Changing the Way we think about Traffic Safety: Current Traffic Safety Research Initiatives

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Traffic Safety: A Growing Concern

- The concern about traffic safety has been growing over the years in developed and developing countries alike.

- In 2010; **33,883** people were killed in traffic crashes in the US. About **2.24 million** people were injured (total **5.5 million** crashes cost exceeds **$230 Billion**).
Fatality rate vs. Motorization

Developed Infrastructure

(Evans, 2004)
Crash Rates?

- In the US in 2008, Traffic fatalities, 0.78 per 100 Million Vehicle Km Traveled, **12.3 Fatalities per 100,000 Population**, **14.5 Fatalities per 100,000 Registered Vehicles**, and 17.9 Fatalities per 100,000 Licensed Drivers.

- In Belgium in 2007, **10.2 fatalities per 100,000 of the population (adjusted)**, -21.8% change from 1997. Front seat belt wearing rate 79%

- In Greece in 2007, **14.1 fatalities per 100,000 of the population (adjusted)**, -24.9% change from 1997. Front seat belt wearing rate 75%

- In China in 2005, the fatality rate was about **7.6 per 100,000 people**

- In Egypt in 2006, Traffic Fatalities were **8.6 per 100,000 of the population**, **156.3 Fatalities per 100,000 Registered Vehicles**
Recently there is a notable improvement

The number of traffic fatalities in 2010 reached its lowest level since 1961.

There was a 9.7% decline in the number of people killed in motor vehicle crashes in the United States, from 41,259 in 2007 to 37,261 in 2008. This decline of 3,998 fatalities is the largest annual reduction in terms of both number and percentage since 1982.

Although people may have traveled less in 2008 due to the higher price of gas, the overall injury rate per 100 million VMT declined by 2.4 percent, and the fatality rate also fell to a historic low of 1.27 per 100 Million VMT in 2008.
Fatalities and Fatality Rates per 100 million VMT from 1949 - 2010

Adapted from FARS, USDOT

In 2011 about 1.05, FL 1.25 Fatality per 100 mil VMT
Strategic Highway Safety Plan

- **NATIONAL GOAL**: AASHTO in 1998, a total reduction of annual highway fatalities by 5,000 to 7,000.

- In 2003, AASHTO, the Governors Highway Safety Association, The American Association of Motor Vehicle Administrators, and the U.S. Department of Transportation set as a goal the reduction of the nation’s highway fatality rate by 2008 to not more than one fatality per 100 million vehicle miles traveled (VMT).
To achieve these goals, the updated AASHTO SHSP in 2005 proposed an integrated approach and a series of tools to facilitate for state and local transportation and safety agencies to develop comprehensive highway safety plans. The plan also includes strategies in **22 key emphasis areas** that affect highway safety.
42,000 people were killed in highway crashes in 2003. The following chart shows the number of deaths associated with specific emphasis areas identified in the SHSP.

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<thead>
<tr>
<th>Emphasis Area</th>
<th>2003 Deaths</th>
<th>Comments</th>
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<tr>
<td>Young drivers</td>
<td>3,571</td>
<td>Ages 16–20</td>
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<td>Suspended/revoked licenses</td>
<td>6,973</td>
<td>Involving a driver with invalid licensing</td>
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<td>Older drivers</td>
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<td>3,914</td>
<td>Age 74+</td>
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<td>Aggressive/speeding drivers</td>
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<td>3,565</td>
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<td>Impaired drivers</td>
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<td>Drowsy or distracted drivers</td>
<td>3,730</td>
<td>Inattentive</td>
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<td>1,577</td>
<td>Fell asleep</td>
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<td>Safety belts</td>
<td>18,019</td>
<td>Driver’s and occupants unbuckled</td>
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<td>Pedestrians</td>
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<td>Bicyclists</td>
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<td>Vehicle and train crash</td>
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<td>Motorcyclists</td>
<td>3,661</td>
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<td>Heavy trucks</td>
<td>4,986</td>
<td>Deaths in vehicles</td>
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<td>Safety enhancements in vehicles</td>
<td></td>
<td>Cannot accurately ascertain, although 14 unintentional deaths were associated with carbon monoxide alone in 2002</td>
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<td>Run-off-the-road</td>
<td>18,781</td>
<td>Most harmful event involved fixed object or rollover</td>
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<td>Intersections</td>
<td>6,903**</td>
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<td>Work zones</td>
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<td>Survivability of severe crashes</td>
<td>1,850**</td>
<td>Rural: Time from crash to hospital &gt;1 hour</td>
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<tr>
<td></td>
<td>258**</td>
<td>Urban: Time from crash to hospital &gt;1 hour</td>
</tr>
<tr>
<td><strong>TOTAL DEATHS</strong></td>
<td>42,643*</td>
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</table>
Currently AASHTO is developing “Toward Zero Deaths: a National Strategy on Highway Safety”.

