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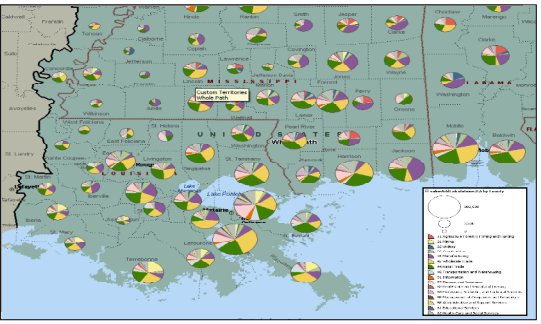

The Regional Economic Accounting Tool: Updates and Extensions

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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National Infrastructure Simulation & Analysis Center

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- Patriot Act [PL107-56] identified NISAC as the center for Critical Infrastructure Interdependency Modeling, Simulation, and Analysis
- Provide a common, comprehensive view of U.S. infrastructure, its response to disruptions, and impacts
- Operationally-tested rapid-response capability
  - 24/7 crisis action analysis
  - Jointly executed by Sandia and Los Alamos National Laboratories
- Types of analyses:
  - Hurricanes
  - Earthquakes
  - Other acute event analyses

NISAC

Los Alamos

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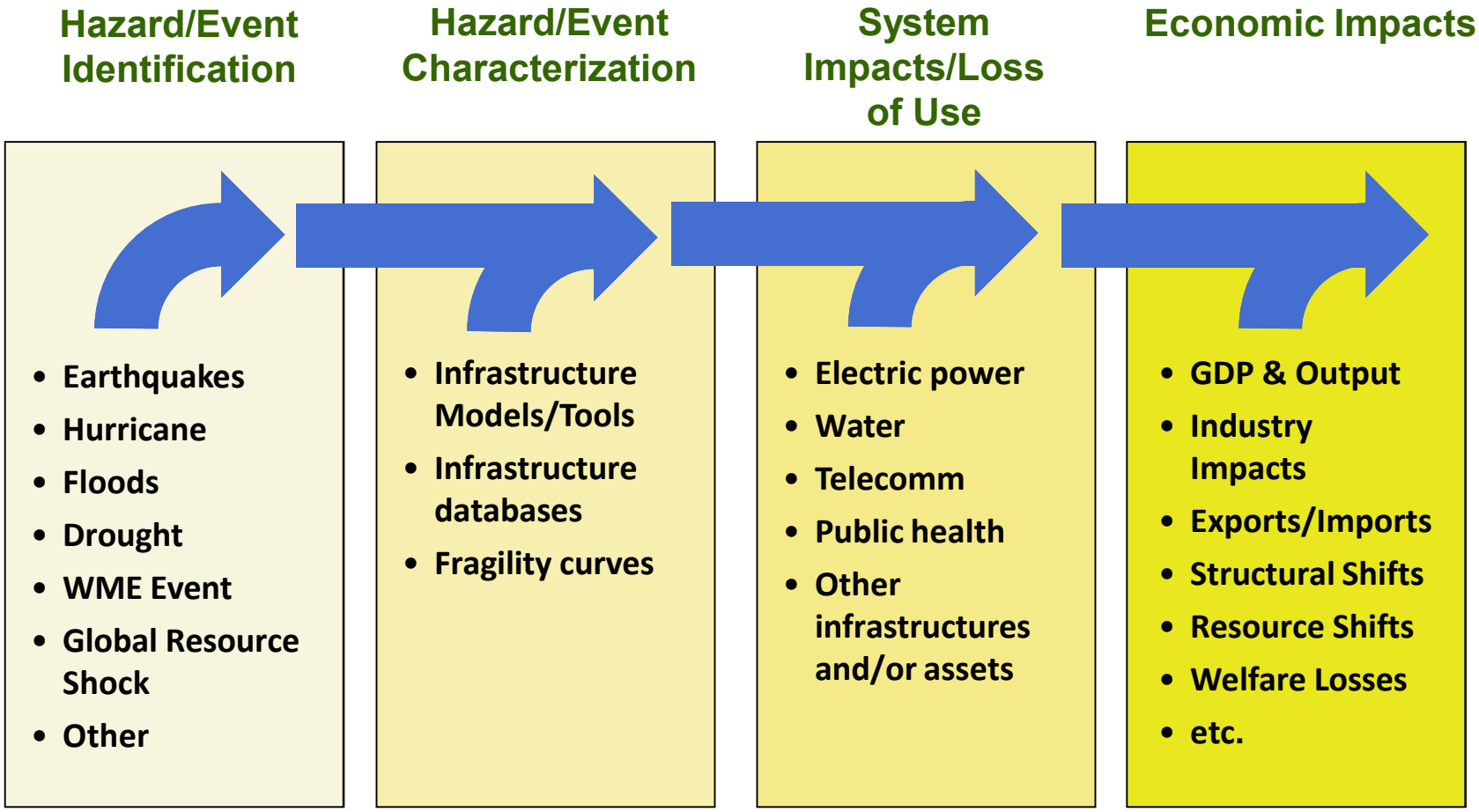
Economic Analysis Approach



