Estimation of Target Crashes and Safety Benefits for Different Phases of Countermeasure Intervention

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Presentation Outline

• Introduction
• Crash Prevention
• Crash Severity Reduction
• Crash Injury Mitigation
• Concluding Remarks
Crash Scenarios and Countermeasures

- **Pre-Crash Scenario**
- Attempted Avoidance Maneuver
- Pre-Impact Stability
- Impact Scenario
- Injury Scenario
- Harm

**Prevention**
- Stability Control
- Rear-End Crash Warning
- Lane Departure Warning
- Red Light Violation Warning

**Severity Reduction**
- Automatic Braking

**Injury Mitigation**
- Next-Generation Airbags
- Advanced Seatbelts

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Crash Analysis and Benefits Estimation

Crash Data

Operational Conditions

System Functions and Minimum Specifications

Select & Build Prototype(s)

Objective Tests

Benefit/Cost Estimation

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Crash Analysis Framework

Top-Down Analysis

Prioritize Scenarios
Select Dominant Scenarios

Bottom-Up Analysis

Determine Applicable Cases
Analyze Cases

Breakdown of Crash Types

Single Impact
Multiple Impacts
First Impact
Not Vehicle in Transport

Vehicle Object Crashes
Vehicle Vehicle Crashes

Single Vehicle
Multiple Vehicles

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Safety Benefits Estimation

Harm Reduction = $H_{wo} - H_w = H_{wo} \times SE$

- $H_{wo}$ and $H_w$: Total harm without and with countermeasure intervention
- SE: Countermeasure effectiveness in reducing harm

Harm Measures:
- No. crashes
- No. persons/body regions injured at MAIS 2$^+$ or 3$^+$
- Value of statistical life
- Functional years lost

MAIS: Maximum Abbreviated Injury Scale
**Harm Values**

- **VSL (Crash Avoidance)**
- **VSL (Crashworthiness)**
- **FYL**

**VSL: Value of Statistical Life**

**FYL: Functional Years Lost**

42.7 $6,104,610 $6,128,666

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Crash Prevention: Pre-Crash Scenarios

Proportion

0% 6% 12% 18%

- Control Loss without Prior Vehicle Action
- Lead Vehicle Stopped
- Road Edge Departure without Prior Vehicle Maneuver
- Vehicle(s) Turning at Non-Signalized Junctions
- Straight Crossing Paths at Non-Signalized Junctions
- Lead Vehicle Decelerating
- Vehicle(s) Not Making a Maneuver – Opposite Direction

Frequency  Functional Years Lost  Economic Cost

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Crash Prevention: Benefits Estimation

\[ \sum_{i=1}^{n} N_{wo}(S_i) \times E(S_i) \]

- \( n \): Number of pre-crash scenarios, \( S_i \)
- \( N_{wo}(S_i) \): Annual number of baseline crashes preceded by \( S_i \)
- \( E(S_i) \): System effectiveness in avoiding crashes preceded by \( S_i \)
Crash Prevention: Benefits Estimation

No. crashes × \{1 – \text{exposure ratio} \times \text{prevention ratio}\}

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Severity Reduction: Target Crashes

Target Vehicles:
• Light vehicles of model year ≥1998 with frontal damage from first impact (most harmful event)

Target Occupants:
• All occupants in target vehicle and all other persons involved in the crash
• MAIS levels 2 through 6

Crash Imminent Braking:
• No braking
• No Control loss
Injury Mitigation: Target Crashes

Target Vehicles:
• Light vehicles of model year ≥1998 with frontal damage from first impact (most harmful event)

Target Occupants:
• Driver and front seat passenger ≥ 13 years old in target vehicles
• MAIS levels 3 through 6
• Head and thorax MAIS $3^+$, and lower limbs MAIS $2^+$

Advanced Restraints:
• Restrained target occupants

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Crash Severity and Injury Mitigation: Target Vehicle-Object Scenarios

Crash Scenario Ranking

Road Departure – Ground
Road Departure – Pole
Road Departure – Structure
Road Departure – Tree

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Crash Severity and Injury Mitigation: Target Vehicle-Vehicle Scenarios

LTAP/OD Pre-Crash Scenario

SCP Pre-Crash Scenario

Crash Scenario Ranking

- Opposite-Direction - Front-Front
- Rear-End - Front-Back
- LTAP/OD - Front-Front
- SCP - Front-Left Side
- Turning - Front-Left Side
- SCP - Front-Right Side

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Severity Reduction: Benefits Estimation

Filter

Crash Data
Applicable Pre-Crash/Impact Scenarios

Derive

Modeling & Test Data
Impact Speed $\Delta V$

Crash Data
Impact Scenarios

Baseline Occupant Distributions

Safety Benefits

$\{\text{Avg. harm} \times \text{Bas. Occp. Dist.} - \text{Avg. harm} \times \text{CM Occp. Dist.}\}$

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Injury Mitigation: Benefits Estimation

- **x5(j)**: Proportion of occupants represented by 5%-ile dummy in speed j
- **piMAIS^5(j)**: Probability of MAIS i injury for 5%-ile dummy in speed j
- **x50(j)**: Proportion of occupants represented by 50%-ile dummy in speed j
- **piMAIS^50(j)**: Probability of MAIS i injury for 50%-ile dummy in speed j
- **x95(j)**: Proportion of occupants represented by 95%-ile dummy in speed j
- **piMAIS^95(j)**: Probability of MAIS i injury for 95%-ile dummy in speed j
- **piMAIS(j)**: Probability of MAIS i injury in speed j

\[ E_i(j) = \frac{\text{piMAIS}(j) \text{with CM}}{\text{piMAIS}(j) \text{without CM}} \]

Crash data

Test/simulation data

\( i \equiv \text{Index to injury type} \)

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Concluding Remarks

Estimation of target crashes and safety benefits for different countermeasures is underway in a number of U.S. DOT-sponsored projects:

• Advanced Crash Avoidance Technologies (ACAT) program
• IntelliDrive℠ Vehicle-to-Vehicle (V2V) Communications Safety
• Integrated Vehicle Based Safety System (IVBSS)
• Vehicle Safety Communications – Applications (VSC-A)
• Pre-Crash Sensing Crash Imminent Braking (CIB)
• Pre-Crash Sensing Advanced Restraint Systems (ARS)
• Other projects