Frequency Analysis of Hazardous Material Transportation Incidents as a Function of Distance from Origin to Incident Location

Nir Keren, Ph.D.
Carlos Samuel, M.S.
Department of Agricultural and Biosystems Engineering
Iowa State University
Motivation

• More than 3.1 billion tons of HazMat shipped annually
• about 800,000 shipments per day
• Need to improve assessment of probability of HazMat transport incidents
• Understanding of “what is happening” between shipment origin and incident location
Methodology & Scope

Data:

- HMIRS
- Flammable-combustible materials
- 2,145 incidents
- 1995-2004
- Iowa, Texas, California, New Jersey, Illinois
The US Code of Federal Regulations (CFR) 171.15 requires that incidents will be reported for each of the following consequences:

Incident resulted with:

- fatality(is)
- injury required hospitalization
- general public evacuation was required
- closure of a major transportation artery or facility
- A release above threshold quantities
Data in HMIRS, among others, include the following seven variables:

- City of origin
- State of origin
- ZIP code of origin
- Route of incident
- City of incident
- State of incident; and
- County of incident.
The challenge: Obtaining distances between points of origin of shipment and incident locations

HMIRS lacks the information on routes of transportation

Alternative measure was needed to determine these distances.
Geocoding

• Geocoding is the process by which locations such as addresses and ZIP codes that are not in spatial format are placed as points on a map by Geographic Information System computer software similar to putting pins on a paper map.

• Data then can be analyzed for the purpose of distance mapping, using Haversine Formula for great circle
Figure 2: Obtaining great circle distances
Haversine Formula

\[ \Delta \sigma = \arctan \sqrt{\frac{[\cos \Phi_2 \sin \Delta(\lambda_2 - \lambda_1)]^2 + [\cos \Phi_1 \sin_2 \Phi - \sin \Phi_1 \cos \Phi_2 \cos(\lambda_2 - \lambda_1)]^2}{\sin \Phi_1 \sin \Phi_2 + \cos \Phi_1 \cos \Phi_2 \cos(\lambda_2 - \lambda_1)}} \]

- \( \lambda_1 \) and \( \lambda_2 \) are the longitudes of origin and incident location, respectively.
- \( \Phi_1 \) and \( \Phi_2 \) are the latitudes of origin and incident location, respectively.
- \( \Delta \sigma \) – Angular distance in radians.

\[ D = R \cdot \Delta \sigma \]
Frequency of incidents by Distance

Histogram

- Mean = 695.86
- Std. Dev. = 620.626
- N = 2,145
Frequency of incidents by log-distance

Histogram

$\mu \approx 659 \text{[miles]}$

$\mu \approx 15 \text{[miles]}$

Mean = 5.71914624
Std. Dev. = 1.79649036
N = 2,145
Analysis by States

• All five states demonstrated similar bi-modal patterns when analyzed separately
• Only CA have had an average distance significantly different than the other states
• Tamhane’s pair wise comparison provided that the bi-modal pattern is not a random result of the summation of data from the five states
Time Series

- Incident data in HMIS represents an accurate information source.
- Data may prove valuable for incident forecasting.
- An Autoregressive Integrated Moving Average (ARIMA) time series analysis was utilized for incident prediction.
- Trends depicting incident occurrences similar those in study will prove meaningful for future analysis.
Time Series

- The Box-Jenkins method can be used to develop stochastic-dynamic models, in which the behavior of the variable of primary interest is related not only to its past behavior, but to the behavior of other variables as well.
- Modeling with ARIMA/Box Jenkins is particularly useful when little knowledge is available on the underlying data-generating process.
Discussion

• Average distance for first mode:
  – 15 miles
  – Attributed to a high percentage of incidents occurring at short-haul distances of 161km (100 miles) or less
  – A possible explanation: a high level of flammable-combustible material handling in local/short haul carriers. This constant handling may lead to fatigue which in turn may lead to HazMat incidents.
  – Further examinations in order to provide insights and policy development
• Average distance for second mode:
  – 659 miles
  – For long-haul drivers, fatigue is an important safety issue because of the monotony of driving for many hours at a time.
  – 659 miles => 9 – 11 driving hours
  – Federal hours-of-service regulations suggest driving a maximum of 11 hours after a consecutive 10 hour rest period.
  – It is suggested that federal regulations be set around the limit of eight hours.
  – Further effort to assess the effectiveness of such a change
Discussion (cntd.)

• Probabilities extractions should be carefully done to address the bi-modal behavior demonstrated here.