International Co-operation on Theories and
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Predictable motorway curves are safer

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Introduction

Motorway curves present significant safety challenges influenced by various factors. Poor coordination between road characteristics upstream of a curve can lead to unsafe approach speeds and increase accident risks. Experience aids drivers in adjusting speed, aligning their speed with road characteristics based on expectations. These expectations are based on multiple experiences with road regularities which get associated with safe speeds. This study hypothesizes that disparities between expected and actual curve radii increase unsafety.

To investigate, a Bayesian model is created to mimic driver expectations. Bayesian models can capture drivers' probabilistic expectations, incorporating prior experiences and updating beliefs given certain road characteristics. These beliefs are thought to mimic expectations, which change dynamically during curve approach, guiding drivers' proactive speed adjustments. Deviations between expected and actual radii could lead to accidents because drivers may not decelerate enough based on their expectations. These disparities between expected and actual radii are tested as an independent variable in a crash frequency analysis, to quantify the actual risk of road designs which deviate from expectations.

Research methodology

This research comprises three primary steps. First, a model mimicking human drivers' expectations is developed. Second, these modelled expectations are compared to real curves to identify any differences from reality. Finally, the study investigates the correlation between the extent of deviation between expectations and reality and crash frequency.

Information on the design and amounts of crashes and traffic from all ramps in The Netherlands was provided by Rijkswaterstaat, the Dutch national road authority. This data was used to learn a tree augmented Bayesian belief network (TAN) with the class label being the horizontal radius of the curve, mimicking the expectations drivers have of this curve. The independent variables used are the type of ramp (on, off, or connecting), previous element (discontinuities like exit-lanes, intersections or curvature), curve angle and the number of lanes.

The horizontal radii are matched to operational speeds, to reflect driver behaviour. A confusion matrix is built comparing the actual horizontal radii to the predicted (hence expected) radii by the TAN. The difference between actual and expected are grouped by the amount of km/h difference this resembles. This difference is then used as an independent variable in a zero inflated negative binominal crash frequency analysis to test the relation between expectations and crash risk.

Results

The TAN reveals the complex relations between the independent variables and the curve radius, showing the importance of analysing these variables together, and revealing the influence of roadway type and preceding road characteristics in building expectations. Using the TAN, predictions are made about the expectations drivers have about the curve radius *given* specific road characteristics provided as independent variables.

The confusion matrix shows that 28% of the curves in the database match the expectations drivers are assumed to have build based on all the curves available in The Netherlands exactly, and 58% within a range of 10 km/h higher or lower than expected. Especially the curves with radii tighter than 150 meters show a large variability in expectations.

The group with higher expected curve radius than present has a significant higher accident risk (i.e. number of accidents divided through the annual average daily traffic (AADT)) than the group of curves with lower expected curve radius.

The difference in expected and actual curve radius is used as the independent variable in the count process of crash frequency in the model, while AADT is used in the process to determine excess zero's in the data and account for these in the crash frequency model. The model shows a significant negative relation for AADT, suggesting that with less traffic, less accidents occur. The model also shows a significant positive relation for the difference in expected and actual curve radius. This shows, that when drivers expect the curve radius to be larger than it actually is, crash risk increases.

Discussion and conclusions

The TAN shows how road categories impact the expectations of drivers, which is in line with Self Explaining Road (SER) principles. Furthermore, the crash frequency analysis shows that if expectations deviate from reality, crash risk increases, providing quantitative evidence for the success of SER on Dutch motorways.

The research provides the engineering community a set of design parameters to adhere to in the form of combinations of road types and curve characteristics which match expectations of drivers. It furthermore quantifies the crash risk if these parameters are omitted, helping road safety authorities in examining road safety pro actively in early design phases.