Economic impacts driven by size and composition of affected economy and duration of event

The Regional Economic Accounting Tool

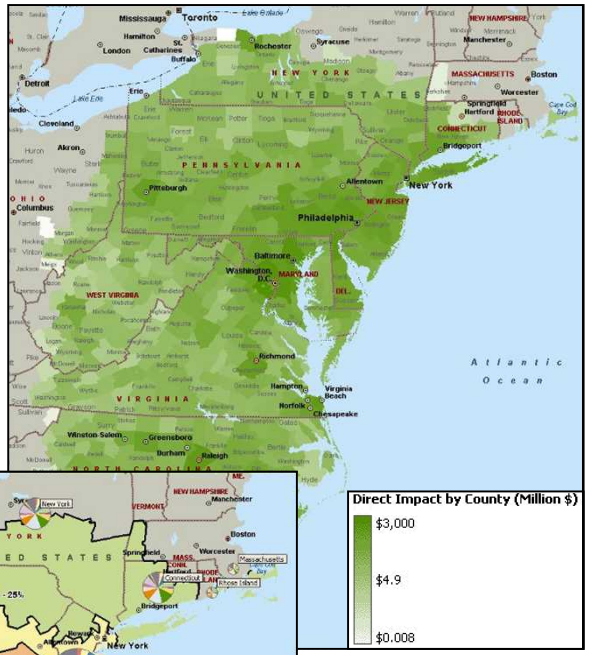
- REAcct was developed to be a simple tool to rapidly provide order-of-magnitude estimates of the potential severity of an event

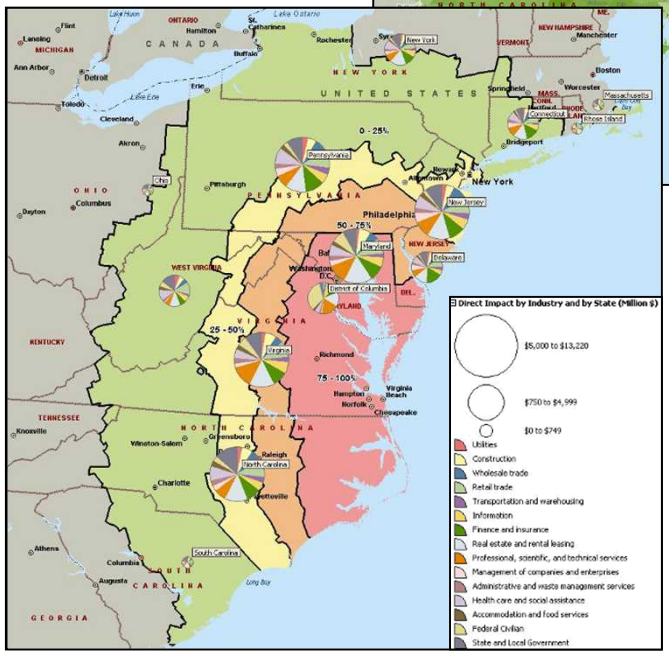
- Advantages of REAcct:
  - Provides approximate estimates quickly
  - Relatively easy to use, thereby reduces cost
  - Based on input-output (I-O) methodology
  - Uses the Geographic Information System (GIS) to provide regional detail

- Expressed as changes to GDP due to short-term (less than one year) business interruptions

- Does not consider property damage, contamination, or offsets

Distribution of direct gross domestic product (GDP) reductions by county





Distribution of economic impact by state and industry in the storm path

The REAcct Tool: Exercise Support and Real Events

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- REAcct is unique in that it can quickly provide impact-zone estimates of acute disruptive events
- REAcct has already provided estimates for actual and hypothetical events
  - Exercise Support
    - TOPOFF IV (Week of 10/15/07; first formal call for 24/7 response)
    - Pre-Season Hurricane Swath Analysis (Spring of 2007)
  - Real Events
    - Nearly Every Hurricane (Starting Hurricane Season of 2005)
    - Minnesota Pipeline Explosion (11/29/07)
    - California Wildifres (Week of 10/23/07)
    - Deepwater Horizon (Week of 4/22/2010 through Summer of 2010)

Calculation of Direct and Indirect Losses

- Direct losses to industry *i* in region *r*:

$$DL_{ir} = \frac{Y_i^{US}}{365 * E_i^{US}} * E_i^r * d_r$$

- Total direct losses:

$$DL = \sum_{r=1}^{R} \sum_{i=1}^{I} \frac{Y_i^{US}}{365 * E_i^{US}} * E_i^r * d_{ir}$$

