Evaluation of Economic Impacts due to Disruptions in Freight

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Introduction

•Why is this topic important?



Decision Making

Economic Effects

Other possible reasons?





• Become acquainted with the topic

• Develop a framework

• Identify performance measures

• Sources for data retrieval



Framework





Direct Impacts

- Measured when a disruption first occurs
- Assuming we know the network...

– (Hu, 2008):

- $C_{vehicle} = Time loss * unit private operating cost * average speed$
- $C_{\text{transportation}} = C_{\text{vehicle}} * \%$ of commercial freight * Total # vehicles impacted
- American Trucking Association uses value of \$1.25 (1994) or \$2.90 per mile (2011)
- Freight Analysis Framework (FAF) provides percentages of commercial freight, by industry & region
- IHS Global Insight used for CMAP
- State DOTs provide information on AADT flows and adjustment factors



Direct Impacts

- Disruption Impact Estimating Tool Transportation (DIETT)
 - Developed by NCHRP (NCHRP
 - Uses direct costs and GIS information to assess TCPs.
 - Mountain passes, tunnels, and bridges (i.e. National Bridge Inventory Database from FHWA)





| N: | 1 | | T | h-10 | | | | | | | TRANSPORTATION | CHOKE POINT (TCP) PRIORITIZATI | ON SCENAF | RIOS |
|--------|----------------------------|------------------------------------|------------------------|---------------------|-------------|--|---|---------------------------------|--|--|------------------------|---|-----------|--------------|
| File | cion Impact E | stimating 100 | i - Transpor | cation | | | | | | | | Default Categories | Values | Instructions |
| 110 | | | | | | | | | | | | Average Tons of Cargo Per Truck | 15.00 | |
| State: | | Metropolis | | | Database: | e:\nextrans | s\diett\GeoDatabase | ATCP.mdb | | | | Average Tons of Cargo Per Rail Car | 65.00 | |
| Trusk | o Por Dou | 1000 | | | • | | | | | | | Average Tons of Cargo Per Barge | 1,000 | |
| HUCK | sreibay | | | | | | | | | | | \$/Ton/Mile - Truck | \$0.2620 | |
| Span | Length (m) | 20 | | | Records: | 4031 | Scoring Method | Ne: | xt Quit | | TRANSPORTATION IMPACT | \$/Ton/Mile - Rail | \$0.0226 | |
| | | | | | | | | | | | SCENARIO DEVELOPMENT | Traffic Volume on Detour - Truck | Low | |
| | Value (\$1000 | 1 Description | Boute | Material | Design | Detour | Traffid Span I | enatk TCP | Length Over 0 | n Bridge | | Traffic Volume on Detour - Rail | Med | |
| | \$120 | 37 miN HS | Carries: 0 | Prestressed c | Box Beam or | 4.0 | 12427 | 42.6 | 76.5 Highwau with/ Hi | abwau/Ped | | Transportation-related Cost of Delay (\$/Ton/Day) - | | |
| F- | \$27 | 7 07-I A-002-12 | Carries: SB | Concrete con | Box Beam or | 4.0 2.0 | 27092 | 42.0 22.3 | 46.9 Highway with/ Hi | ghway/Ped | | Barge | \$2.00 | |
| | \$1.692 | 2.6 MINUCT | Over I-20 I | M Concrete con | Tee Beam | 13.0 | 13341 | 23.8 | 86.6 Highway with/ Hi | ghwayn ou | | Cargo Losses / Day (% of Cargo Value) | 2.2% | |
| | \$2,293 | 3 1.3 MI.N.OF | 0ver: 1-85 1 | M Concrete con | Tee Beam | 13.0 | 36810 | 20.7 | 107.6 Highway with/ Hi | ghway | | Default Categories | Values | Instructions |
