Implementation and Evaluation of Weather Responsive Traffic Estimation and Prediction System

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Outline

- Background
- Overview of Traffic Estimation and Prediction System (TrEPS)
- Incorporating Weather In TrEPS
- Implementing and Evaluating WRTM Strategies using TrEPS Models
  - Study Networks
  - Off-line Calibration
  - On-line Implementation
  - Scenario Manager
- Demonstration of Benefits of WRTM Strategies
- Demonstration of Real-time TrEPS (DYNASMART-X)
Background

- Weather Impact on Traffic Safety and Operations
  - Low visibility
  - Slick pavement
  - Reduce road capacity, cause delay
  - Other hazardous conditions on roadways

- Weather Responsive Traffic Management (WRTM)
  - Forecasting weather in real-time for operational purposes
  - Sensing of traffic conditions
Traffic Estimation and Prediction System (TrEPS)

Weather-sensitive traffic operations model

**Estimation**: weather-sensitive traffic simulation-assignment model

**Prediction**: weather-sensitive traffic simulation-assignment model

Weather-responsive traffic management strategies

Weather data

- Weather monitoring systems
- Weather forecast
- Alert weather conditions
Incorporating Weather in TrEPS

- Capture Weather Effects in a DTA Model

- Main Objectives
  1. Assessing the **impacts of adverse weather on transportation networks**.
  2. Evaluating **effectiveness of weather-responsive traffic management (WRTM) strategies** in alleviating traffic congestion due to adverse weather conditions.
Objective 1

Model impacts of adverse weather on transportation networks

Weather Scenario Specification
- Rain intensity ($r$)
- Snow intensity ($s$)
- Visibility ($v$)

Supply-side Parameter Calibration

Weather Adjustment Factor (WAF)
- Free-flow speed,
- Saturation flow rate,
- Section capacity,
- etc.

Simulate Traffic Flow under Adverse Weather
The inclement weather impact on each of the supply-side parameter can be represented by a corresponding weather adjustment factor (WAF)

\[ F_i = \beta_0 + \beta_1 \cdot v + \beta_2 \cdot r + \beta_3 \cdot s + \beta_4 \cdot v \cdot r + \beta_5 \cdot v \cdot s \]

- \( F_i \): weather adjustment factor for parameter \( i \)
- \( v \): visibility
- \( r \): precipitation intensity of rain
- \( s \): precipitation intensity of snow
- \( \beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5 \): coefficients
**Objective 2**

Evaluate effectiveness of WRTM strategies

![Weather controlled variable speed limit sign (source: Lind, 2007)](image)

**TrEPS**

**DYNASMART**

**Traffic Advisory**

**Variable Message Sign**

- Speed reduction
- Optional detour
- Travel penalty (extra delay) warning

**Traffic Control**

- Variable Speed Limits via VMS
- Signal Control
- Ramp Metering

**Evaluate the effectiveness of advisory/control strategies**

![Graph showing travel time vs. departure time] (image)
Various WRTM Strategies

- **Advisory VMS**: Display weather information or warning on VMS
- **Mandatory VMS**: Display road closure information on VMS (e.g. snowplowing operations, flooded area, icy road)
- **Speed Management**: Adjust speed limits in response to prevailing weather conditions (Variable Speed Limit)
- **Signal Control**: Modify signal timing plans to improve traffic conditions under inclement weather
- **Ramp Metering**: Modify ramp metering timing plans in response to prevailing weather conditions
- **Demand Management**: Use demand management scheme to reduce the overall volume under adverse weather conditions (e.g. vehicle restriction, dynamic pricing)
Implement and Evaluate WRTM Strategies using TrEPS Models
General Approaches

1. Identify and select study networks
2. Calibrate and validate off-line and on-line TrEPS models
3. Identify existing or recommended weather-response traffic management (WRTM) strategies
4. Implement and evaluate WRTM strategies using TrEPS
Study Networks

Selected Networks for Study:
- Chicago
- New York
- Baltimore
- Virginia Beach
- Houston
- Irvine
- Salt Lake City
- Portland

Candidate networks for network selection:
- National Climatic Data Center, NOAA
Salt Lake City

- 2,250 zones
- 17,947 links
  - 16,293 arterials
  - 576 ramps
  - 136 highways
  - 791 freeways
  - 151 HOV lanes
- 8,309 nodes
  - 1,134 signalized intersections
- Demand horizon
  - 6am – 9am
- Simulation horizon
  - 6am – 10am
Long Island

- 1,431 zones
- 21,790 links
  - 17,942 arterials
  - 2,059 ramps
  - 31 highways
  - 1,588 freeways
  - 170 HOV lanes
- 9,402 nodes
  - 4,691 signalized intersections
- Demand horizon
  - 5am – 10am
- Simulation horizon
  - 5am – 11am
Chicago Study Networks