The national strategy will have two tiers: Cultural Change and Building the Foundation of Safety.
Examples of Implementation guides and tools

- **Highway Safety Manual**, Provide factual information and tools to facilitate roadway design and operational decisions based on explicit consideration on safety consequences.

- **SafetyAnalyst**: A set of software tools used by highway agencies to improve their programming of site-specific highway safety improvements.

- **IHSDM: Interactive Highway Safety Design Model**, A suite of software analysis tools for evaluating safety and operational effects of geometric design decisions on highways.
Highway Safety Manual

• The Transportation Research Board has recently (2010) published the *Highway Safety Manual* to fill the gap between state-of-the-art and state-of-practice.

  – Part A: Introduction, Human Factors and Fundamentals
  – Part B: Roadway Safety Management Process
  – Part C: Predictive Method
  – Part D: Crash Modification Factors
Highway Safety Manual

Highway Safety Manual (HSM) Implementation Goals

• Integration of Safety in day to day activities
• HSM becomes a tool routinely used by transportation professionals
• Safety is always another quantified parameter
  – Safety Performance Measurement
    • Safety Performance Functions (SPF)
    • Crash Modification Factors (CMF)
Strategic Highway Research Program

**SHRP2**: Strategic Highway Research Program 2, Safety, aims to prevent or reduce the severity of highway crashes by understanding driver behavior and performance.

Use Naturalistic driving data from multiple locations in the US.

Understand how the driver interacts with and adapts to the vehicle, traffic environment, roadway characteristics, traffic control devices, and the environment.

Collect pre-crash, crash, and exposure data.
Recent Safety Improvement Programs

- FHWA: Highway Safety Improvement Program
- FHWA: Intersection Safety Program
- FHWA: Local and Rural Road Safety Program
- FHWA: Pedestrian & Bicycle Safety Program
- FHWA: Roadway Departure Safety Program
- FHWA: Speed Management Safety Program
- FHWA: Guidance Memorandum on Consideration and Implementation of Proven Safety Countermeasures
<table>
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<th>Countermeasure(s)</th>
<th>Crash Type</th>
<th>Crash Severity</th>
<th>Area Type</th>
<th>Road Type</th>
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<th>Study Type</th>
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<td>Raise posted speed</td>
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<td>Raise posted speed by 5 mph</td>
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<td>Raise posted speed by 10-15 mph</td>
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<td>Reduce mean speed by 5% through speed limit change and enforcement</td>
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<td>Reduce mean speed by 10% through speed limit change and enforcement</td>
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Consideration and Implementation of Proven Safety Countermeasures

- Road Safety Audits (crash reduction up to 60%)
- Rumble Strips and Rumble Stripes (15% of injury crash reduction on rural two-lane roads).
- Median Barriers (Cable systems)
- Roundabouts
- Left and Right-turn lanes at stop controlled Intersections
- Yellow change intervals
- Medians and Pedestrian refuge areas at Urban and Suburban Areas
- Safety Edge (30-35°)
Safety Edge

For a 30° Safety Edge, $\alpha = 30^\circ$
Recent Safety Improvement Programs

- NHTSA: Aggressive Driving Enforcement: Strategies for Implementing Best Practices
- NHTSA: Identifying Strategies to Reduce the Percentage of Unrestrained Young Children
- NHTSA: Increasing Seat Belt Use Through State-Level Demonstration Projects
- NHTSA: Development and Testing of Countermeasures for Fatigue Related Highway Crashes
- NHTSA: Driver Strategies for Engaging in Distracting Tasks Using In-vehicle Technology
- CMF Clearinghouse
Find out more about the Star Quality Ratings for CMFs

Read more about the star quality rating applied to CMFs in the Clearinghouse. The star rating is based on a scale (1 to 5), where a 5 indicates the highest or most reliable rating.

A crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site. The Crash Modification
Current Safety Approach

• Mostly Re-active
• Depend on black “hot” spot identification and identifying the factors that contribute to crash occurrence and severity
• Problems already occurring and damage already done
• Important but not enough
• Challenges are increasing and resources are limited
Macro/Micro Level
GIS Analysis

County Severe Crashes Rate per Mile

Pasco/Pinellas/Hillsborough Counties Cntd.

Legend
Severe Crash Rate

- 0.00 - 100 crashes/mile
- 101 - 200 crashes/mile
- 201 - 300 crashes/mile
- 301 - 400 crashes/mile

Signalized Intersections
- Rank 1: 0.0 - 2.25
- Rank 2: 2.25 - 4.5
- Rank 3: 4.5 - 8
- Rank 4: 8 - 14
- Rank 5: 14 - 20

Roadway
- Rank 1: 0.0 - 2.25
- Rank 2: 2.25 - 4.5
- Rank 3: 4.5 - 8
- Rank 4: 8 - 14
- Rank 5: 14 - 20
Fog/Smoke Areas

GIS Cluster analysis
Visibility range reporting algorithm to base speed limit reporting algorithm to DMS/VSL

System Components

Base

Visibility Sensor

Station

Components of station electronic enclosure
Green circles represent the zones within a half mile of the schools (buffer zones) and darker color in circles represents higher number of crashes per school within the buffer zones. Red triangles denote the crash locations and blue lines denote major streets.
A WEB-BASED Application for Providing Crash Profiles at Intersections

A Manual for Intersection Safety

1500 signalized intersections divided into 45 signalized categories.

2500 non signalized intersections divided into 60 categories.
ZIP areas that were identified to have high number of crashes due to driving under the influence (DUI) per mile of roadway are Center Hill (33514), Geneva (32732), Melbourne Beach (32951), Orlando (32832), Seville (32190), Windermere (34786), and Zellwood (32798).
Advances in Traffic Safety

Pro-Active Approaches

• Transportation Safety Planning (TSP)
• Real-Time Crash Prediction
• Microscopic Traffic Simulation in Safety Research
• Intelligent Transportation Systems’ Applications
Advances in Traffic Safety

Pro-Active Approaches (cont.)

• Using Driving Simulators to Evaluate Safety
• Strategic National Highway Safety Plan
• “Forgiving” Roadway Design.
• Road Safety Audits
• Incorporating Safety in Design
Transportation Safety Planning

• TSP is a proactive approach to the prevention of accidents and unsafe transportation conditions by establishing inherently safe transportation networks.

• Integrate safety considerations into the transportation planning process at all levels. This step should be followed by consideration of safety objectives in the longer range transportation plan (i.e., 20 year plan).

• Lead to further collaboration among transportation planners, traffic engineers, safety stakeholders, and others.
Macroscopic Aggregate Safety Analysis

**Predictor Categories**

- Trip Generation
- Demographics & Socio-economic
- Road Characteristics
- Transportation Infrastructure
- Weather Conditions
- Amount of Travel

**State**
- Noland (2003)

**County**
- Abdel-Aty et al. (2009), Amoros and Laumon (2003); Noland and Oh (2004); Valverde and Jovanis (2006)

**Census Tract**
- Wier et al. (2009)

**T A Z**
- Hadayeghi et al. (2003, 2006); De Guevara et al. (2004); Abdel-Aty et al. (2010)
Macroscopic Safety Analysis
TAZ level Analysis

- TAZs are defined as part of the Census Transportation Planning Package

- The most important criteria used to define TAZs include spatial contiguity, homogeneity, compactness, etc.

