>
</tbody>
</table>

- Preceding tangent speed, curve radius and climbing lanes *increase* speed
- Superelevation *reduces* speed
- Strongest effects: tangent speed, curve radius

n = 129
R² = 0.323

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Validation (1/3)

- Relationship directions are logical
  - Overtaking/climbing and tangent length provide speeding opportunity
  - Increased tangent speeds are transferred into following curves; radius also increases speed

- Further validation: comparison of speed differences to „objective safety“ = empirical Bayes (EB) estimate of accident frequency
Validation (2/3)

- 6-year frequency of single-vehicle accidents (all severity levels)
- Simple prediction model (with AADT and length) combined with accident history ⇒ EB
- Two variants of speed differences
  - relative (braking/accelerating from tangent to curve)
  - absolute (braking/accelerating combined)
Validation (3/3)

- Both tendencies (braking/acceleration) increase accident frequency – minimal difference is the safest
- The same confirmed by absolute speed differences
Discussion

- Using FCD has some disadvantages
  - company fleets $\Rightarrow$ biased sample of drivers
  - uncertain selection of free-flowing vehicles
  - low $R^2$ of regression models (often $0.3 - 0.5$)

- Comparison of FCD with traffic counters
  - 7 profiles $\Rightarrow$ FCD speed $\sim 2$ km/h higher

- Cross-comparison of methods would be valuable (Aalborg, BRSI, Technion...)
Conclusions (1/2)

- The project objective is to increase self-explaining character of Czech national roads (i.e. decrease speed differences)
- To this end we developed a method of identification of speed inconsistencies
- During analysis of speed data we found strong influence of several variables
Conclusions (2/2)

- Overtaking possibility, tangent length, curve radius increase speed $\Rightarrow$ reconstructions?
- Uniform low-cost treatments may also help
  - chevrons (according to $\Delta V$ levels)
  - advisory speed limits
  - road marking

Consistent signing/marking $\Rightarrow$ Consistent (self-explaning) „look“ $\Rightarrow$ Consistent speeds $\Rightarrow$ Improved safety

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Thank you for your attention!

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