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How do Roundabout Entry Design Parameters Influence Safety?

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INTRODUCTION

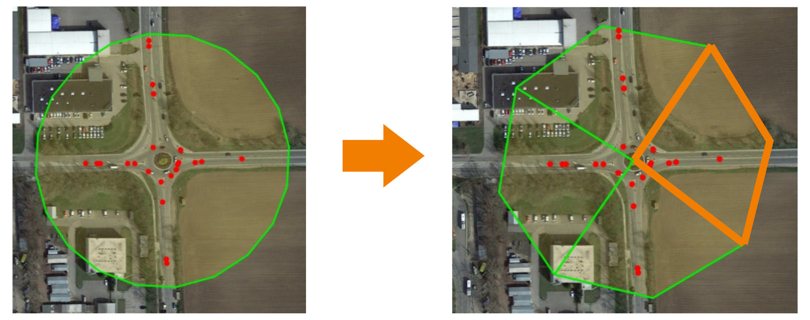
Roundabout is considered the safest intersection design; however, its safety effect may not be satisfactory at each specific roundabout. This is true especially in countries where roundabout design is a relatively new concept, such as in the Czech Republic. Specifically, most Czech roundabout crashes were found to occur on entries. **This motivated the presented study to answer the question, how do entry design parameters influence safety on Czech roundabouts, and if possible, use the findings to update current Czech roundabout design guidelines.** To this end, the study comprised three analyses: crash-based safety performance functions, speed analysis, and finally safety performance functions which incorporated speed. All three analyses proved that entry design parameters have a statistically significant influence on safety, in terms of crash frequency, severity and speeds. Given the study objective, this fact should be considered in Czech roundabout design guidelines.

1. In the first analysis, link between geometry and safety was established through crash frequency/severity SPFs.
2. The second analysis showed the link between geometry and speed.
3. One may thus anticipate a causal chain: geometry – speed – safety. In order to confirm existence of this chain, the third analysis attempted to develop SPF, which contain both geometry and speed variables.

DATA

Czech Republic

- 200 typical roundabouts (unsignalized),
- 781 individual leg segments,



- 5.193 data records separated into 8 annual records.

MINISTRY OF EDUCATION, YOUTH AND SPORTS

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METHODS

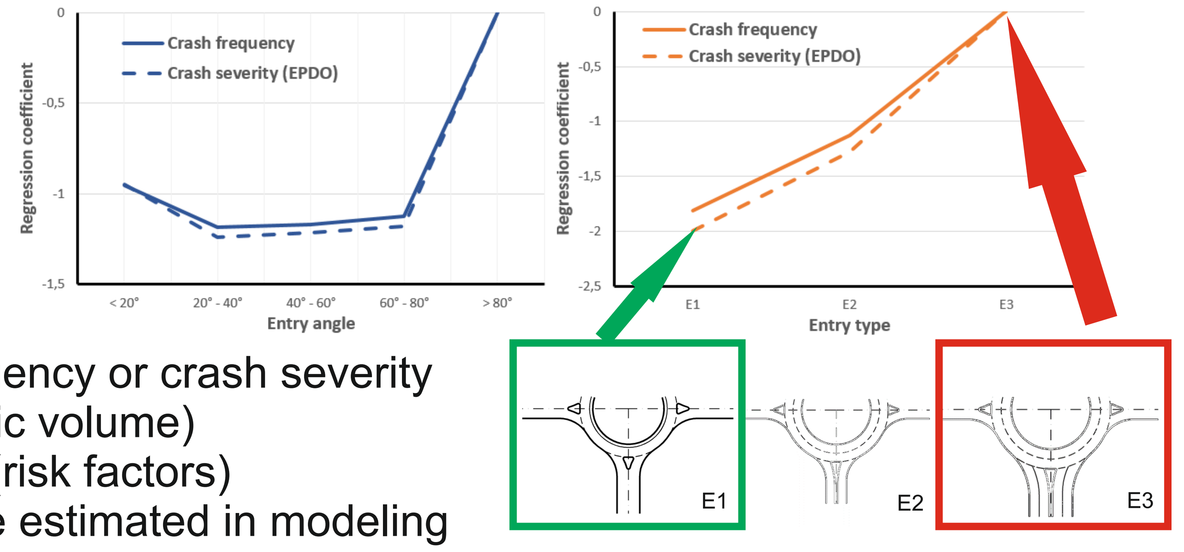
Analysis 1 – Safety performance functions