| | \$222 | 2 1.65 miE Jct | Over: US 60 | D Concrete con | Box Beam or | 1.0 | 102809 | 28.6 | 58.8 Highway with/ Hi | ghway/Ped | | % of Cargo High Value - Truck | 60% | |
| | \$359 | 0.9 MI W US | Over: I-10-I | M Concrete con | Tee Beam | 2.0 | 30590 | 29.3 | 106.7 Highway with / Hi | ahuau | | V of Oargo Mad. Value - Truck | 00% | |
| | \$274 | 5.3 MI E SR 5 | Over: I-10-I | M Concrete con | Tee Beam | 5.0 | 15969 | 20.7 | 54.6 Highway with | | | % of Cargo Med. Value - Truck | 30% | |
| | \$4,148 | 3 5 MI S CAFF | 0 ver: 1-20-1 | M Concrete con | Tee Beam | 23.0 | 30310 | 22.3 | 81.1 Highway with | | | % of Cargo Low Value - Truck | 10% | |
| | \$53 | 8 07-LA-010-27 | Carries: I-10 | Concrete | Tee Beam | 2.0 | 67698 | 23.5 | 24.7 Highway witi | | | 100%) | 100% | |
| | \$2,315 | 5 0.9 MI E MIS | Over: I-10-I | M Concrete con | Tee Beam | 18.0 | 23705 | 23.8 | 86.3 Highway with | | | 10078) 9(of Oceans High Malus - Deil | 000/ | |
| | \$86 | 6 07 LA-101-S | Carries: US | Concrete con | Tee Beam | 3.0 | 42098 | 20.4 | 52.1 Highway with/ Hi | ghway | 1 | % of Cargo High Value - Rall | 20% | |
| | \$146 | 6 07-LA-405-23 | Carries: 0 | Concrete con | Box Beam or | 2.0 | 93206 | 25.0 | 59.7 Highway with/ Hi | ghway/Ped | | % of Cargo Med. Value - Rail | 50% | |
| | \$224 | 6 MI N JCT 16 | 0 ver: 1-65 1 | M Concrete con | Tee Beam | 2.0 | 17715 | 20.7 | 75.3 Highway with/ Hi | ghway | | % of Cargo Low Value - Rail | 30% | |
| | \$121 | 3MLS JCT 15 | 0 ver: 1-59 1 | M Concrete con | Tee Beam | 2.0 | 7512 | 22.3 | 80.8 Highway with/ Hi | ghway | | % of Cargo Total Value - Poil (Should Equal 100%) | 100% | |
| - | \$1,885 | 3.7 MI.N.UF | Uver: 1-65-1 | M Concrete con | Tee Beam | 23.0 | 13825 | 22.3 | 80.8 Highway with/ Hi | ghway | DIRECT ECONOMIC IMPACT | % of Cargo Total Value - Kall (Should Equal 100%) | 100% | |
| - | \$2,483 | B 6.1 MI.N.UF | Uver: 1-65 1 | M Concrete con | Tee Beam | 23.0 | 13825 | 29.3 | 106.7 Highway with/ Hi | ghway | SCENARIO DEVELOPMENT | % of Cargo High Value - Barge | 5% | |
| - | \$453 | JULIUSII& | Uver: 1-59 r | M Loncrete con - | lee Beam | 5.0 | 8227 | 32.0 | TT6.7 Highway with7 Hi | gnway 🗾 | | % of Cargo Med. Value - Barge | 25% | |
| | | | | | | | | | | Þ | | % of Cargo Low Value - Barge | 70% | |
| | | | | | | | | | | % of Cargo Total Value - Barge (Should Equal 100%) | 100% | | | |
| | <u>oner manueu</u> | <u></u> | | | | | | | | | | Alternate Route Reliability - Truck | 95% | |
| | 1. Select ' | State" * | D DU | | | 5. Click on "So | coring Method" to se | parameters | NU 1 | | | Alternate Route Reliability - Rail | 99% | |
| | 2. Select o 3. Select o | iesired Tručks lesired "Span Li | -er Day enoth (m)'' | | | Prioritize or When done | r desired category - " e press "Next" - This | vaiue (\$1000) akes vou into |) is recommended the spread sheet model | | | Inventory Cost: % of Cargo/Year | 18% | |

- 3. Select desired "Span Length (m)"
- 4. Repeat steps 2 3 until the record count equals approximately 500

