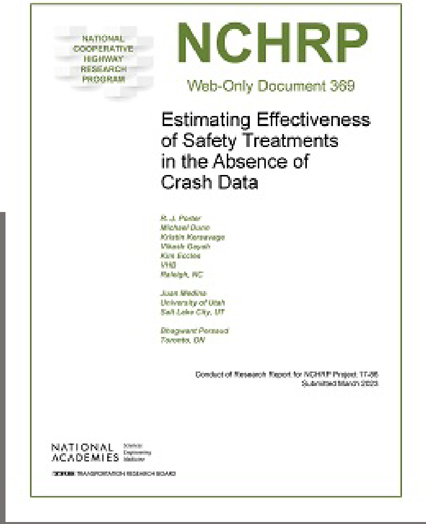
Estimating Effectiveness of Safety Treatments in the Absence of Crash Data (NCHRP Web-Only Document 369)


NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP

Web-Only Document 369

Estimating Effectiveness of Safety Treatments in the Absence of Crash Data

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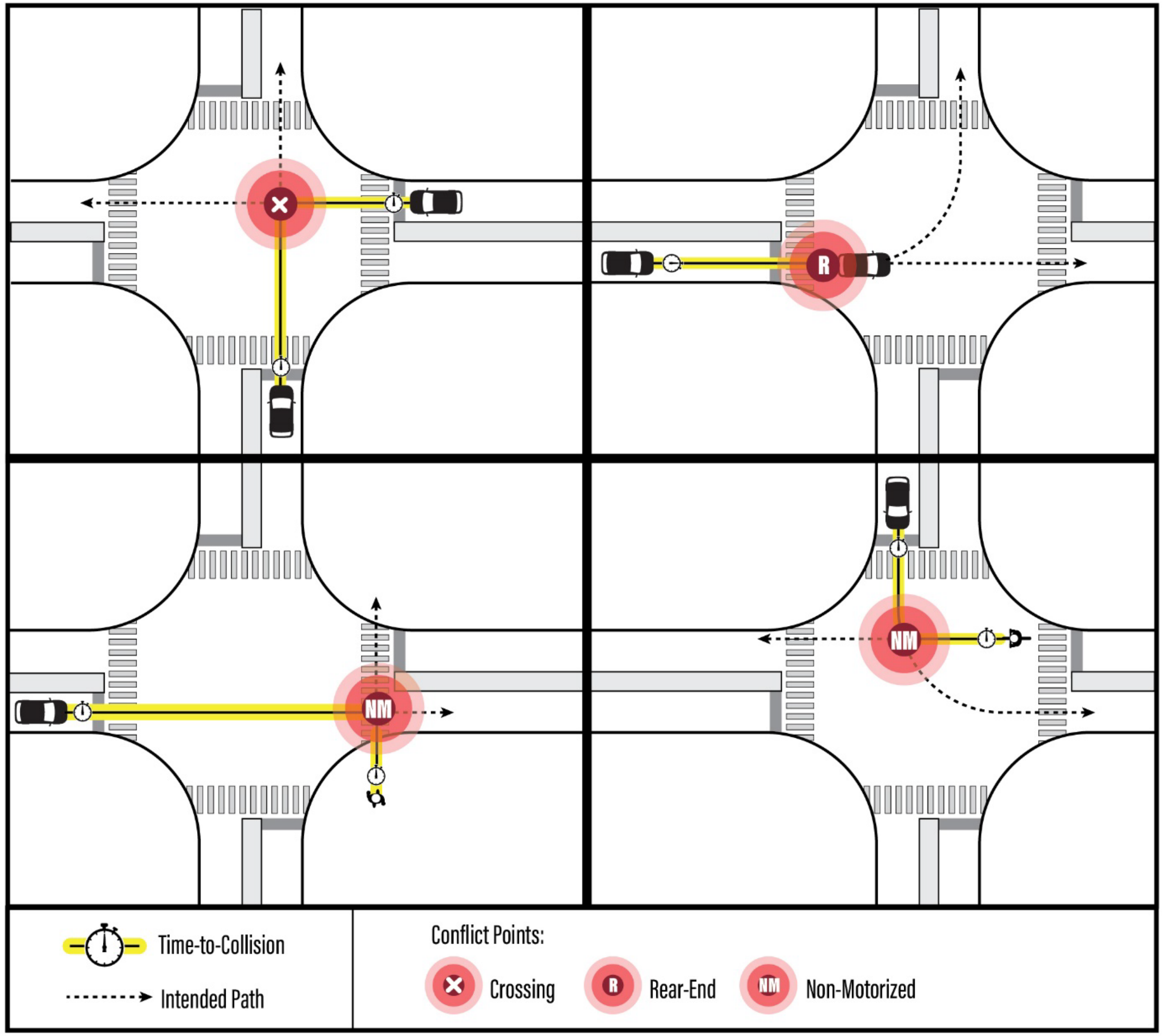
Presented by Jeff Gooch on behalf of Kristin Kersavage.

