CRS PURDUE UNIVERSITY
CENTER FOR ROAD SAFETY

TOWARDS RISK-BASED SAFETY MANAGEMENT: A PILOT STUDY FOR RURAL FREEWAYS

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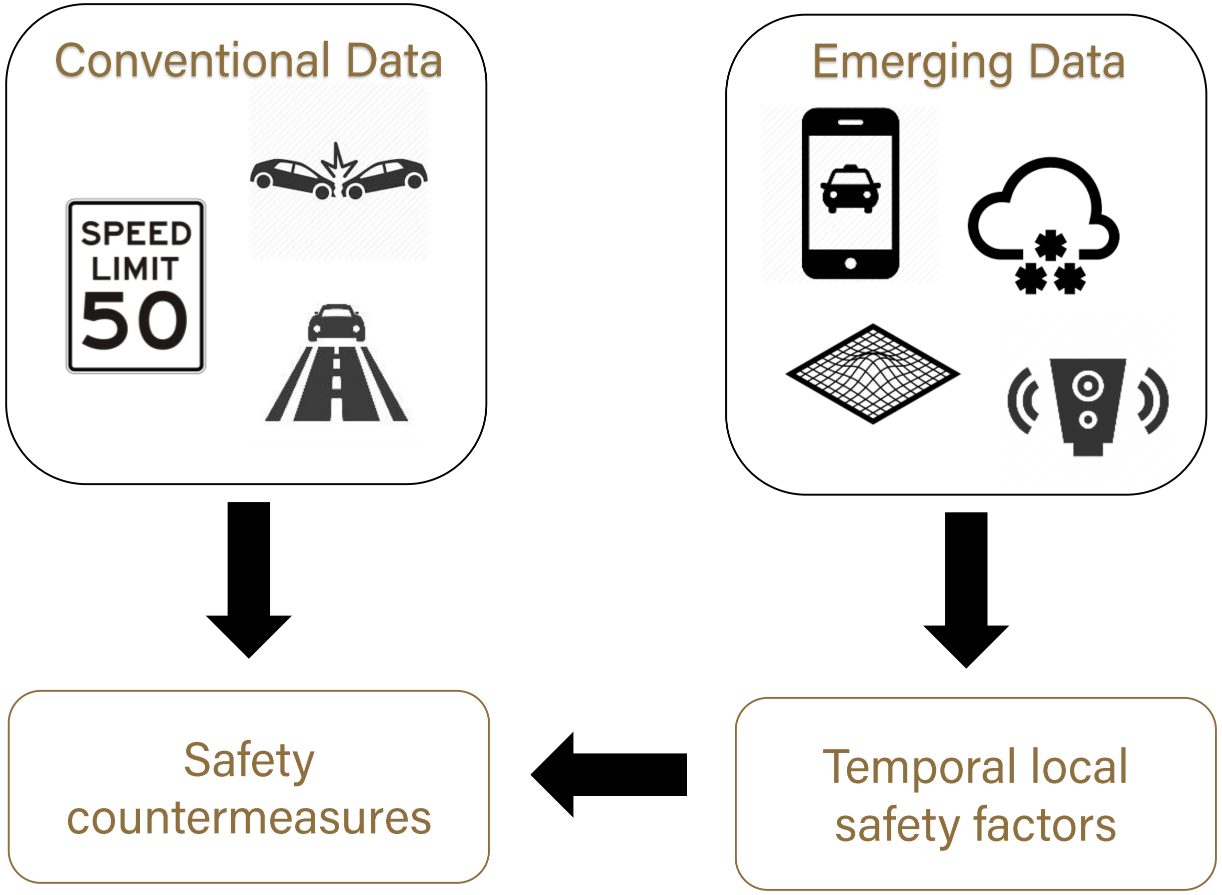
INTRODUCTION

Current Road Safety Management

- Safety performance functions to assess safety of individual roads
- Aggregation period of 3 to 5 years
- No temporal variability of safety captured
- No possibility to consider operational improvements



INTRODUCTION

Literature Review

- Crash risk strongly varies across space and time. Aggregated crash risk estimates do not reflect the true nature of risk.
- Exponential advancement of temporal high-resolution data enables near-real-time crash risk estimation.
- Methods for identifying local high-risk conditions in short intervals have evolved.
- Methodology includes advanced statistical regression, supervised machine learning, and deep learning methods.
- Massive data from CAVs and extensive road instrumentation are anticipated.

