SEASONAL CRASH PREDICTION MODEL FOR URBAN SIGNALIZED INTERSECTIONS

Wisconsin Southeast Region

Boris Claros, Andrea Bill, Madhav Chitturi, and David Noyce
Overview

- **Highway Safety Manual**
  - Provides Guidance
    - Safety Analysis and Evaluation
  - Methodologies and Tools
    - Crash Prediction Models
    - Calibration, Model Development
    - Network Screening, Countermeasures
    - Safety Effectiveness, Crash Cost/Benefit
  - Applications
    - Planning, Programing, Project Development, Construction, Operations, and Maintenance
Overview

- Conventional Crash Prediction Models
  - Crashes per Year
  - Data Aggregation
  - Do Not Consider Weather
  - Omit Seasonal Fluctuations
    - Traffic
    - Weather
  - Negative Binominal
    - Combination of Poisson and Gamma Probability Distributions
    - Convenient, Simple, and Practical
Objectives

- **Wisconsin Southeast Region**
  - Expanded Data Collected for NCHRP 03-118 Project
  - Focus on Jurisdiction Specific Models

- **Assemble Seasonal Database 2005-2016**
  - **Crashes** 250 ft from Center of Intersection
  - **Traffic** Traffic Counts (AADT), I-43 Traffic Sensors
  - **Geometry** Number of Lanes
  - **Operations** Posted Speed Limit
  - **Signal Control** Permissive, Protected/Permissive, Protected
  - **Weather** Weather Stations, Snowfall
Methodology

- **Intersection Sampling**
  - Pool of 549 Signalized Intersections
  - Selection Process
    - Systematic Review of all Intersections
    - Consistency of Geometry and Operations
      - Urban
      - Two-way Four-Legged Intersections
      - Approaching legs skew angle no greater than 15 degrees
      - Distance Greater than 500 ft from adjacent Intersections
      - Less than 10 miles from weather station
  - 208 Intersections Selected
Methodology

- **Data Sources**
  - **WisTransPortal**
    - Crashes
  - **WisDOT Central Office and Southeast Region**
    - Traffic Count Reports and As-built Plans
  - **National Center for Environmental Information**
    - Weather Station Monthly Reports
  - **Google Earth**
    - Aerial and Street View
Methodology

- **Data Collection**
  - **Geometry, Speed Limit, and Signal Control**
    - 601 As-built Plans Reviewed, Google Earth
  - **Traffic**
    - 636 Traffic Count Reports Reviewed
    - Daily Traffic Counts from Sensors Along I-43
  - **Weather**
    - 17 Weather Stations
  - **Crashes**
    - By severity: Fatal and Injury, Property Damage
Methodology

- Exploratory Analysis

Weather

- Snowfall, SW (inches)
- Daylight, LIT (hours)

Temperature, TEMP (°F)

Traffic

- Daily Traffic, DT (vpd)
- MADT as Percentage of AADT

Month

- JAN
- MAR
- MAY
- JUL
- SEP
- NOV

Day

- 1
- 30
- 59
- 88
- 117
- 146
- 175
- 204
- 233
- 262
- 291
- 320
- 349

January through December

Exploratory Analysis

- MADT as Percentage of AADT

- Snowfall, SW (inches)
- Daylight, LIT (hours)
Methodology

- Exploratory Analysis

Crash Frequency

<table>
<thead>
<tr>
<th>Month</th>
<th>PDO</th>
<th>FI</th>
<th>Ave PDO</th>
<th>Ave FI</th>
</tr>
</thead>
<tbody>
<tr>
<td>JAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JUN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JUL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Crash Rate

<table>
<thead>
<tr>
<th>Month</th>
<th>PDO</th>
<th>FI</th>
<th>Ave PDO</th>
</tr>
</thead>
<tbody>
<tr>
<td>JAN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JUL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOV</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Crashes per Million Entering Vehicles (MEV)
Methodology

- **Seasonal Model Development**
  - **Negative Multinomial**
    - Extension of the Negative Binomial
    - Accounts for Multiple Periods of Analysis
  - **Maximum Likelihood**
    - Optimization to Obtain Prediction Model Coefficients
  - **Negative Multinomial Likelihood Function**

\[
\ln[\hat{L}_i^*(\varphi, \beta_1, ..., \beta)] = \beta \ln(\beta) + \left[ \sum_{j=1}^{m_i} \text{obs}_{ij} \ln(\text{pred}_{ij}) \right] + \ln\Gamma\left( \sum_{j=1}^{m_i} \text{obs}_{ij} + \beta \right) \\
- \ln\Gamma(\beta) - \left( \sum_{j=1}^{m_i} \text{obs}_{ij} + \beta \right) \ln\left( \sum_{j=1}^{m_i} \text{pred}_{ij} \right) + \beta
\]
Methodology

- **Predictor Variables**

**First Variable: AADT**

![Graph showing crashes/season vs. AADT for different seasons]

**Next Variable: Speed Lim.**

![Graph showing speed major+minor vs. ratio]

First Variable: AADT

- Winter
- Spring
- Summer
- Fall

Next Variable: Speed Lim.