* NOTE - Only Fredonia is active. Some calculations may take several minutes

8. If you desire to do another run, restart the DIETT application

| | | | TCP CH | | RESULTS | | | | | | |
|------------------|---|-------|--------|-----------------|-------------|------------|---------------|------------|----------|-------------|------------|
| | | | | TCP Identifiers | Total Costs | | I/Disruption | Total Cost | Economic | | |
| | | | | | | | Transportatic | | | | |
| | # | | | | | Span | n | | rotal | As a % of | Costs As |
| | | Туре | Name | No./Code | Material | Length (m) | | | | Cargo Value | % of Total |
| | | | | | | | | | | | |
| | 1 | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF: | #REF! | #REF! | #REF! |
| ΡΠΟ | 2 | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! |
| IUN | 3 | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! |
| | 4 | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! |
| U Ν Ι V Ε | 5 | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! |

Indirect Impacts

• The consequences of direct impacts





Indirect Impacts

- Economic
 - Input/Output (I/O) Model
 - Computable General Equilibrium (CGE) model
- Societal
 - Safety & Security
 - Environmental



Input / Output Model

 Use matrices to predict the flow of goods and services between different sectors

Hypothetical Transactions Table

Industry Purchasing

| | | Pro | cess | ing | Sect | or | | | | Final Deman | d | | |
|--------------|-------------------------------------|-----|------|-----|------|-----|-----|--|------------------------------|-------------------|-------------------------------------|------------|---------------------|
| | Outputs ¹ | (1) | (2) | (3) | (4) | (5) | (6) | (7) Gross inventory accumula- | (8) Exports to foreign | (9) Government | (10) Gross private capital | (11) | (12) Total Gross |
| 10 | + | A | В | C | D | E | F | tion (+) | countries | purchases | formation | Households | Output |
| ec | (1) Industry A | 10 | 15 | 1 | 2 | 5 | 6 | 2 | 5 | 1 | 3 | 14 | 64 |
| 00 | (2) Industry B | 5 | 4 | 7 | 1 | 3 | 8 | 1 | 6 | 3 | 4 | 17 | 59 |
| in | (3) Industry C | 7 | 2 | 8 | 1 | 5 | 3 | 2 | 3 | 1 | 3 | 5 | 40 |
| ess | (4) Industry D | 11 | 1 | 2 | 8 | 6 | 4 | 0 | 0 | 1 | 2 | 4 | 39 |
| nc | (5) Industry E | 4 | 0 | 1 | 14 | 3 | 2 | 1 | 2 | 1 | 3 | 9 | 40 |
| Pr | (6) Industry F | 2 | 6 | 7 | 6 | 2 | 6 | 2 | 4 | 2 | 1 | 8 | 46 |
| try Pr | (7) Gross inventory depletion () | 1 | 2 | 1 | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 8 |
| sec | (8) Imports | 2 | 1 | 3 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 2 | 13 |
| Ind nents | (9) Payments to government | 2 | 3 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 2 | 12 | 32 |
| Payn | allowances | 1 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| | (12) Total Gross | 19 | 23 | - | 5 | 9 | 12 | 1 | 0 | 8 | 0 | 1 | 85 |
| | Outlays | 64 | 59 | 40 | 39 | 40 | 46 | 12 | 23 | 18 | 18 | 72 | 431 |

¹Sales to industries and sectors along the top of the table from the industry listed in each row at the left of the table. ²Purchases from industries and sectors at the left of the table by the industry listed at the top of each column.