- **40443 links**
  - 144 links are tolled
  - 1400 freeways
  - 201 highways
  - 2120 ramps
  - (96 of them are metered)
  - 36722 arterials

- **13093 nodes**
  - 2155 signalized intersections

- **1961 zones**
  - 1944 internal
  - 17 external

- **Demand period**
  - 5am -10am hourly demand
  - 355 unique link counts
  - Observation Interval: 5 min
Irvine

- 626 links
  - 91 freeways
  - 99 ramps
  - 436 arterials
- 326 nodes
  - 70 signalized intersections
- 61 zones
- Demand period
  - 6 hours of AM period
  - 9 freeway and 6 HOV link counts are available
Off-line model calibration

- Supply-side parameters
  - Traffic flow model parameters
  - Weather Adjustment Factors (WAF)

- Demand-side parameters
  - Network building
  - Dynamic OD demand
On-line Implementation

- Approaches of Implementing and Evaluating WRTM Strategies
  - Three Components of TrEPS Framework
    - **WRTM Strategy Repository**: A set of available WRTM strategies defined for different weather categories
    - **Scenario Manager**: Interaction supporting tool which receives weather information, retrieve WRTM strategies and output necessary input files for TrEPS
    - **DYNASMART-X**: Real-time TrEPS model which interacts continuously with loop detectors, roadside sensors and vehicle probes, providing real-time predictions and estimates of traffic conditions
On-line Implementation

Implementation of WRTM Strategies

- Identify weather conditions.
- Retrieve available WRTM strategies.
- Simulate the effect of various scenarios using TrEPS.
- Integrate the knowledge from simulation outputs into deployment decision making.
Evaluation of WRTM Strategies

- Extract various performance measures from resulting traffic states.
- Evaluate benefits of WRTM strategies.
- Update or modify strategies.
Scenario Manager

- **Before the simulation**
  - Assist users in establishing the WRTM strategy repository, which defines different weather categories and specifies a set of strategies that could be evaluated for each weather category.

- **During the simulation**
  - Access to various sources of weather information including both the current observations and the future weather forecast and create a likely weather scenario in a software-specific format.
  - Retrieve a set of strategies for the current weather condition based on the pre-defined WRTM strategy repository and, for any selected strategy, prepare the corresponding input files in a software-specific format.

- **After the simulation**
  - Extract various performance measures from the simulation output (i.e., vehicle trajectory) to evaluate WRTM strategies. It could be used as a complementary tool to DYNASMART-X GUI, which provides real-time link performance measures.
  - Record the history of the implementation or what-if scenario experiments; and store the tested strategies in conjunction with the corresponding performance measures.
Sources of Weather Data

- **Historical data**
  - *Clarus* archive database (2009 - present)
  - ASOS stations

- **Current Observations**
  - *Clarus* system

- **Weather forecast**
  - National Weather Service hourly forecast

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### Clarus Initiative

A National Surface Transportation Weather Observing and Forecasting System

### Table: Observation Data

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*Clarus system*

Scenario Manager

Mode for Weather Responsive Traffic Management (WRTM)

Scenario Manager Main Window

WRTM mode
Scenario Manager

Steps for Scenario Generation

Step 1: Weather Event Specification

Select location and time horizons

Utilize historical weather data as base ingredients for constructing weather scenarios
Scenario Manager

Steps for Scenario Generation

Receive real-time weather information and find similar weather conditions from past data by automatic filtering.
Scenario Manager

Steps for Scenario Generation

Step 2: WRTM Strategy Specification

- Identified weather scenario
- Available WRTM strategies for the specified weather condition above
Scenario Manager

Steps for Scenario Generation

Step 3: Generate Scenario Files for DYNASMART-X
Steps for Scenario Generation

Post-process: Performance Measures

Extract various performance measures from vehicle trajectory for the evaluation

- Reliability measures (travel time distribution)
- Link performance (speed, density, flow rate)
- Link flow composition (OD pair proportions)
- etc.
Scenario Manager

Network Information (e.g., Chicago network)

Network Viewer

Synchronized with real-world network (by Google map)

Description for selected links
Demonstration of Benefits of WRTM Strategies

Evaluating effectiveness of VMS Strategies during adverse weather events using DYNASSMART
Salt Lake City

- 2,250 zones
- 17,947 links
  - 16,293 arterials
  - 576 ramps
  - 136 highways
  - 791 freeways
  - 151 HOV lanes
- 8,309 nodes
  - 1,134 signalized intersections
- Demand horizon
  - 6am – 9am
- Simulation horizon
  - 6am – 10am
Description of 4 Scenarios