RESEARCH COMPONENTS

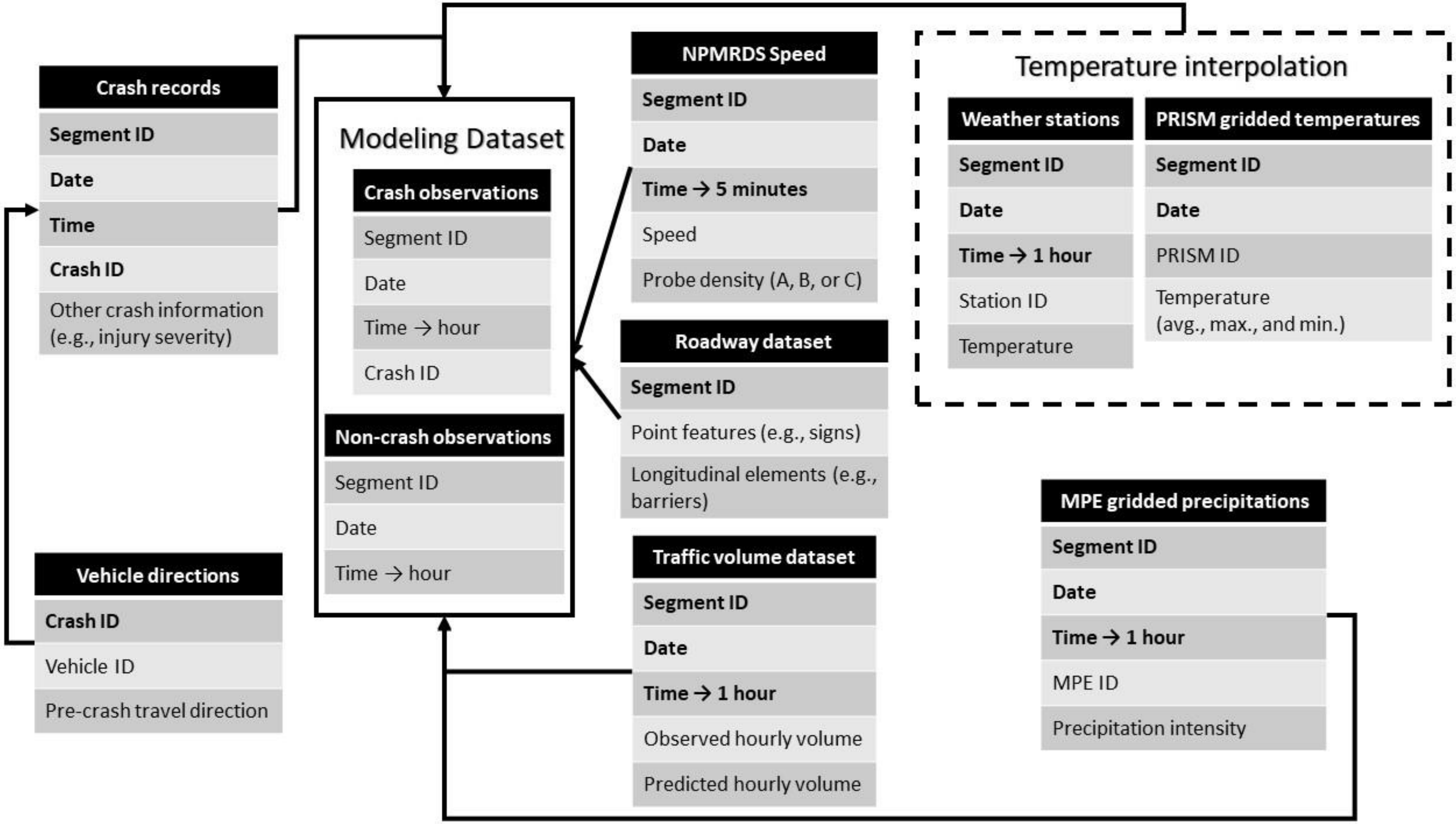
- Currently available high-resolution safety-relevant data
- Disaggregate safety analysis to supplement conventional safety management systems
- Case study of rural interstate freeways in Indiana, USA
- Time-dependent factors of crash probability and injury severity
- Incorporation of the new knowledge in the existing Indiana safety management system
- Implementation consideration: massive data management, supporting tools, courses and workshops, organizational and cultural barriers