Background: Alternative, or Surrogate, Measures of Safety

- Measures intended to supplement or be used in place of crash records for quantifying safety performance
- Tarko et al. (2009)
  - Based on an observable non-crash event
  - Linkage exists to crash event
- If linkage exists, can potentially be used to estimate CMF without crash data



Background: Alternative, or Surrogate, Measures of Safety

- Establishing links between surrogate measures and crashes has been a challenging endeavor
  - Emerging technologies provide increasing opportunities for progress
- Researchers and practitioners regularly perform evaluations with surrogate measures, even if established, quantitative linkages between the surrogates and crashes do not exist
  - How should we interpret these studies?
- Surrogate measures, data collection approaches, evaluation results spread over more than 40 years of literature
  - Any one evaluation may have multiple surrogates to choose from and may be influenced by available data collection options and budget

NCHRP 17-86 Research Objective

- Develop a procedural guide for using alternative, or surrogate, measures of safety for developing CMFs and other quantifiable measures in the absence of crash data
- The Guide draws a broad umbrella over the types of measures covered
  - Range of potential crash types and facility types
  - Different data collection approaches (including leveraging existing data collection capabilities)
  - Is more of a first step towards a strategic research program than a “final answer”

Research Approach

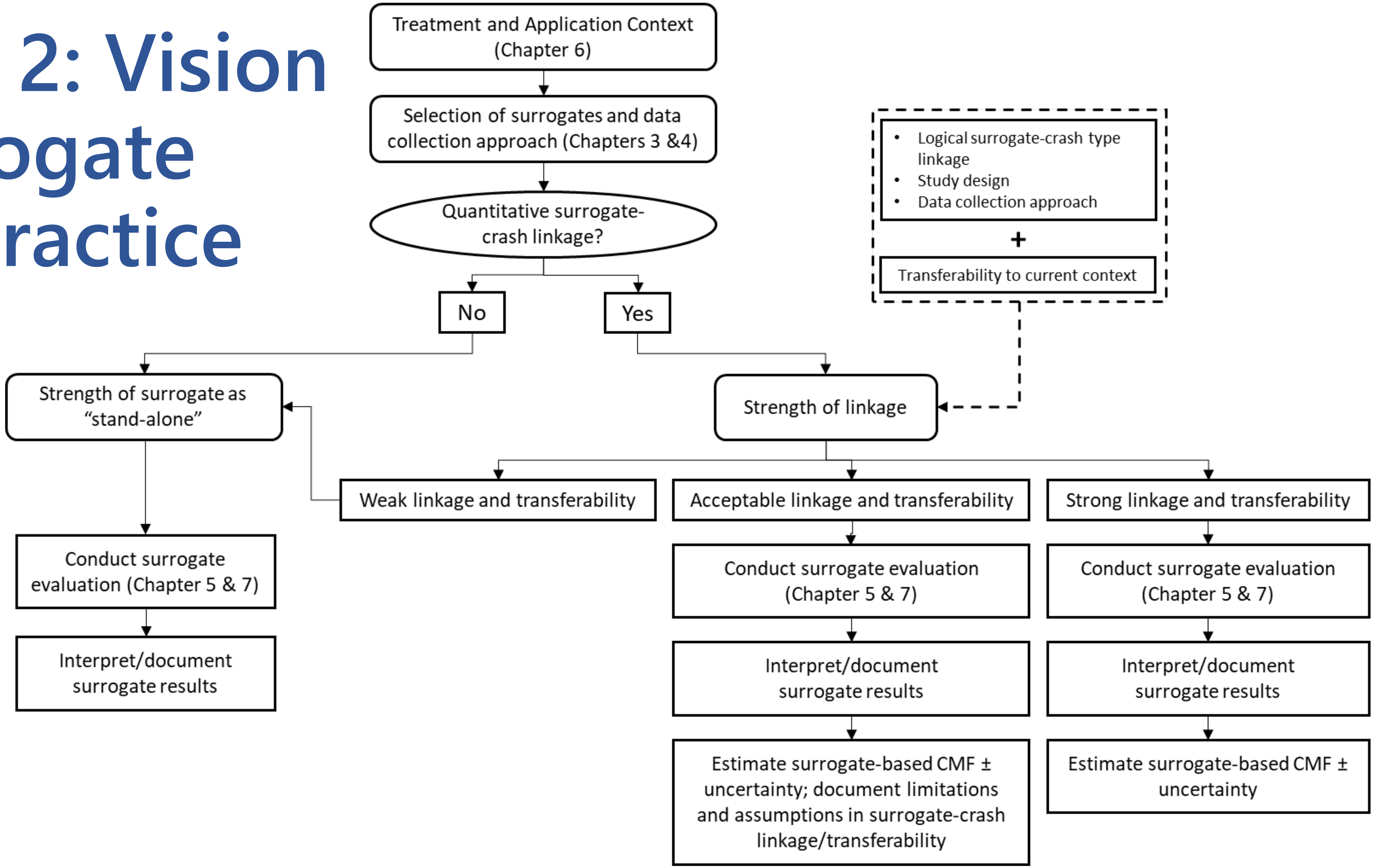
PHASE I	DEVELOP/REFINE RESEARCH PLAN	Task 1—Submit AWP and Hold Kickoff Meeting
		Task 2—Review Literature
		Task 3—Identify Opportunities for Using Surrogates
		Task 4—Identify Treatments with No/Low-Rated CMFs
		Task 5—Phase 2 Data Collection and Analysis Plans
		Task 6—Outline for Procedural Guidance and Use Cases
		Task 7—Interim Report and Panel Meeting