Reported data was used to develop safety performance functions. The basic model form comprised only exposure (*AADT*), with further explanatory variables (*Xi*) being added stepwise, keeping only the ones with achieved statistical significance below 5 %:

$$\hat{N} = e^{\beta_0} \cdot (AADT)^{\beta_1} \cdot e^{\sum_{i=2}^{n}(\beta_i \cdot x_i)}$$

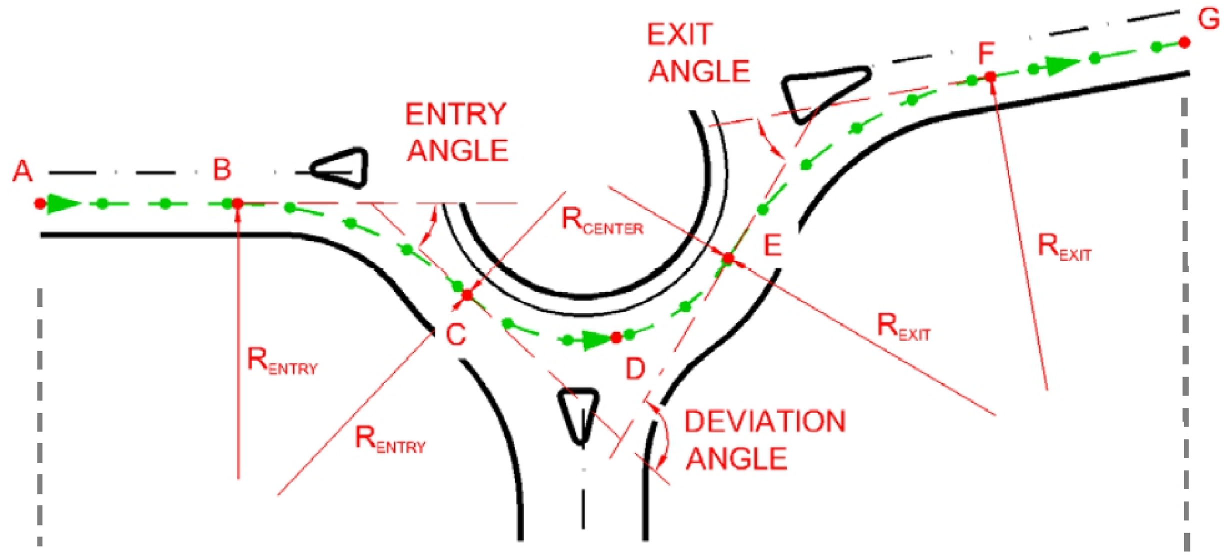
where:

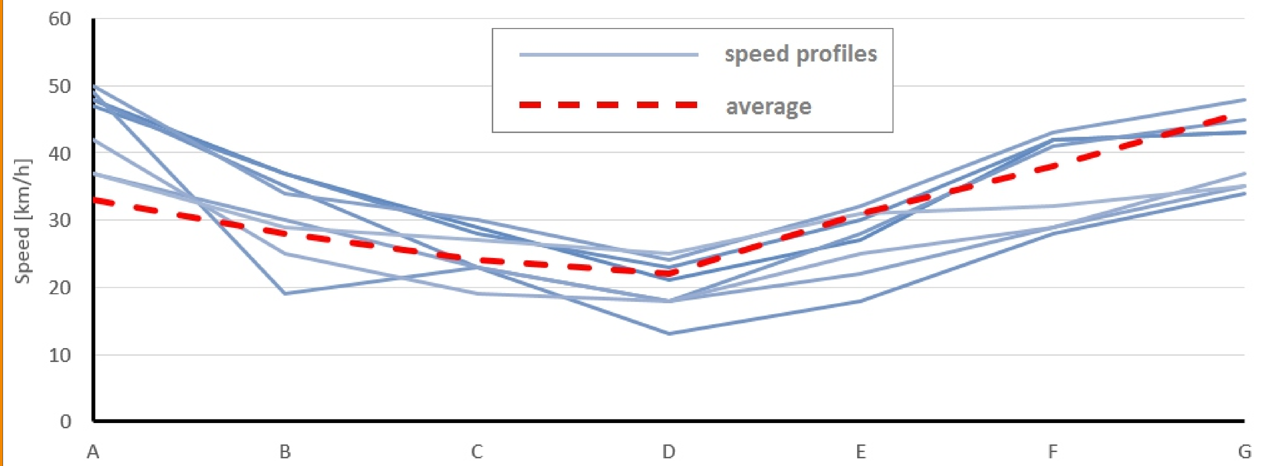
$\hat{N}$ expected annual crash frequency or crash severity
AADT exposure variable (daily traffic volume)
x_i other explanatory variables (risk factors)
β_i regression coefficients, to be estimated in modeling