AVAILABLE DATA

Name	Description	Source	Granularity
National Performance Management System Data Set (NPMRDS) by INRIX	Speed	GPS and connected smartphones	5 minutes Segment (L ~ 4 Km) All/Cars/Trucks
Multi-sensor Precipitation Estimates (MPE)	Precipitation	Radar, precipitation gages, and satellite estimates	1 hour 4 Km
Parameter-elevation Regressions on Independent Slopes Model (PRISM)	Temperature	Short- and long-term monitoring networks	1 day 4 Km
INDOT's Traffic Count Database System (TCDS)	Volume	Permanent and coverage detectors	1 hour
Automated Reporting Information Exchange System (ARIES)	Crashes	State police	1 min Lat/Lon

AVAILABLE DATA

Data Linkage Structure



AVAILABLE DATA

Modeling Sample

- 133 miles of rural freeways:

  25 miles on I-64,

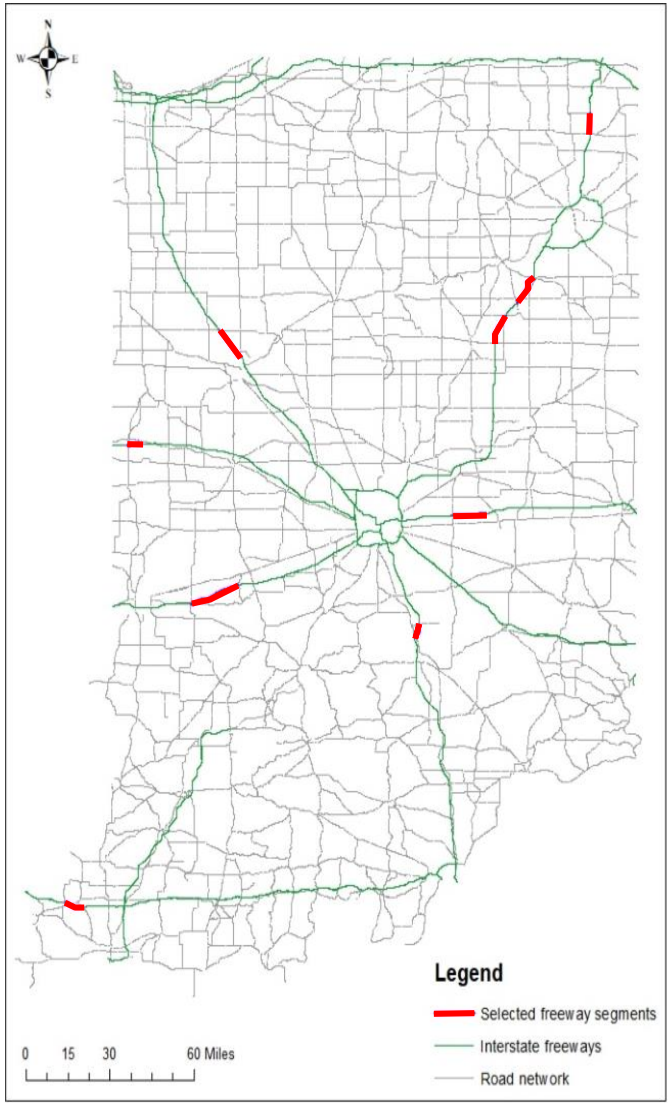
  23 miles on I-65,

  39 miles on I-69,

  40 miles on I-70,

  6 miles on I-74

- 5% of the total mileage of rural interstates in Indiana



PROPOSED ANALYSIS METHOD

Sequential Mixed Logit Model

Observation: Hourly probability of crash at various severity levels along 0.5 mile

- Model 1: Crash vs. No Crash
- Model 2: Injury vs. No Injury (conditioned on crash occurrence)

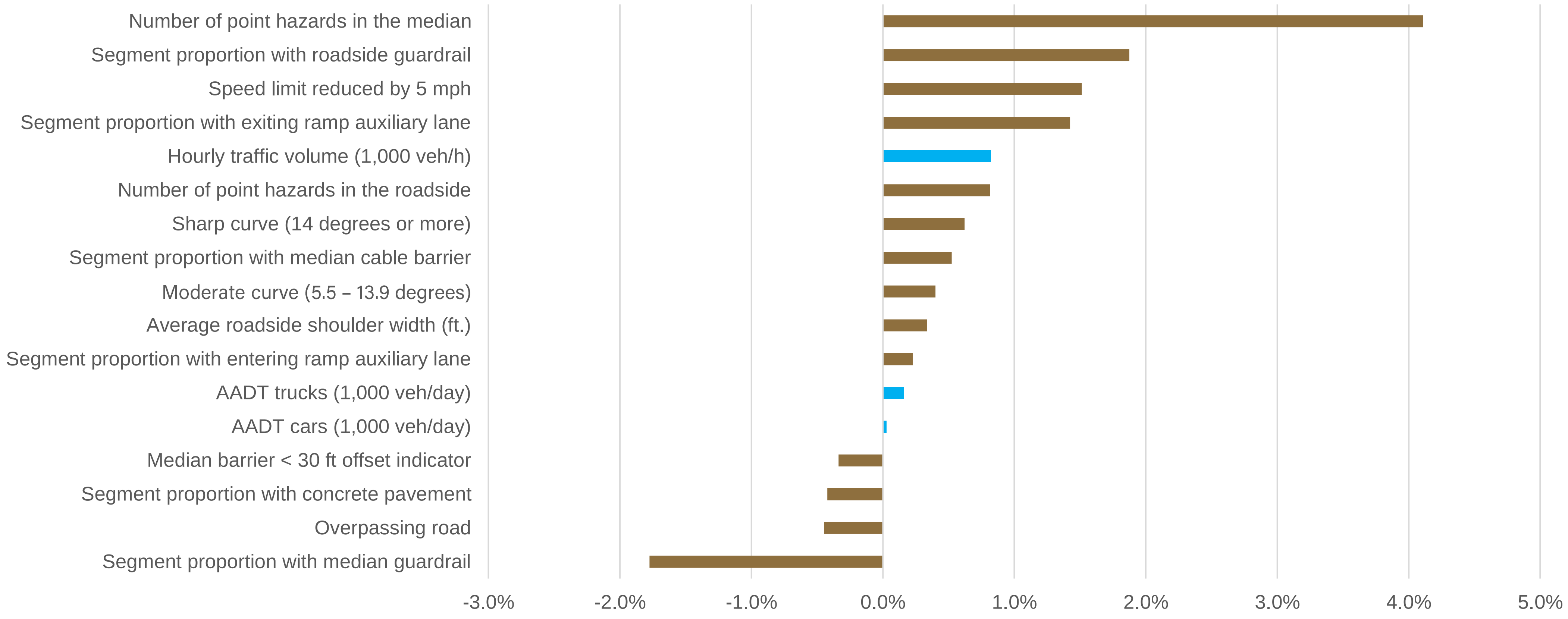
$$P_n = \frac{\exp(\boldsymbol{X\beta})}{1 + \exp(\boldsymbol{X\beta})}$$