Phase II	EXECUTE RESEARCH PLAN	Task 8—Data Collection (Case Studies)
		Task 9—Data Analysis (Case Studies)
		Task 10—Procedural Guidance
		Task 11—Final Report and Deliverables

Procedural Guide: Chapters

1. Introduction
2. Vision for Surrogate Use in Practice
3. Surrogate Measure Definitions
4. Data Collection Technologies
5. Study Design and Statistical Analysis Considerations
6. Types of Treatments for Evaluation with Surrogate Measures
7. Case Studies
8. Summary and Recommendations for Future Work
9. References

Chapter 2: Vision for Surrogate Use in Practice



Chapter 3: Surrogate Measure Definitions

1. Surrogates that identify potential conflicts between users

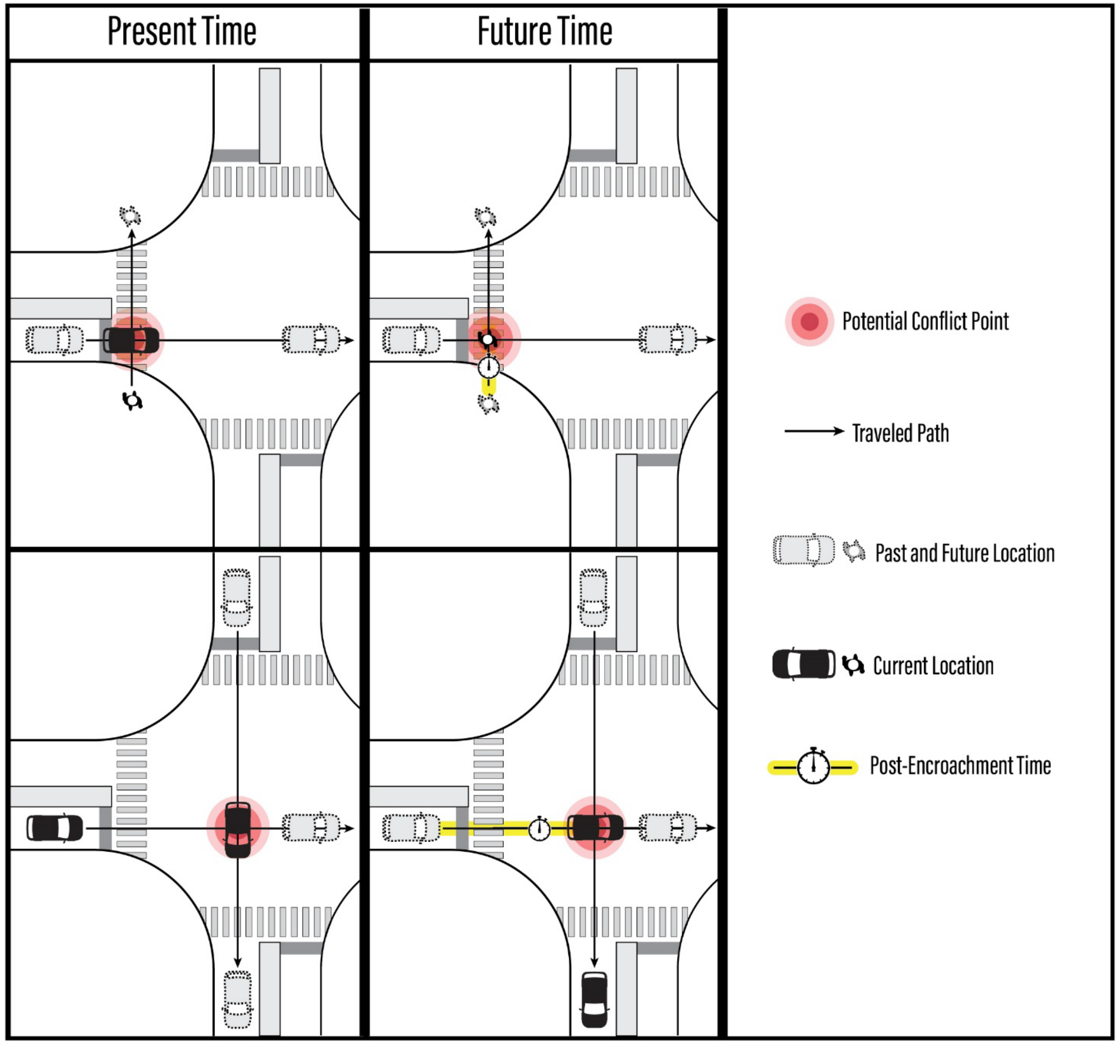
2. Surrogates that measure collision avoidance behaviors

