Risk Assessment of Hazardous Materials Transportation Routes

Ashrafur Rahman
PhD Candidate

Nicholas E. Lownes, Ph.D., P.E.
Associate Professor

Department of Civil and Environmental Engineering
University of Connecticut
An incident involving a vehicle carrying hazardous materials (Hazmat) cargo can produce undesirable short and long term consequences to human health and the environment, including severe illness, death, irreversible pollution, and in the worst case may require evacuation.
Hazmat Incident

- Hazmat incident is a ‘Low Probability High Consequence’ event

Hazmat Shipment

![Graph showing tons of hazmat shipped by mode (truck, rail, water, pipeline) for 2002 and 2007. The graph shows a significant increase in the total tons shipped over the years.]
Objectives

1. To formulate an improved measure of link risk

2. To Formulate and solve a hazardous materials flow model in robust and stochastic framework

3. To obtain a prohibition strategy support system by Network Vulnerability Analysis
Risk Assessment

Traditional Risk measure:

\[
Risk_{\text{on link } (i,j)} = \frac{\text{Accident } / \text{ Release Probability}}{\text{Consequence } / \text{ Population}}
\]

Risk Assessment Approach

- Identification of an appropriate spatial threshold for the risk associated with a hazmat release
- Accommodating spatial variability in risk measurement
- Selecting appropriate measure of risk
Spatial Threshold of Risk

**FIGURE** Circular impact area of a vehicle and the resulting fixed bandwidth impact area around a link. ¹

=0.5 mile to 5 miles

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**TABLE** Impact Area by Hazmat Class²

<table>
<thead>
<tr>
<th>Hazmat Class</th>
<th>Impact Area (mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosives</td>
<td>1.0</td>
</tr>
<tr>
<td>Flammable Gas</td>
<td>0.5</td>
</tr>
<tr>
<td>Poison Gas</td>
<td>5.0</td>
</tr>
<tr>
<td>Flammable/Combustible Liquid</td>
<td>0.5</td>
</tr>
<tr>
<td>Flammable Solid; Spontaneously Combustible; Dangerous when wet</td>
<td>0.5</td>
</tr>
<tr>
<td>Oxidizer/Organic Peroxide</td>
<td>0.5</td>
</tr>
<tr>
<td>Poisonous, not gas</td>
<td>5.0</td>
</tr>
<tr>
<td>Corrosive Material</td>
<td>0.5</td>
</tr>
</tbody>
</table>

(¹Batta and Chiu 1988)
(²US DOT 1996)
Spatial Variability of Risk

\[ \sqrt{- \frac{1}{b}} \]

Where
- \( b \) = distance of block centroid to link
- Selected impact area (buffer) size

Decay Functions

- No decay
- Linear
- Exp (dis)
- Circular
Risk Measure

Link Risk:

\[
\text{Link Risk} = \left( \frac{a}{t} \right)^{\frac{L}{C}}
\]

Where,

- \( a \) = release accident rate on the link
- \( t \) = travel time on the link (min)
- \( L \) = length of each link (mile)
- \( C \) = census blocks inside the impact area
- \( b \) = decay value of each block
- \( p \) = population in block
Application of the Risk Measure

Risk assessment for hazardous materials transportation routes

![Map of routes with bars for risk, population, travel time, and route length comparison](image)

**Current Route**
- Route 34
- I-95

**Proposed Route**
- Route 34
- I-95 & Route 10

**RESULTS**

<table>
<thead>
<tr>
<th>Routes</th>
<th>Risk</th>
<th>Traditional Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 34</td>
<td>148,025</td>
<td>142,209</td>
</tr>
<tr>
<td>I-95 &amp; Route 10</td>
<td>80,861</td>
<td>68,566</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Routes</th>
<th>Population</th>
<th>Travel Time (min)</th>
<th>Route Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 34</td>
<td>26,186</td>
<td>3.63</td>
<td>12,401</td>
</tr>
<tr>
<td>I-95 &amp; Route 10</td>
<td>17,187</td>
<td>5.08</td>
<td>19,542</td>
</tr>
<tr>
<td>Proposed Route</td>
<td>3.63</td>
<td>5.08</td>
<td>19,542</td>
</tr>
</tbody>
</table>
## Bi-Objective Hazmat Flow Model

**Data**

**Decision Variable**

**Bi-Objective Model**

<table>
<thead>
<tr>
<th>Travel time, and Risk, (or )</th>
</tr>
</thead>
</table>

### Hazmat flow on arc for each O-D pair:

<table>
<thead>
<tr>
<th>P1</th>
<th>( )</th>
<th>( )</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>( )</td>
<td>( )</td>
</tr>
<tr>
<td>s.t.</td>
<td>( )</td>
<td>( )</td>
</tr>
</tbody>
</table>

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**Regulator**

**Carrier**
Preliminary Research: Static Bi-Objective Routing Problem

**FIGURE** Sioux-Falls Network.

**FIGURE** Pareto-Efficient Routes.
Ongoing Research: Stochastic, Time-Varying Bi-Objective Hazmat Flow Problem

Motivation:

- Multi-criteria: multiple stakeholders
- Time Varying: network attributes
- Uncertainty: network attributes are unknown

(1) Chang, Nozick, and Turnquist 2005
Thanks!

Question?
arahman@engr.uconn.edu