$$P_n^{mixed} = \int P_n \, f(\boldsymbol{\beta}|\boldsymbol{\varphi}) d\boldsymbol{\beta}$$

where P is the probability of crash (or severe outcome if considering the injury severity), **X** are contributing factors, and $\boldsymbol{\beta}$ are estimated parameters, $f(\boldsymbol{\beta}|\boldsymbol{\varphi})$ is the density function of $\boldsymbol{\beta}$ with $\boldsymbol{\varphi}$ referring to a vector of parameters of that density function, e.g., for normal distribution, $\boldsymbol{\varphi} = (\boldsymbol{\mu}, \boldsymbol{\sigma}^2)$.

RESULTS AND DISCUSSION

Average Marginal Effects on Hourly Crash Probability (temporal effect)



RESULTS AND DISCUSSION

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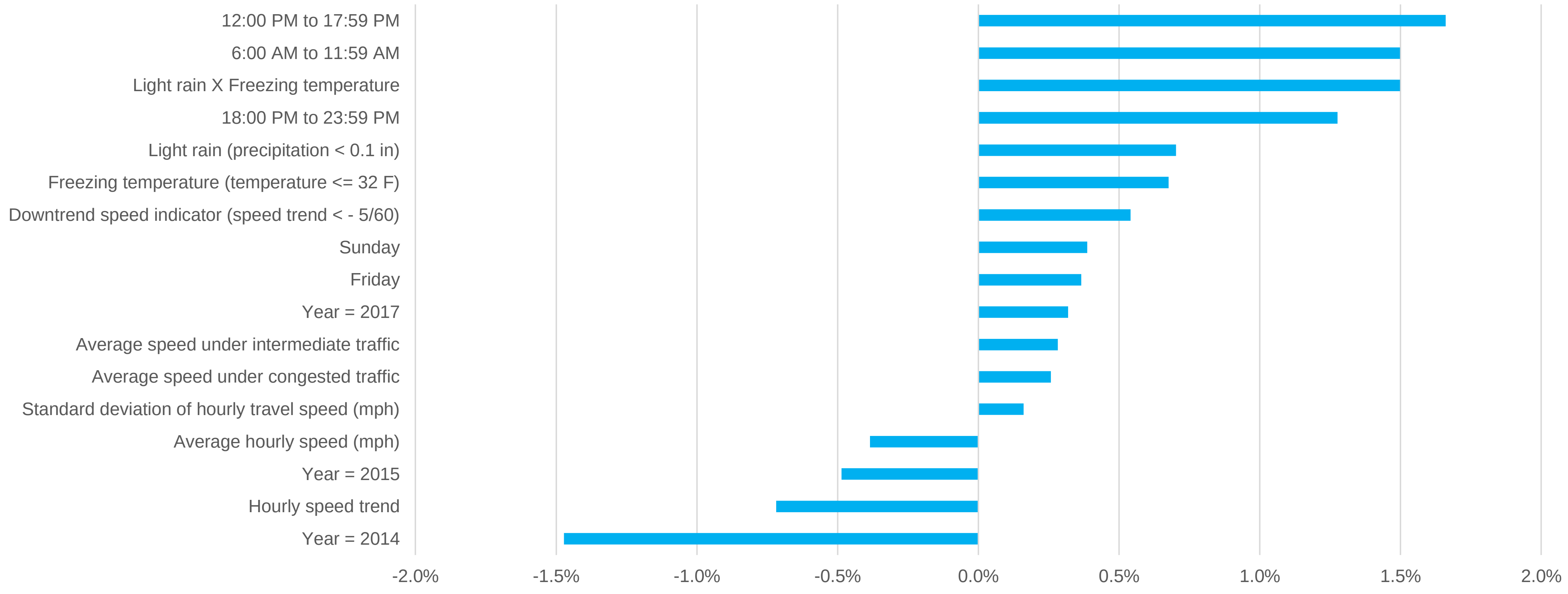
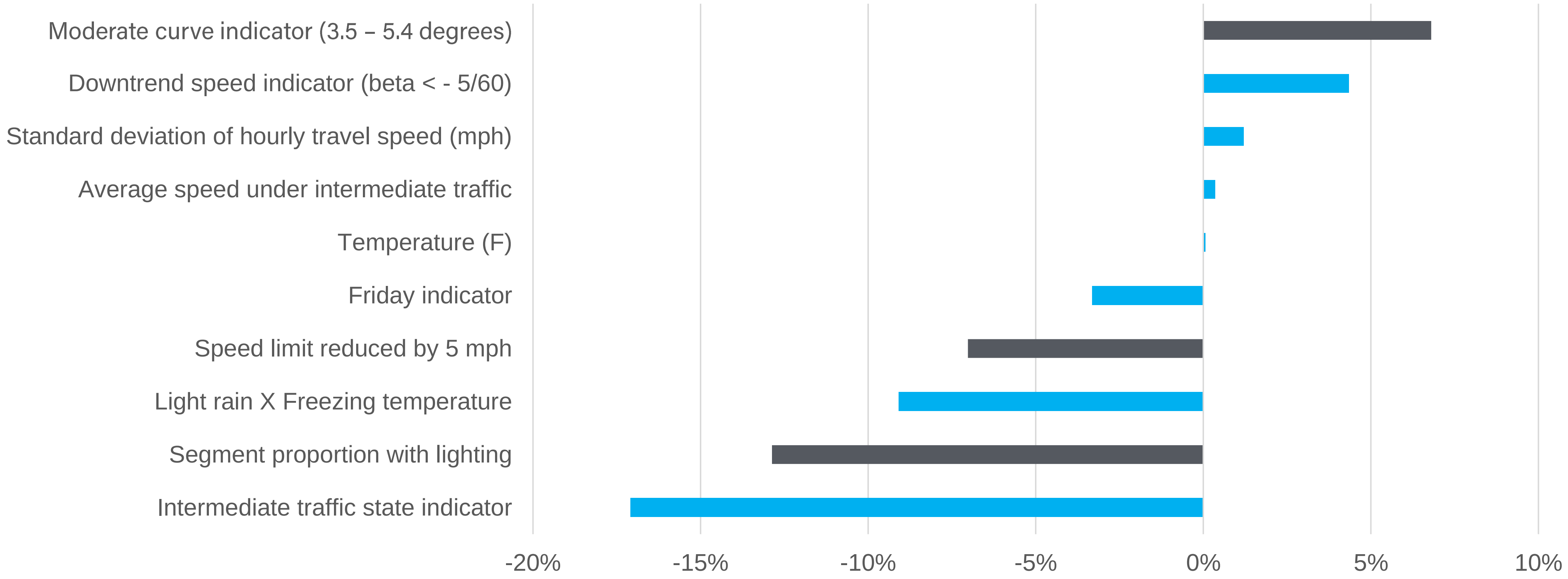