3. Surrogates obtained from macroscopic traffic-level measures

4. Surrogates that measure user attention, choices, and behavior

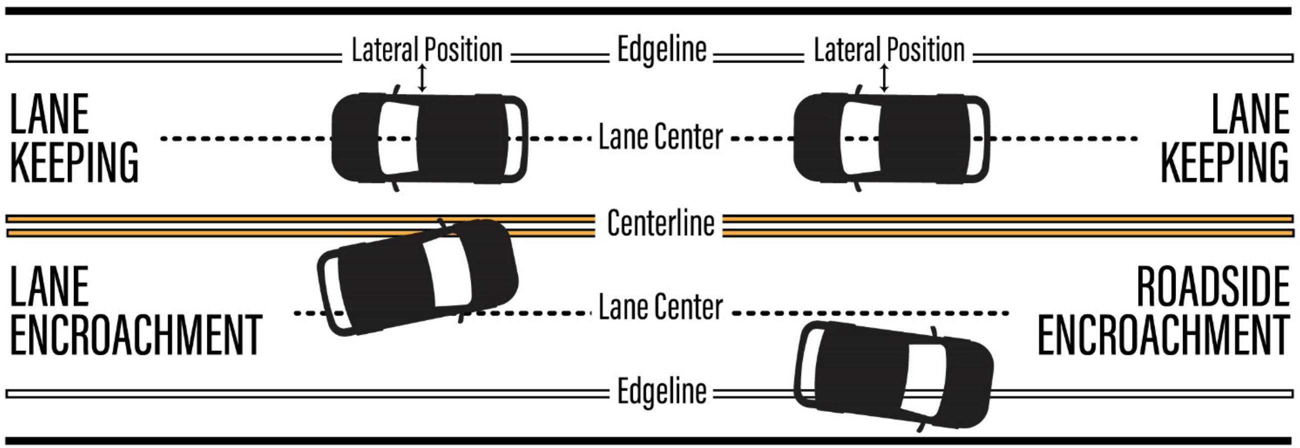
Chapter 3 Examples: Potential Conflicts and Collision Avoidance Maneuvers