2. Heavy Snow: Visibility ranges from 5 to 1.75 miles, snow intensity ranges from 0.06 to 0.15 inches per hour network-wide.
3. Heavy Snow with VMS – Detour: 50 % of vehicles are detoured from some heavily impacted links to alternative routes.
4. Heavy Snow with VMS – Variable Speed Limit: Speed reduction strategies are implemented on heavily impacted corridors.
Weather Scenario (Heavy Snow)

- **Visibility ranges:**
  - Max. 10 miles
  - Min. 0 miles

- **Snow intensity ranges:**
  - Light snow: < 0.05 inches/hour
  - Medium snow: 0.05 – 0.1 inches/hour
  - Heavy snow: > 0.1 inches/hour

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![Graph showing Visibility and Snow Intensity vs. Time](image-url)
Weather Impact

Clear Day

Heavy Snow
Management Strategies

VMS – Detour

VMS - VSL
Overview of the 4 Scenarios

- Clear Weather
- Heavy Snow
- Heavy Snow with VMS – Detour
- Heavy Snow with VMS – Variable Speed Limit
A Closer Look: Link Densities and Speeds
Scenarios

- Clear Day
- Heavy Snow
- VMS – Detour
- VMS - VSL
Long Island

- 1,431 zones
- 21,790 links
  - 17,942 arterials
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- 9,402 nodes
  - 4,691 signalized intersections
- Demand horizon
  - 5am – 10am
- Simulation horizon
  - 5am – 11am
Description of 3 Scenarios

1. **Clear Day**: Maximum visibility with zero precipitation.

2. **Heavy Snow**: Visibility ranges from 9 to 2 miles, snow intensity ranges from 0.03 to 0.16 inches per hour network-wide.

3. **Heavy Snow with VMS – Detour and Variable Speed Limit (VSL)**: 50% of vehicles are detoured from some heavily impacted links to alternative routes. Moreover, speed reduction strategies are implemented on freeway corridors.
Weather Scenario (Heavy Snow)

- Snow intensity ranges:
  - Light snow: < 0.05 inches/hour
  - Medium snow: 0.05 – 0.1 inches/hour
  - Heavy snow: > 0.1 inches/hour

- Visibility ranges:
  - Max. 10 miles
  - Min. 0 miles
Weather Impact:
Congestion Increase

Clear Day

Heavy Snow
A Combined Management Strategy

VMS – Detour

VMS - VSL
Overview – @ Minute 60

- Clear Weather
- Heavy Snow
- Heavy Snow with VMS – Detour & VSL
Overview – @ Minute 120

Clear Weather

Heavy Snow

Heavy Snow with VMS – Detour & VSL
Overview – @ Minute 180

Clear Weather

Heavy Snow

Heavy Snow with VMS – Detour & VSL
Overview – @ Minute 240

- Clear Weather
- Heavy Snow
- Heavy Snow with VMS – Detour & VSL
Overview—@ Minute 300

Clear Weather

Heavy Snow

Heavy Snow with VMS – Detour & VSL
Overview—@ Minute 360

Clear Weather

Heavy Snow

Heavy Snow with VMS – Detour & VSL
A Closer Look: Link Densities and Speeds
Chicago

- 40443 links
  - 144 links are tolled
  - 1400 freeways
  - 201 highways
  - 2120 ramps
  - (96 of them are metered)
  - 36722 arterials
- 13093 nodes
  - 2155 signalized intersections
- 1961 zones
  - 1944 internal
  - 17 external
- Demand period
  - 5am -10am hourly demand
  - 355 unique link counts
  - Observation Interval: 5 min
Description of 3 Scenarios

1. **Clear Day**: Maximum visibility with zero precipitation.

2. **Heavy Snow**: Visibility ranges from 2.5 to 0.5 miles, snow intensity ranges from 0.03 to 0.1 inches per hour network-wide.

3. **Heavy Snow with VMS – Variable Speed Limit (VSL)**: Speed reduction strategies are implemented on freeway corridors.
Weather Scenario (Heavy Snow)
Link from 14074 to 13899 (Density)

Clear

Snow

Snow + VSL
Link from 14074 to 13899 (Speed)

- Clear
- Snow
- Snow + VSL
Link from 14074 to 13899 (Queue)

- Clear
- Snow
- Snow + VSL
Link from 14074 to 13899 (Volume)

Clear

Snow

Snow + VSL
Demonstration of Real-time TrEPS (DYNASMART-X)

Long Island network
Welcome to Long Island in DYNASMART-X World
Thank you