Input / Output Model

Software and databases such as <u>RIMSII, IMPLAN, and REMI</u>

| Detailed industry code and title | Related 2002 NAICS Codes | |
|--|---------------------------------------|-------------|
| AGRICULTURE, FORESTRY, FISHING AND HUNTING | | |
| 1110 Crop production | | |
| 1111C0 Oilseed and grain farming | 11111-2, 11113-6, 11119 | |
| 111200 Vegetable and melon farming | 1112 | |
| 1113B0 Fruit and nut farming | 11131-2,111331-4, 111335-6, 111339 | |
| 111400 Greenhouse, nursery, and floriculture production | 1114 | 1 |
| 111910 Tobacco farming | 11191 | 1 |
| 111920 Cotton farming | 11192 | 1 |
| 1119C0 All other crop farming, including sugarcane and sugar beet farming | 11193-4, 111991-2, 111998 | 1 1 1 |
| 1120 Animal production | | 1 |
| 1121A0 Cattle ranching and farming | 11211, 11213 | 1 |
| 112120 Dairy cattle and milk production | 11212 | 1 |
| 112A00 Animal production, except cattle and poultry and eggs | 1122, 1124-5, 1129 | 2 |
| 112300 Poultry and egg production | 1123 | 22 |
| 1130 Forestry and logging | | 2 |
| 113A00 Forest nurseries, forest products, and timber tracts | 1131-2 | 2 |
| 113300 Logging | 1133 | 2 |
| 1140 Fishing, hunting and trapping | | 2 |
| 114100 Fishing | 1141 | |
| 114200 Hunting and trapping | 1142 | 3 |
| 1150 Support activities for agriculture and forestry | | 3 |
| 115000 Support activities for agriculture and forestry | 115 | 3 |
| MINING | | 3 |

| | 1.0100 | 1.0200 | 1.0301 | 1.0302 |
|--|---|--|--|--|
| 1 | 1.5957 0 .0001 .0033 .0429 .1780 .0001 .0089 .0091 | 1.2644 0 .0003 .0014 .0296 .5404 .0001 .0081 .0194 | 1.9012 0 .0003 .0031 .0461 .1867 .0001 .0098 .0092 | 1.3775 0 .0001 .0003 .0022 .0331 .3033 .0001 .0081 .0084 |
| 11 | .0227 .0723 .0114 .0026 .0043 .0093 .0092 .0060 .0165 | .0212 .0712 .0177 .0020 .0021 .0030 .0063 .0057 .0041 .0140 | .0246 .0664 .0124 .0027 .0031 .0043 .0083 .0108 .0108 .0108 | .0204 .0551 .0173 .0022 .0037 .0067 .0111 .0067 .0158 |
| 21 22 24 25 26 27 28 29 30 | .0009 .0020 .013 .1188 .0377 .0535 .1481 .0793 .0646 .0514 | .0008 .0019 .0012 .1041 .0325 .0499 .1112 .0688 .0459 .0382 | .0010 .0023 .0015 .1130 .0417 .0463 .1443 .0868 .0706 .0643 | .0008 .0019 .0012 .1004 .0339 .0506 .1157 .0716 .0510 .0463 |
| 31 32 33 34 35 36 37 38 | .2017 .0146 .0137 .0743 .0419 .0752 .0664 .7000 | .1341 .0133 .0120 .0608 .0362 .0730 .0574 .6145 | .2417 .0159 .0150 .0816 .0462 .0914 .0712 .7745 | .1609 .0129 .0126 .0690 .0377 .0714 .0594 .6384 |

RIMSII provides tables for final demand, employment, output, earnings



(BEA, 2011)

Computable General Equilibrium (CGE) Model

- S.A.M a matrix representation of the national accounts for a given country
- Constraints are used to relate economic principles
- Non-linear



Allow for input substitution



Computable General Equilibrium (CGE) Model

- •Predominant model for estimating
- •World Bank, IMF
- •GTAP at Purdue (GTAP.org) IMPLAN

(CIRDAP, 1998)



13

Resiliency

- Resiliency is defined as the ability to rapidly restore service after a disruption. (WSDOT, 2009).
- Encompasses direct and indirect impacts.
- Many states have instituted resiliency plans.
- Proper planning has been shown to reduce congestion and mitigate disruptions.(Cambridge, 2007).