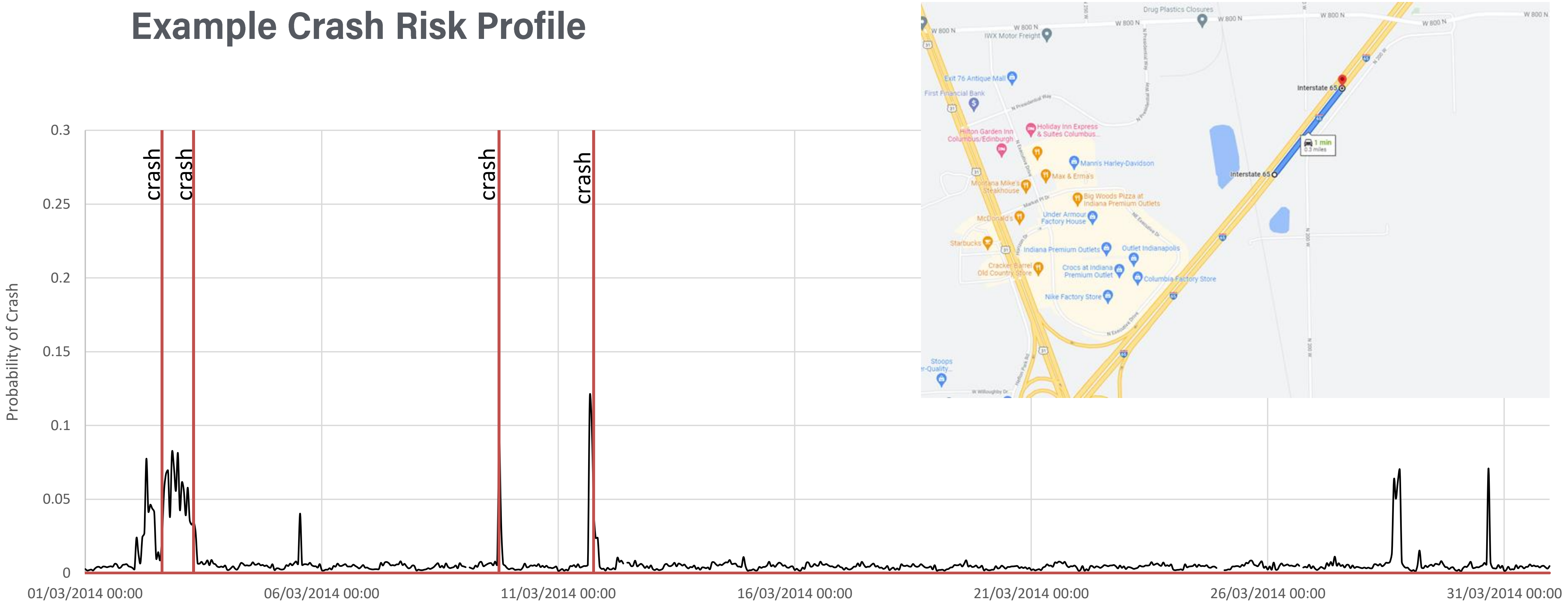
RESULTS AND DISCUSSION

Average Marginal Effects on Probability of Injury (temporal effect)