Analysis 2 – Speed

"Location" variable is likely to be a proxy for speed, which was not considered in SPF. In this regards, it would be interesting to measure speed and use it in modeling. Therefore, alternative approach was used for the second analysis step: speeds were measured on a sub-sample of 200 roundabouts and used to explore its relationship to roundabout geometry.





To assess the influence of radii and angles on speed, Spearman correlation coefficients were calculated.

These were correlations between:
- speed 50m upstream of entry and entry angle,
- speed 50m upstream of entry and entry radius,
- speed in center and central radius.

The first two associations relate to roundabout entries,

Analysis 3 – Safety performance functions with speed

- Entry angle has a protective effect: the higher angle, the lower speed and risk.
- Increasing speed is associated to increasing crash frequency.
- Typically, AADT has a positive relationship to crash frequency; on the contrary, negative coefficient of traffic flow was found in all three SPFs.

$$\hat{N} = e^{5{,}211} \cdot (AADT)^{-0{,}727} \cdot e^{\alpha \cdot -0{,}052} \cdot e^{V_{50m} \cdot 0{,}066}$$

RESULTS

- **AADT** has a positive influence as expected. In addition, coefficient 0.583 is close to values 0.576 from previous Czech SPF or 0.58 from New Zealand SPF.
- **Collision distance** has a negative association: the longer distance, the more space for potential evasive manoeuvers and lower crash frequency/severity.
- **Standard deviation of angles between legs** has a positive relationship (the more dispersion, the more complex environment and higher crash frequency/severity), consistently with Czech design standards.
- **Entry angle** has minimum safety influence values between 20° and 80°.
- Figure provides analogical graph for **entry types.** The trend is rising from E1 (single entry and circulatory lane) to E3 (two entry and circulatory lanes).
- **Truck apron** has a protective influence: its presence is associated with lower crash frequency/severity.
- On the contrary, **bypass** presence is associated with higher crash frequency/severity. This is probably due to adding another conflict point, which increases crash risk and severity.
- **Location** in rural areas seems to increase crash severity, compared to urban roundabouts; the same holds for presence of pedestrian crossing.

CONCLUSIONS

Further activities should aim to expand sample size and consider the mentioned limitations of crash, AADT and speed data.

The analyses were different in terms of their data needs: while crash-based SPFs required crashes, traffic volumes and geometry (i.e., data that are usually available network-wide), the second and third approach required speed data, that had to be especially collected. With the aim of investigating the influence of roundabout entry design parameters on safety, the analyses concluded as follows:

Analysis 1 developed approach-level SPFs. Consistently with literature, a number of variables were significantly related to crashes, including entry angle and entry type. Using crash severity (EPDO) in addition to crash frequency also enabled revealing significant influence of location (rural/urban) and presence of pedestrian crossing on roundabout leg.

Analysis 2 identified influence of radii and angles on speed. Speeds were measured on a sub-sample of roundabouts and used to explore its relationship to roundabout geometry. Correlation was found between approach speeds (50m upstream of entry) and entry angle and entry radius.

Analysis 3 successfully incorporated approach speed into SPF and confirmed that increasing speed is associated to increasing crash frequency; again it was demonstrated that entry angle has a protective effect.

The presented results indicate existence of a causal chain: geometry – speed – safety. The study found that:

1. Both crash frequency and severity is influenced by roundabout entry geometry.
2. At the same time, the geometry influences driving speeds.
3. Safety performance is thus dictated by both geometry and speeds.