Environmental

• In the form of noise, disturbance of wildlife, releasing of pollutants

• EPA is the primary source of models in US for regulatory purposes

 Current model – Motor Vehicle Emission Simulator (MOVES)



Environmental



- MOVES
 - Estimates based on sec by sec vehicle performance characteristics
 - Estimate emissions at national level down to individual transportation projects
 - Output in a variety of units
 - Inputs include time of day, time span, geographic bounds, and road types



Environmental

How to place a monetary value on emissions

- (NHTSA, 2011) uses \$21/ton
 - \approx \$0.20 / gal of gas

| Table 3.4.3-1 Social Cost of CO ₂ , 2010 – 2050 (in 2008 dollars per metric ton) | | | | | | | | | |
|--|------------|------------|--------------|--------------------------------|--|--|--|--|--|
| | | | | | | | | | |
| Year | 5% Average | 3% Average | 2.5% Average | 3% 95 th percentile | | | | | |
| 2010 | \$4.80 | \$21.85 | \$35.84 | \$66.26 | | | | | |
| 2015 | \$5.82 | \$24.30 | \$39.21 | \$74.33 | | | | | |
| 2020 | \$6.94 | \$26.85 | \$42.58 | \$82.39 | | | | | |
| 2025 | \$8.37 | \$30.22 | \$46.86 | \$92.30 | | | | | |
| 2030 | \$9.90 | \$33.49 | \$51.05 | \$102.10 | | | | | |
| 2035 | \$11.44 | \$36.76 | \$55.34 | \$112.00 | | | | | |
| 2040 | \$12.97 | \$40.02 | \$59.63 | \$121.81 | | | | | |
| 2045 | \$14.50 | \$42.98 | \$62.28 | \$130.48 | | | | | |
| 2050 | \$16.03 | \$45.84 | \$66.37 | \$139.06 | | | | | |
| Stock Price in Dollars | | | | | | | | | |
| ³⁵ (NHTSA, 2011) | | | | | | | | | |

 Let the markets decide!





 Safety refers to the ability for users of the system to reach their destination safely

 Quantified by the monetary value of damage to vehicles or operators

• Like environmental, very subjective



- How to measure
 - (Liu, 2003) gives a hint
 - Hangzhou-Ningbo Expressway in China
 - -2 to 4 lanes
 - Comparing a normal route to a detour

$$\mathbf{P}_{a} + \mathbf{P}_{b} + \mathbf{P}_{c} + \mathbf{P}_{d} = \mathbf{P}_{total}$$





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Safety & Security

- Available data
 - Indiana uses ARIES
 - HSIS covers CA, IL, ME, NC, MN, OH, UT, WA
 - Crash details such as road name, vehicle make, milepost
- Cost of life
 - US DOT recommended \$5.8 mil (2007)



ARIES: Fatal and injury collisions involving large trucks, 2009.



(ICJI, 2010)





- Security: Risk assessment associated with an accident
 - Process of evaluating potential consequences from events and their probabilities (CCPS, 1995)
- Relevance
 - Hazardous chemicals
 - Terrorist attacks
 - Natural disasters



- How to quantify risk
 - Definition of events
 - i.e. Types of chemicals (Egidi, 1995)
 - Estimate of the magnitude (consequences)
 - Impact area, population density
 - -P(x) or frequency of occurrence
 - Department of Transportation (DOT) Hazardous Materials Information System (HMIS) database,
 - The National Weather Service
 - USGS.gov



Putting It All Together Borman Corridor



(Google, 2011)