Number of severe (fatal and severe injury) crashes per TAZ in Hillsborough County for 2005 and 2006
## Severe Crash Models

### Variables - TRIP related only

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<td>0</td>
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### Variables - Total Trip Production & Attraction

<table>
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<tr>
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<th>S. E.</th>
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<tbody>
<tr>
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<td>logta</td>
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# Pedestrian & Bicycle Crash Models

## Variables - ROAD related only

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pedestrian and Bicycle related Crash (Model D)</th>
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<tbody>
<tr>
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<td>Estimate</td>
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<td>Intercept</td>
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## Variables - ALL

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<tr>
<td>Pearson Chi-Square Value/DF</td>
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</tbody>
</table>
Let any TAZ $i$ shares its boundary with $1, 2, \ldots, k$ different neighboring zones. Any variable $x$ will then be transformed to $x_B$ such that,

$$x_B = \frac{1}{2}\left[x_i + \frac{d_{i1} * x_1 + d_{i2} * x_2 + \ldots + d_{ik} * x_k}{d_{i1} + d_{i2} + \ldots + d_{ik}}\right]$$

where,
- $x_i = \text{variable } x \text{ for } i^{th} \text{ zone}$,
- $d_{i1} = \text{length of the shared boundary between zones } i \text{ and } 1$,
- $x_1, \ldots, x_k = \text{variable } x \text{ for the } 1, 2, \ldots, k \text{ neighboring zones},$
- $d_{i1} + d_{i2} + \ldots + d_{ik} = \text{perimeter of zone } i$. 
Schematic model of the proposed methodology

Parent Bayesian Framework

Sub-model for Interior Crashes/TAZ

$\mu_{interior}[i]$

Estimates posterior distribution of Interior crashes within a TAZ

Sub-model for Boundary Crashes/TAZ

$\mu_{boundary}[i]$

Estimates posterior distribution of boundary crashes within a TAZ

Spatial Error Component

Full model estimates joint probability distribution of aggregate crashes within a TAZ

$\mu_{total}[i] = \mu_{interior}[i] + \mu_{boundary}[i]$
Real-Time Crash Prediction

- Objective of freeway traffic management is to monitor and mitigate *recurring* (during peak hours) and *non-recurring congestion* (from incidents, weather etc.)

- Traffic management authorities rely on traffic surveillance apparatus (e.g., *loop detectors*, radar detectors, video cameras) to monitor freeway traffic conditions.

- Loop detectors provide speed, volume, and lane-occupancy for very short durations.
How are Traffic Flow Parameters Collected?

Loop Detectors
Automated Traffic Ramp Controller’s
(Speed, Volume & Occupancy) / (30sec. to 1 min.)

Toll Tag Reader
(Speed / 1 min.)

Side-Fire Radar
(Speed, Volume & Occupancy) / 20 Sec.
Which patterns are we looking for?

Traffic flow parameters prior to the time of crash

![Diagram showing traffic parameter changes before, during, and after a crash](image-url)
Approach to Proactive Freeway Management

- Analyze historical crashes and traffic surveillance data corresponding to each crash and detect patterns that are often repeated before the crash occurrence.

- If these patterns are repeated in the future on a freeway section that section may be identified as a real-time "black-spot".

- Real-time proactive measures should be developed to avoid crashes.
Microscopic/Disaggregate Safety Analysis
Data Source (Loop detectors)
Real-Time Crash Risk

Hazard Ratio: Contour plots of hazard ratios corresponding to coefficient of variation in speed (42 model outputs)
Crash Prediction Model

Crash Precursors

**Crash Precursor #1:**
Variation in speed upstream of crash location

Upstream of crash location
Crash Prediction Model

Crash Precursors

**Crash Precursor #2:**

Speed upstream of crash location minus speed downstream of crash location
Crash Prediction Model
Crash Precursors

Crash Precursor #3: Covariance of volume across adjacent lanes upstream of crash location

Upstream of crash location
Crash Prediction Model

External Control Factor

Road geometry of crash location
- Straight road sections
- Merging/diverging road sections
Interstate-4 Freeway, Orlando, FL
Micro-Simulation: Variable Speed Limits