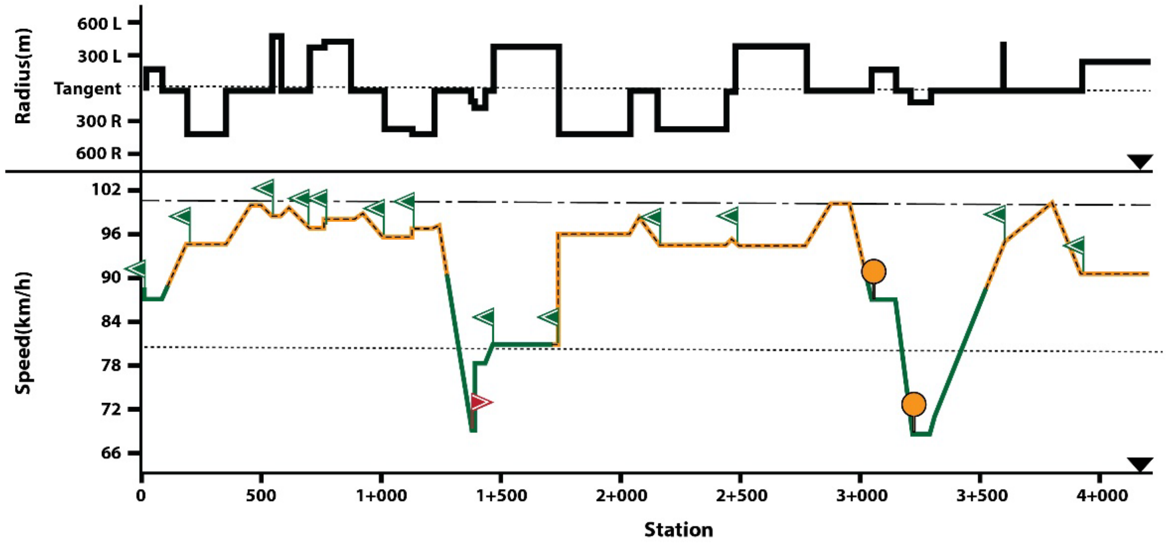
- Potential Conflicts
  - Time-to-collision (TTC)
  - Post Encroachment Time (PET)
  - Time exposed time-to-collision (TET)
  - Time integrated time-to-collision (TIT)
  - Conflict severity index (SI)
  - TTC or PET combined with speed
- Collision Avoidance
  - Deceleration rate to avoid a crash (DRAC)
  - Deceleration rate
  - Yaw rate



Chapter 3 Examples: Macroscopic Traffic-Level and User Behavior

- Macroscopic Traffic Level
  - Average speed
  - Speed variation
  - Speed difference between upstream and downstream locations
  - Average density or detector occupancy
  - Density difference between upstream and downstream locations
  - Average flow
  - Flow variation
- User Behavior
  - Traffic violations
  - Eye glance behavior
  - Lane keeping and encroachments
  - Longitudinal speed profiles





Chapter 4: Data Collection Technologies

- Video
- Vehicle detectors
- Lidar
- Probe vehicles
- Naturalistic driving studies
- Microscopic traffic simulation
- Test track/closed course studies
- Laboratory-based simulators
- Field observations
- Crash simulation
- For each technology:
  - General description
  - Types of surrogates that can be measured
  - Resources required
  - Ability to capture real-world complexity

Chapter 5: Study Design and Statistical Analysis

- Evaluating treatments with surrogates
  - Study design principles
- Establishing surrogate-crash linkages
- Applying surrogate-crash linkages
- Transferability of surrogate findings

Example 5.4: (from Rajeswaran et al., 2022)

Rajeswaran et al. developed and evaluated crash-conflict models for 4-legged signalized intersections using TTC or PET estimated from microsimulation for the peak hour. Two sets of thresholds (2.5 and 5 seconds for PET and 0.5 and 1 seconds for TTC) were evaluated. Models were estimated with and without speed variables – the average or maximum speed of conflicting vehicles. The models were of the form shown in Equations 5, 6, and 7:

$$Crashes/year = e^{\alpha} * (Conflicts)^{\beta_1} \quad (5)$$

$$Crashes/year = e^{\alpha} * (Conflicts)^{\beta_1} * (Average\ Speed)^{\beta_2} \quad (6)$$

$$Crashes/year = e^{\alpha} * (Conflicts)^{\beta_1} * (Maximum\ Speed)^{\beta_2} \quad (7)$$

where "Crashes" pertains to the type of crash that is being modelled against, α is the estimate of the intercept, β_1 is the estimate of the coefficient for conflicts, and β_2 is the estimate of the coefficient for average or maximum speed. These parameters were estimated using regression modeling with the conflict and crash data.

Models based on PET threshold of 5 seconds and Equation 6 were deemed best based on the lower Negative Binomial overdispersion parameters, with a small difference between models with the two PET thresholds. For these models the estimate of α was -3.3908, while β_1 was 0.6165 for total crashes and 0.5208 for injury crashes and β_2 was 0.914 and 1.021 for total and injury crashes, respectively.

Chapter 6: Is a Treatment a Strong Candidate for Surrogate-Based Evaluation?