- Speed major+minor
- Ratio
- F1
- F(S)
Results

- **Seasonal Prediction Model**

**Fatal and Injury Crashes (FI)**

\[ N_j = \varphi_j \times \left[ \frac{19.822}{1 + 54.709 \exp \left( -0.721 \frac{\text{AADT}_{maj+min}}{10,000} \right)} \right] \times \left[ \frac{0.100 \left( \frac{S_{maj+min} - 50}{10} \right)^2 - 0.478 \left( \frac{S_{maj+min} - 50}{10} \right) + 1}{0.1267 \exp \left( -0.618 \frac{RL}{LL} \right)} + \varphi_j \times \left[ \frac{0.095 RL}{100} \right] \times \left[ 0.424 \sin \left( \frac{P_{\alpha}}{2} \right) + 1 \right] + \varphi_j \times \left[ 0.038 \left( \frac{SW}{DY} \right)^{2.328} \right] \]

**Property Damage Only Crashes (PDO)**

\[ N_j = \varphi_j \times \left[ \frac{4.613}{1 + 21.424 \exp \left( -0.907 \frac{\text{AADT}_{maj+min}}{10,000} \right)} \right] \times \left[ \frac{0.107 \left( \frac{S_{maj+min} - 50}{10} \right)^2 - 0.362 \left( \frac{S_{maj+min} - 50}{10} \right) + 1}{0.158 \exp \left( -0.206 \frac{RL}{LL} \right)} \times \left[ \frac{\exp \left( -0.061 RL \right)}{100} \right] \times \left[ 0.327 \left[ \sin \left( \frac{P_{\alpha}}{2} \right) + \sin \left( \frac{PP_{\alpha}}{2} \right) \right] + 1 \right] \times \left[ 0.588 \left( \frac{DY}{DY} \right)^{0.106} \right] \]
Results

- **Seasonal Prediction Model**

\[ N_{x,j} \], crashes per season \( j \) (winter, spring, summer, fall) and severity \( x \) (FI and PDO);

\[ AADT_{\text{min+maj}} \], sum of minor and major road AADT;

\[ S_{\text{min+maj}} \], sum of minor and major road posted speed limit;

\[ TL \], number of through lanes;

\[ LL \], number of exclusive left turn lanes;

\[ RL \], number of exclusive right turn lanes;

\[ P \], permissive signal control;

\[ PP \], protected/permissive signal control;

\[ SW \], annual accumulation of snowfall (in);

\[ DY \], days a year with snowfall > 1 (in);

\[ \beta \], inverse overdispersion (1/k);

\[ \beta_{0-10} \], model coefficients;

\[ \phi_j \], crashes per season \( j \) scale factor.

<table>
<thead>
<tr>
<th>Coeff.</th>
<th>FI</th>
<th>PDO</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td>7.246</td>
<td>7.627</td>
</tr>
<tr>
<td>( \phi_{\text{winter}} )</td>
<td>0.533</td>
<td>1.589</td>
</tr>
<tr>
<td>( \phi_{\text{spring}} )</td>
<td>0.483</td>
<td>1.147</td>
</tr>
<tr>
<td>( \phi_{\text{summer}} )</td>
<td>0.574</td>
<td>1.183</td>
</tr>
<tr>
<td>( \phi_{\text{fall}} )</td>
<td>0.525</td>
<td>1.268</td>
</tr>
</tbody>
</table>
Results

- Seasonal Model Prediction Assessment

seasonal variation as % of annual estimates

Fatal and Injury (FI)

Property Damage Only (PDO)

Seasonal Variation as % of Annual Estimates

- Model FI
- Rate FI
- Baseline

- Model PDO
Conclusions

- Seasonal Crash Prediction Signalized Intersections
- Jurisdiction Specific Model
  - Wisconsin Southeast Region
- Fatal and injury Crashes (FI)
  - Spring – Lowest Crash Prediction
  - Summer – Highest Crash Prediction
- Property Damage Only Crashes (PDO)
  - Winter – Reached Peak
  - Other Seasons – Below Average
Update for the Crash Database
Safety Overview

- What is transportation?
  - Safe and efficient movement of people and goods

- How do we define Safe? Safety?
  - “Freedom from danger”
  - “The state of being certain that adverse effects will not be caused by some agent under defined conditions”
  - “The reciprocal of safety is risk”
What is a crash?