EXAMPLE RISK PROFILE

Example Crash Risk Profile



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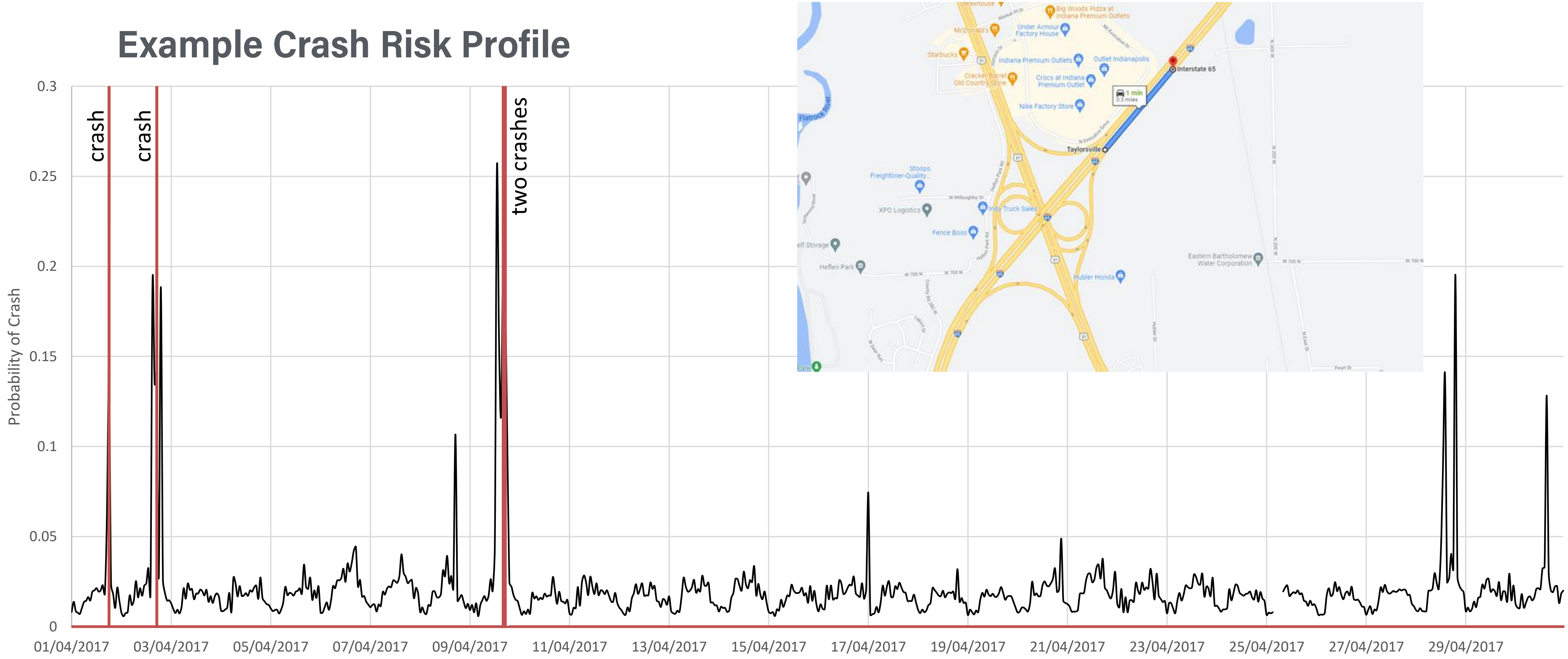

RISK CONSIDERTION IN ROAD SAFETY MANAGEMENT

1. Identify safety needs
   - Identify locations with high crash frequency and severity
   - Identify periods with high crash risk and severity
2. Identify contributing conditions of crashes
   - Non-temporal or aggregated factors (infrastructure, traffic flow, etc.)
   - Temporal risk factors (traffic conditions, weather, etc.)
3. Select potential countermeasures
   - Geometric changes and other non-temporal countermeasures
   - Operational countermeasures
4. Predict the benefits and costs of considered countermeasures
   - Crash Modification Factors (CMFs)
   - Model-based simulation of risk reduction
5. Final selection of countermeasures for implementation

IMPLEMENTATION CONSIDERATIONS

- Management of big data
  - Data ownership and cost
  - Secure and fast data transfer
  - Quality control and quality assurance
  - Privacy protection
  - Massive computations expected
- Need of a suite of tools to perform the new challenging tasks
- Continuous update and maintenance of the tools and systems
- Changes in safety management practice
  - Involvement of IT personnel
  - Training of transportation engineers
  - Safety management versus traffic operations (potential reorganization)
  - Potential inertia or resistance inside organizations

CLOSING REMARKS

- Knowing infrastructure features that negatively affect safety in temporary conditions may help better program infrastructure improvements in relation to the regional climate and character of traffic.
- Identified periods with high-risk conditions improve planning field safety audits when such conditions are expected.
- Risk models allow estimating safety benefits of conventional and operational improvements more accurately than CRFs.
- The most valuable use of risk models is justifying safety operational countermeasures at identified locations and under identified high-risk temporal conditions.
- Examples of countermeasures for safer traffic operations include:
  - variable speed limits,
  - variable messages signs with warnings,
  - broadcasting warnings around high-risk locations during high-risk periods,
  - broadcasting high risk conditions and their sources to CAVs,
  - dynamic lane management strategies,
  - adaptive truck traffic control, etc.

CLOSING REMARKS

Acknowledgement

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Thank you