Stabilization in 30-second speed profiles following ITS strategies implementation
VSL & VMS in Driving Simulator

Warning Message

Variable Speed Limit
Proactive Traffic Management

Between 2005-2010 we were pioneers in analyzing real-time data collected from inductive loop detectors and radars in a safety framework, but there are no safety studies that attempted the use of traffic data from one of the most growing surveillance system; the tag readers on toll roads (AVI).
AUTOMATIC VEHICLE IDENTIFICATION (AVI) SYSTEM

• This system estimates the segment travel time by monitoring the successive passage times of vehicles equipped with electronic tags.

• Data are gathered using AVI tag readers that are installed solely for the purpose of estimating travel times and some for toll collection.
ILDs Speed vs. AVIs Speed

Commonly deployed inductive loop detectors (ILDs) measure time-mean-speed (TMS), whereas AVIs measure space-mean-speed (SMS).
ILD vs. AVI

• Our current research implemented for the first time data collected from the AVI in a real-time traffic safety analysis.

• AVI data were found to be promising in providing a measure of crash risk in real-time. The management of expressways can benefit from the collected AVI traffic data not only to ease the congestion and enhance the operation but also by evaluating the increased risk.
The 15-mile on I-70 in Colorado is equipped with AVI, RTMS, and Weather Stations.

- There were five sets of data used in this study; roadway geometry data, crash data, and the corresponding AVI, RTMS and weather data.
- Traffic data consists of space mean speed captured by 12 and 15 AVI detectors located on each east and west bounds, respectively along I-70. Volume, occupancy and time mean speed are collected by 15 RTMSs on each direction.
- AVI estimates SMS every 2-minute while RTMS provides traffic flow parameters every 30-second. Weather data were recorded by three automated weather stations along the roadway section for the same time period.
Exploratory Comparison between AVI and RTMS Data

Normal Traffic Condition (No Crash)

PDO Crash

Speed Variance (PDO)

Fatal Crash

Crash Location: Milepost 217.7

Crash Location: Milepost 217.5
## Variable Importance

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
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<tbody>
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<td>Avg. Occ. Upstream1_Time Slice _2</td>
<td>1.000</td>
<td>Avg. Occ. Upstream 2_Time slice_3</td>
<td>1.000</td>
<td>Avg. Speed Crash Segment Time Slice_2</td>
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<td>1-Hour Visibility</td>
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<td>Avg. Occ. Upstream 2_Time slice_3</td>
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<td>Log. Coef. of Var. of Speed Crash Segment Time Slice_2</td>
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<td>Avg. Speed Downstream Segment Time Slice_2</td>
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<td>10-Minute Precipitation</td>
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<td>1-Hour Visibility</td>
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<td>No. of Lanes</td>
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<td>Avg. Speed Upstream 1_Time Slice_2</td>
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## Models Comparison

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<th>Model Description</th>
<th>Overall Classification Rate</th>
<th>True Positive Rate</th>
<th>False Positive Rate</th>
<th>True Negative Rate</th>
<th>ROC Index</th>
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<tbody>
<tr>
<td>Model-1</td>
<td>All Data</td>
<td>92.157%</td>
<td>88.889%</td>
<td>6.481%</td>
<td>93.519%</td>
<td>0.946</td>
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<tr>
<td>Model-2</td>
<td>RTMS</td>
<td>87.879%</td>
<td>73.333%</td>
<td>7.154%</td>
<td>92.845%</td>
<td>0.762</td>
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<td>Model-3</td>
<td>AVI</td>
<td>87.653%</td>
<td>70.192%</td>
<td>6.393%</td>
<td>93.607%</td>
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<td>Model-4</td>
<td>Weather</td>
<td>84.364%</td>
<td>55.714%</td>
<td>5.854%</td>
<td>94.146%</td>
<td>0.675</td>
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</table>

![ROC Index Graph](image-url)
Components of Active Traffic Management

- Speed Harmonization
- Temporary Shoulder Use
- Queue Warning
- Ramp Metering
- Truck Restrictions
- HOV/HOT Lanes