- What is the quality of existing CMFs for that treatment, if available?
- Is it feasible to develop a crash-based CMF for that treatment? E.g.,
  - Facilities with low traffic volumes or low crash counts (this increases the number of locations that would be needed to obtain a meaningful sample of crashes).
  - Treatments that are few in number, making it difficult to identify candidate locations (this relates to new and innovative treatments).
  - Treatments with dynamic features (e.g., signal timing schemes that change frequently through the day and over time).
  - Treatments that have far-reaching spatial effects that would be difficult to capture using a crash-based study.
- Is the treatment likely to impact severe crash types (e.g., ped/bike, angle/broadside, head-on, roadway departure)?
- Does an appropriate surrogate exist to measure safety performance and how easy is it to capture?

Chapter 6: Example Categories and Reasons

- **Pedestrian and bicyclist strategies**: Surrogates can help fill significant gaps that still exist in crash-based analysis of pedestrian and bicyclist safety strategies.
- **Traffic management and operations (particularly dynamic TSMO strategies)**: Surrogates can help address the dynamic nature of traffic management strategies and the traffic and weather conditions under which they operate, which tend to pose challenges for crash-based evaluations.
- **Intersection design and control strategies**: Surrogates can help uncover effects of key intersection characteristics likely to influence safety performance that are not yet captured in crash-based methods. This may include "nuanced" safety effects and/or trade-offs in how some intersection characteristics affect certain crash types versus others.
- **Roadway and roadside design strategies**: Surrogates can serve as additional evidence to support the findings of cross-sectional crash-based findings that may receive lower crash-based CMF quality scores.

Chapter 7: Case Studies

- Lead Pedestrian Interval (LPI) Evaluation in Bellevue, WA*
- Traffic Signal Coordination Evaluation in Salt Lake City, UT*
- Surrogate-Based Evaluation of Sequential Flashing Chevron Signs on Rural, Two-lane Highways (Donnell et al., 2017)**
- Surrogate Measures as Crash Pre-Cursors (Abdel-Aty et al., 2004)**
- Effect of Geometric Design Consistency on Road Safety (Ng and Sayed, 2004)**
- Crash and Crash-Surrogate Events: Exploratory Modeling with Naturalistic Driving Data (Wu and Jovanis, 2012)**
- Case Study Content
  - Introduction
  - Surrogates Studied
  - Data Sampling Technique
  - Analysis Methods and Results
  - Crash Linkages

* Case study conducted during 17-86 by project team with data contributions from City of Bellevue, Washington, the Utah Department of Transportation, and AMAG Technology

** Case study prepared based on published literature to show other example applications

Example Case Study: LPI Evaluation

- Goughnour et al. (2018) developed CMFs for LPI from a crash-based safety evaluation, but there has not been widespread safety evaluation of LPIs outside of that research.
- **Data used**: video-derived conflict data from 20 intersections in Bellevue, WA processed by AMAG
- **Surrogates studied**: related to spatial and temporal proximity (referred to as a critical conflict based on TTC and PET)
- **Statistical analysis method**: before-after with comparison group (C-G) method focusing on vehicle/pedestrian and rear-end conflicts
- **Link to crashes**: Vehicle/pedestrian conflict reduction estimate was not statistically significant but did indicate some level of alignment with the CMFs computed by Goughnour et al (2018). Rear-end conflict reduction estimate was statistically significant but a direct comparison with Goughnour et al. was not possible because that study did not compute a CMF for rear-end crashes

Summary

- The guide considers a wide range of surrogates
- There are a variety of methods for collecting data on surrogate measures
  - May be able to invest in a data collection approach and technology that is specifically for conducting a surrogate evaluation
  - May wish to leverage data that have already been or already are being collected
- An appropriate study design and analysis method maximizes the chances of uncovering useful and reliable results
- Surrogate measures do not, in general, directly equate to crash outcomes nor can they be assumed to be a relative measure of safety performance without an **established linkage** between the surrogate measure and crashes

Summary

- Targeted research dollars has led to improved knowledge on designing and executing a crash-based evaluation where agencies regularly use results from these evaluations to inform safety program decisions
- Continued interest by agencies in use of surrogate measures would support the establishment of a strategic research program
  - Could **develop a "star" or "point-rating" system** for surrogate evaluations and surrogate-crash linkages similar to that for CMFs
  - Could have similar criteria along with additional surrogate-specific criteria (e.g., a logical link to crashes and the applicability of the surrogate to real-world contexts)

Thank you

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