- When is a crash reportable?
  - Per Wisconsin Statute 346.70(1), any crash within the State of Wisconsin must be reported when it results in:
    - Injury of a person
    - $1,000 or more damage to any person’s vehicle or property
    - Damage of $200 or more to state or other government-owned property other than a vehicle
Fatalities

- “Every law enforcement agency investigating... A traffic [crash] resulting in a death...is required to provide a report of the [crash] in an automated format to the department within 10 days after the date of the [crash]”
  - WI §§346.70(1) and (4)

- Reporting unborn children fatalities not required on crash report
Fatalities

- “Injuries should be classified on basis of conditions at scene of crash” (ANSI)
  - Exception is fatalities
    - If crash results in fatality within 30 days, injury severity should be changed to fatality.
## Fatalities

- WI Crash database fatality vs. FARS fatality

<table>
<thead>
<tr>
<th></th>
<th>Vehicles</th>
<th>Where Crashes Count</th>
<th>Where Crashes Don’t Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wisconsin DOT</strong></td>
<td>Crashes involving at least one motor vehicle apply. Crashes only involving snowmobiles, ATVs, UTVs, or off-highway motorcycles that were operated in an area they are legally allowed to operate do not require a crash report. Crashes only involving human-powered or animal-powered vehicles do not require a crash report.</td>
<td>Entire right-of-way of a public road, roads or trails in public parks open for any vehicular travel, public or private premises held out to the public for the use of motor vehicles, premises for motor vehicles provided to tenants in buildings of four or more units</td>
<td>Private parking areas at farms or single-family residences; on a road or route that snowmobiles, ATVs, UTVs, or off-highway motorcycles are allowed to use in a crash only involving those vehicles</td>
</tr>
<tr>
<td><strong>U.S. DOT (FARS)</strong></td>
<td>Crashes involving at least one motor vehicle apply, excluding devices used primarily within buildings such as fork lifts and baggage trucks, in addition to vehicles not designed primarily for transportation purposes such as machinery and army tanks.</td>
<td>any public or private land way open to the public, including the entire right-of-way or other boundaries; land ways within gated communities or military posts if guards customarily admit traffic; parking lot land ways used for circulation within parking lots</td>
<td>a land way where its entirety is under construction and traffic is prohibited from entering; parking lot stalls; parking lot aisles used primarily for access to parking lot stalls</td>
</tr>
</tbody>
</table>
DT4000 Vs MV4000

- MV4000

  - WisDOT MV4000 Instruction Manual
    - Primary training resource for WI officers
    - Last updated in 1998
    - Brief and vague concerning engineering fields
      - No baseline definition of when to flag hills or curves
      - Poor definition of traffic barrier
      - No discussion of roundabouts

Paper crash report backlogs in Texas. (GAO-10-454)
Self reporting crash report form
- When law enforcement does not file report

DT4002 reports submitted
- 2017: 12,240
- 2018: 13,163

DT4000 reports submitted
- 2017: 139,963
- 2018: 144,080
Crash reporting

When to report a crash

If law enforcement is called to the crash, then law enforcement may complete the report. If law enforcement does not file the report, you will need to complete the Wisconsin Driver Report of Crash DT4002.

Per Wisconsin Statute 346.70(1), any crash within the State of Wisconsin must be reported when it results in:
- Injury of a person
- $1,000 or more damage to any person’s vehicle or property
- Damage of $200 or more to state or other government-owned property other than a vehicle

If you received a letter from the Department of Transportation stating you were involved in a reportable crash and requesting you to complete a report, you must complete a crash report.

How to report a crash

Information you need before starting your crash report:
- Your Driver license number
- Vehicle Identification Number (VIN)
- Your Social security number
- Your Vehicle insurance information

If your vehicle was parked and unoccupied when the crash occurred, and you do not have information on the other driver or vehicle, please follow these instructions.

If you need assistance, please use this FAQ and definition document.

This service may not be available on Sundays from 6-9 a.m. due to regular system maintenance.

To start filling out a crash report, access the “Start Now” button below.