Need to be more pro-active by incorporating real-time accident prediction.
Advanced Safety Performance Functions (SPF)

Advanced Statistical Techniques

- Hierarchical Bayesian Models
- Methods to account for Spatial Effects
- Time Series
- Generalized Estimation Equations (GEE)

Non Conventional Analytical Methods

- Data Mining Techniques
- Neural Networks
- Genetic Programming
- Genetic Algorithms
SPFs for Longitudinal Crash Frequencies

• Generalized Estimation Equations (GEE)
  – GEE come from specifying a known function of the marginal expectation of the dependent variable as a linear function of covariates; assuming that the variance is a known function of the mean; in addition, specifying a “working” correlation matrix for the observations for each location.

• GEEs with Negative Binomial link function were used to model spatial and temporal correlation for 3-year longitudinal crash data.
Spatial Safety Analysis: Corridor Identification & Cluster Analysis

- A total number of 476 signalized intersections along 41 arterials are selected from 3 counties in Fl.
Safety Analysis by Conflicting Patterns

Major Conflicting Patterns
e.g., for Left-turn crashes

Modeling Crash Frequency At the Approach Level: GEE with Negative Binomial to account for “site correlation”.
A conceptual model Multi-level and SpatioTemporal data structure

Level 1: Geographic region
Level 2: Traffic site
Level 3: Traffic crash
Level 4: Driver-Vehicle Unit
Level 5: Occupant

Spatial level: Geographic region & Traffic site
Time level: for Panel data

5 \times ST hierarchy

Traditional Approach

Generalized Linear Model

\[ Y \mid \theta \sim \text{Dist}(\theta) \]

with \[ \theta = f(X, \beta, \varepsilon) \]

\[ Y : \text{Dependent variable(s) of interest, e.g. crash frequency or severity} \]
\[ \text{Dist}(\theta) : \text{Adapted distribution for } Y \mid \theta \text{ and its parameter(s)} \]
\[ X : \text{Covariates representing various exposure/risk factors to crash occurrence} \]
\[ \beta : \text{Coefficients, i.e. factor effects of } X \text{ on } Y \]
\[ f(\cdot) : \text{Link function relating } X \text{ and } Y \]
\[ \varepsilon : \text{Disturbance/error terms in the model} \]

- **GLMs limitation:** each observation in the estimation procedure corresponds to an individual situation. Hence, the residuals from the model exhibit independence.

- **However,** the “independence” assumption may often not hold true since multilevel data structures exist extensively because of the traffic data collection and clustering process.
Solution: Bayesian Hierarchical Modeling

- To examine the effects of various risk factors at different levels
- Cross-group heterogeneity
- Spatial autocorrelation, Time-series correlation
**What is the merit?**

<table>
<thead>
<tr>
<th><strong>Multilevel Model</strong></th>
<th><strong>Bayesian Prior</strong></th>
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<tbody>
<tr>
<td>Simultaneously incorporate risk factors in both individual-level and group-level models with consideration for cross-group variations.</td>
<td>Engineering experiences or justified previous findings can be used as prior knowledge of the posterior model. It is good for small sample size.</td>
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<table>
<thead>
<tr>
<th><strong>Bayesian Prediction</strong></th>
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</thead>
<tbody>
<tr>
<td>Hierarchical modeling is a preferred partial pooling of data. By latent variable approach, Bayesian inference provides automatic prediction for missing data and for new units in new groups.</td>
</tr>
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</table>
Recommendations

• More Proactive approaches are needed in traffic safety
• Improve Safety Databases.
• Incorporate Safety at the Planning Level
• National and regional Goals and Strategic Safety Plan
• Integrated 5E approach
Overall Safety Strategy

Engineering

Education

Emergency Response

Enforcement

Evaluation

5 E’s
Recommendations (cont.)

• Benefit from the wealth of Safety Research from around the world while tailoring it to the specific country (Greece).

• A number of recent studies, including those by the presenter, have shown the usefulness of accounting for specific safety data structure by using Bayesian hierarchical models.

• The proposed 5×ST-level hierarchy represents a conceptual framework with all up-to-date understandings on safety data structure.
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