- •Lake County, IN
- •16 miles long
- •Alternate route from toll roads

Exit list

| County | Location | Mile ^[12] | Exit | Destinations | Notes | | | | |
|--------|--|----------------------|----------|---|---|--|--|--|--|
| Lake | Hammond | 0.00 | | 🤯 I-94 west – Chicago | Illinois state line | | | | |
| | | 0.87 | 1 | US 41 north (Calumet Avenue) – Hammond, Munster | Western end of US 41 concurrency | | | | |
| | | 2.39 | 2 | US 41 south / SR 152 north (Indianapolis Boulevard) – Hammond, Highland | Eastern end of US 41 concurrency; serves Purdue University Calumet | | | | |
| | | 3.35 | 3 | Kennedy Avenue | Serves Visitors' Center | | | | |
| | Gary | 4.92 | 5 | SR 912 (Cline Avenue) – East Chicago, Griffith | Serves Gary/Chicago International Airport | | | | |
| | | 6.44 | 6 | Burr Street | | | | | |
| | | 8.96 | 9 | Grant Street | | | | | |
| | | 9.92 | 10 | 53 SR 53 (Broadway) | Serves Indiana University Northwest | | | | |
| | | 11.01– 11.80 | 11 12 | 65 (0) I-65 to Ind. Toll Rd. − Indianapolis | Signed as exits 11 (south) and 12 (north) eastbound and exits 12A (south) and 12B (north) westbound; freeway narrows from 4 to 3 lanes | | | | |
| | Lake Station | 12.68 | 13 | Central Avenue | Eastbound exit and westbound entrance, which is temporarily closed due to construction | | | | |
| | | 15.00 | 15 | (Ripley Street) | Eastern end of US 6 concurrency; signed as exits 15A (south/east) and 15B (north); westbound exit 15B is part of exit 16 | | | | |
| | | 15.51 | 16 | 🤯 🕖 I-94 east / I-80 east / I-90 / Ind. Toll Rd. | Eastern end of I-80 concurrency; eastern terminus of Borman Expressway | | | | |
| | Road continues east as Interstate 94 | | | | | | | | |
| | 1.000 mi = 1.609 km; 1.000 km = 0.621 mi Concurrency terminus • 🗌 Closed • 🔄 Incomplete access • 🔛 Unopened | | | | | | | | |



Putting It All Together Borman Corridor

- Step 1: Develop a network/Direct Impacts
 - Use FAF, GIS, Census data
 - Shortest path, agent-based?
- Step 2: Economic Impacts
 - Purchase multipliers from RIMSII
 - Purchase SAMs from GTAP
- Step 3: Environmental
 - MOVES
- Step 4: Safety & Security
 - Purchase data from ARIES, HSIS.
 - USGS.gov, HMIS





Putting It All Together Borman <u>Corridor</u>

| Туре | Description | Estimated Cost |
|--------|---|--------------------------|
| FAF | Commodity Flows | Free |
| RIMSII | 62 industries * \$75 | \$4,650 |
| CGE | GTAP:This package includes GTAPAgg, FlexAgg, an abridged version of the GTAP Data Base Documentation, and a GTAPAgg license to allow unlimited aggregations. | \$1,035 |
| MOVES | Emissions Modeling | Downloadable - Free |
| ARIES | Crash Information - Indiana | Permission Needed - Free |
| HSIS | Crash Information - Illinois | Permission Needed - Free |
| | Total | \$5,685 |





• Developed a framework

 Related GDP, output, employment, final demand, emissions, safety, and security

• Identified useful sources



Summary

| Source Summary | | | | | | | |
|----------------|--------------------------------|---|--|--|--|--|--|
| Category | Division | Site | Link | | | | |
| | I/O | RIMSII IMPLAN REMI | BEA.GOV IMPLAN.COMREMI.COM | | | | |
| Economic | CGE | GTAP IMPLAN REMI | GTAP.ORG IMPLAN.COM REMI.COM | | | | |
| | Environmental | MOVES NHTSA | EPA.GOV/OTAQ/MODELS/MOVES NHTSA.GOV | | | | |
| Societal | Safety & Security | HSIS US Geological Survey Hazardous Materials Info System | HSISINFO.ORG USGS.GOV BTS.GOV (KEYWORD:HMIS) | | | | |
| Misc. | Resiliency Freight Database | Resiliency Freight Analysis Framework | (ROSE, 2005,2009) HTTP://WWW.OPS.FHWA.DOT.GOV/FREI GHT/FREIGHT_ANALYSIS/FAF/ | | | | |
| Us | seful Links | Federal Highway Administration Resource and Innovative Technology Administration | HTTP://WWW.FHWA.DOT.GOV/ HTTP://WWW.RITA.DOT.GOV/ | | | | |



Difficulties

No \$ / No respect

• Lack of experience

• Broad topic

• Lots of A.C.R.O.N.Y.M.S.



Thank you!

NEXTRANS

• Prof. Ukkusuri

• Prof. Ukkusuri's Research Group



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