Please note, the crash form application will time out after 30 minutes of inactivity and you will lose your information. On average, a crash report will take no longer than 40 minutes to complete. If you think it will take longer, we suggest typing your narrative in a Word document or in Notepad to avoid timing out and losing your information.
## DT4002 - Wisconsin Driver Report of Crash

### UNIT 1 - Pedestrian

- **Operator Name:** Amanda Mae Mooney
- **Operator Address:** 123 Test Dr Madison, WI 53533
- **Driver License Number:** M000137864109
- **Issuing State:** Wisconsin
- **Operating Commercial Vehicle:** No
- **Gender:** Female
- **Date of Birth:** 09/21/1978
- **Daytime Phone Number:** 111-111-111
- **Owner Name:** Amanda Mae Mooney
- **Owner Address:** 123 Test Dr Madison, WI 53533
- **License Plate Number:** 155WYX
- **Issuing State:** Wisconsin
- **Make:** Hyundai
- **Year:** 2015
- **Color:** Silver/Luminium
- **Insuring Company:** Allstate
- **Policy Holder Name:** Amanda Mooney

### UNIT 2 - Automobile

- **Operator Name:** Joe Schmoe
- **Operator Address:** 123 Test Dr Madison, WI 53533
- **Driver License Number:** S3333333333
- **Issuing State:** Wisconsin
- **Operating Commercial Vehicle:** No
- **Gender:** Male
- **Date of Birth:** 01/01/2000
- **Daytime Phone Number:** 111-111-111
- **Owner Name:** Joe Schmoe
- **Owner Address:** 123 Test Dr Madison, WI 53533
- **License Plate Number:** 123ABCD
- **Issuing State:** Wisconsin
- **Make:** Toyota
- **Year:** 2014
- **Color:** Silver
- **Insuring Company:** Progressive
- **Policy Holder Name:** Joe Schmoe

### Injuries

- **Role:** Driver
- **Injured Name:** Amanda Mae Mooney
- **Gender:** Female
- **Date of Birth:** 09/21/1978

### Narrative

I certified, to the best of my knowledge, that the information on this report is true.

*Customer Signature:*

**Date/Time Submitted:** 02/27/2017 03:08 PM
Where does data Go

- Community Maps
- WisTransPortal
- SCM Tool
- Meta-Manager
- Etc
Crash Data Tools

- Resolve System
- Web Services
- Email Subscriptions
- Community Maps
- Predictive Analytics

Crash Database
- Timeliness
- Accuracy
- Completeness
- Consistency
- Accessibility
- Integration

Analysis
Community Maps

- Major upgrade rolled out in January 2018
  - Crash data imported on a nightly basis
  - Includes all reportable crashes
  - Map locations taken directly from crash report (TraCS / TLT)
- Public facing interface with basic crash information
- Password protected interface with additional detail and access to DT4000 crash reports
- Used extensively across Wisconsin at the county Traffic Safety Commissions
WisTransPortal

- Web based application to analyze:
  - Traffic Operations Data
  - Traffic Safety Data
Overview

- The TOPS Lab Crash Data Retrieval Facility is a convenient, web-based system for extracting Wisconsin Department of Transportation (WisDOT) DT4000 Crash Report Information.

- The facility provides information on all reported crashes in Wisconsin from 1994 to the present year. Information on the location of the crash, vehicles involved, and general crash attributes is available.

  - For crashes prior to 2017, a “legacy” data file translates DT4000 crash elements into equivalent MV4000 format.
Finding the Crash Data Retrieval Facility

- Go to the WisTransPortal home page
- url: http://transportal.cee.wisc.edu/
  - Click “Web Applications”
  - Click “DT4000 Crash Database Query Tools”
  - This will prompt you to enter your username and password
  - Select “Wisconsin Crash Data Analysis Tools”
WisTransPortal

The WisTransPortal System

This page provides access to WisTransPortal systems and data organized by category. Access level restrictions vary by application.

Safety Data

- **Wisconsin Crash Data Analysis Tools**
  Web-based query and analysis tools for Wisconsin police reported crash data and crash reports.

- **Community Maps—TSC Crash Mapping**
  Online crash map populated by county TSCs and local agencies. Based on Google Maps API.

Work Zones

- **WisLCS Wisconsin Lane Closure System**
  WisDOT lane and ramp closure request and acceptance system.

- **WisTMP Wisconsin TMP System**
  WisDOT Transportation Management Plan (TMP) routing and approval system.

Operations / Dispatch

- **TIA Traffic Incident Alert System**
  WSP / TMC traffic incident email alerts and media releases.

- **511 WRS Winter Roads System**
  WSP / TMC 511 winter road conditions reporting system.

- **InterCAD Traffic Incident Database**
  Web-based query and retrieval facility for archived InterCAD traffic incident data.

Winter Maintenance

- **Winter Storm Report System**
  County maintenance Winter Storm Report submission system.

- **RWIS Weather Station Database**
  Web-based query and retrieval facility for WisDOT Road Weather Information System data.

Traffic Data

- **V-SPOC Traffic Detector Database**
  Web-based query and retrieval facility for WisDOT ATMS and TRADAS traffic detector data.

- **Wisconsin Hourly Traffic Data Portal**
Crash Data Tools Homepage

Important links

- Help pages
- Contact Info

Can query crashes

OR

Specific crash reports if known
QUESTIONS?