Evaluating Operational Resiliency of a Highway Corridor, using a GIS-based Freight Network

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Freight transportation system is very important

In Wisconsin, it moves $300 billion in goods

Increased projection is another 70 percent by 2025

Major corridors carry most of the traffic.
  • Hudson to Beloit in WI (I90/94)

Any disruption to this system
  • Congestion
  • Economic impact
Events in Wisconsin

I-90/39 Snow Incident – February 2008

Midwest Flooding – June 2008
Resilience is the measure of how quickly and efficiently a system can recover from a disruption.

Freight transportation system resilience is defined as the ability for the system to absorb the consequences of disruptions, to reduce the impacts of disruptions, and maintain freight mobility.
The resiliency defined as performance with time.

Resiliency Triangle
Methodology

Development of a Statewide Resiliency Plan

- Identification
  - Identify and segment customers of the transportation system
  - Quantify the objectives of the resiliency plan

- Assessment
  - Develop the network inventory for the critical sections of the network.
  - Conduct a vulnerability assessment of the transportation network

- Implementation
  - Recommend the responding strategies in terms of traffic control and incident management.
  - Conduct a small scale simulation for a few customer groups

Vulnerability Assessment Overview

- Step 1: Identify Critical Assets
- Step 2: Assess Vulnerabilities
- Step 3: Assess Consequences
- Step 4: Identify Countermeasures
- Step 5: Estimate Countermeasures Cost
- Step 6: Operational Security Planning

* MIT Center for Transportation and Logistics, Caplice et al. 2008. Development of a statewide Freight System Resiliency Plan
* SAIC, 2002. A guide to Highway Vulnerability Assessment for Critical Asset Identification and
Freight Network Models

- Storing and representing flow of goods.
- Recognize the change in infrastructure.
- GIS freight network model**
  - Transportation links at fair detail, and nature of goods flowing
  - GeoMiler (Used for CFS 2007)
  - ESRI ArcGIS based custom modules for intermodal transportation policy analysis

** Goodchild et al 2008, Scott et al. 2007
Resiliency criteria

– Detours / alternate route distance should not exceed by more than 100% of the disrupted segment
– Detours/ alternate route travel time should not exceed by more than 100% of the disrupted segment flow
– Increased Traffic volumes on the alternate route does not exceed the capacity
– The LOS in the routes stay within the acceptable service level of D
Network Layers
- ORNL’s National Highway Network (NHN)
- WI State Highway Network (STN)

Mapping the STN onto NHN
- Merge the segment attributes using Spatial Matching
- Assign Mile Point based LRM to the Road.
ArcGIS Network Analyst® Extension
Building a robust network including custom evaluators:
  - Turn Costs
  - Hierarchy
  - One-Way Restrictions
  - Truck Routes
  - Time Delay Costs
The Network Dataset

The ArcMap® Illustration of Alternate Route Analysis

GIS map depicting the Network Analyst functionality used in finding multiple Alternate Routes for a disrupted segment (barrier) on I-94.
Model to obtain the alternate routes for O-D pairs along the Interstate Corridor

Python scripting is used for batch processing of the alternate routes. The script also processes for multiple segment disruptions—dis-contiguous or contiguous.
Alternate Routes

- Alternate routes around disruptions.
  - Network Dataset
  - Shortest Path Between Origin & Destination
  - Checking against resiliency criterion
  - Yen’s algorithm
  - Multiple Shortest Paths

- Scripting provided a lot of benefits!!
- There is more geoprocessing capable through ArcObjects
- Made use of VBA for accessing these functionalities.
- ArcGIS 10 integrated Python with more capabilities.
- FMEA (Failure Mode and Effect Analysis)
- Each corridor segment is assigned a RPN (Risk Priority Number) based on failure modes and disruption events.

- For bridges, Bridge Vulnerability Assessment procedure adopted from NYSDOT (1996)*

Vulnerability Assessment contd

• Three network components
  – Bridges
  – Culverts
  – Roadways

• FMEA for:
  Hydrologic
  – Scouring
  – Scouring due to Floods
  Overload
  – Traffic volumes
  – Functional classification of bridge
  Weather related
  – Snow/Ice accumulation
  – Snow Storms
  – Tornadoes
  – Severe winter storm

• The segment Risk rating (RPN) is averaged over the failure modes.
Vulnerability results

• RPN values calculated
• Scale of 1 – 10
  – 10 – high
  – 1 – low
Resiliency

- Resiliency Value = f(
  - Economic Value of Commodity flow,
  - Extra VMT due to detour,
  - Risk Priority Number)

- Top 10 High Risk Segments for policy planning.
- Identified the additional costs incurred by few commodity truck loads with disruptions between the Origin-Destination pairs.
Objectives

- Investigate use of the truck traffic data from American Truck Research Institute (ATRI) for evaluating freight resiliency.
- Use available truck AVL data from ATRI to analyze freight activity
- During the time periods of major weather events in Wisconsin, along I90/94 Corridor.
AVL Data Analysis

- Features along the Route
- Raw Truck GPS Data
- GIS Processing
- Assign AVL Data to Route
- Buffer Zones
- Segmented Truck Speeds
- Performance Measures Script
- Data Refining
February 2008 Winter Storm
Westbound Robustness

- Hudson-Eau Claire: 58 miles
- Eau Claire-Tomah: 76 miles
- Tomah-Mauston: 24 miles
- Mauston-Portage: 39 miles
- Portage-Madison: 22 miles
- Madison-Janesville: 41 miles
- Janesville-Beloit: 16 miles
- Beloit to Hudson Corridor

Robustness:
- Not Applicable
- High
- Moderate
- Low
THANK YOU!!

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