- Total losses to industry *i* in region *r*:

$$TL_{ir} = \frac{Y_i^{US}}{365 * E_i^{US}} * E_i^r * d_i^r * m_i$$

- Total losses from the scenario:

$$TL = \sum_{r=1}^{R} \sum_{i=1}^{I} \frac{Y_i^{US}}{365 * E_i^{US}} * E_i^r * d_{ir} * m_i$$

Data Sources and Enhancements

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- Data Sources
  - US Census Bureau
    - County Business Patterns – Employment by county and NAICS
  - Bureau of Economic Analysis (BEA)
    - U.S. Value Added per industry
    - U.S. Employment per industry
    - RIMS II
- Enhancements
  - **Temporal resolution** – reduce annual smoothing, more current data
  - **Industry interdependencies** – elaboration of industry relationships and possible vulnerabilities to better inform policymakers

Temporal resolution

- Use quarterly data to account for:
  - Seasonal factors
  - Quarter-specific economic conditions or events (historical)
  - More current data
- Adjusted formulation:

$$DL_{irq} = \frac{Y_{iq}^{US}/4}{T_q * E_{iq}^{US}} * E_{iq}^{r} * d_{ir}$$

  - T_q : Days in quarter q
- Tradeoff due to loss of industry sectors: BEA only reports quarterly value-added at the 2-digit NAICS level
  - Number of REAcct industries decreases from 39 to 22
  - Loss in resolution of specific Manufacturing industries
- Data
  - BLS Monthly Employment by Industry (average by quarter)
  - BEA Quarterly Value Added by Industry (seasonally adjusted)

Inoperability Input-Output Matrix

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- Indirect impacts (calculated w/ RIMS II multipliers) in REAcct yield estimates of upstream losses from reduced demand for intermediate inputs by directly affected sectors
- Basic multipliers do not identify the specific sectors which are indirectly affected
- The IIM provides a quick method to identify the sector interdependencies which theoretically comprise the indirect economic impacts

Inoperability Input-Output Matrix

- Basic IO model

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{c} \Leftrightarrow \left\{ x_i = \sum_j a_{ij} x_j + c_i \right\} \forall\, i,$$

Where a_{ij} represents proportion of sector j's output that is consumed by sector i as an intermediate good. c_i represents the final demand for sector i's production. x_i, x_j represent the total output of sector i and j respectively.The technical coefficient matrix, $\boldsymbol{A}$, captures the linear proportionality of all the sectors in equilibrium

Let $\hat{\boldsymbol{x}}$ be a vector of each industry's expected production**.** The demand side interdependency matrix is found as

$$\boldsymbol{A}^* = \mathrm{diag}(\hat{\boldsymbol{x}})^{-1} \boldsymbol{A}^* \mathrm{diag}(\hat{\boldsymbol{x}})$$

The interdependency matrix, $\mathbf{A}^*$, represents the interdependencies between industry sectors, and forms the basis for the calculating interindustry inoperability (Santos & Haimes, 2004).

$$q = \boldsymbol{A}^* q + c$$

c is the normalized loss of output vector:

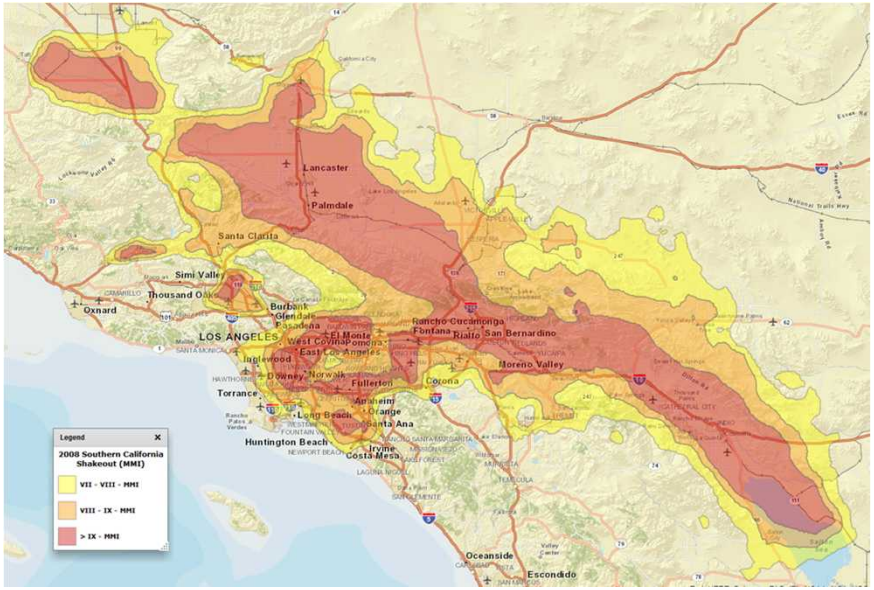
$$c = \frac{x_{REAcct}}{\hat{\boldsymbol{x}}}$$

And then solve for q, the interdependency vector:

$$q = (I - A^*)c$$

Example Scenario: Southern California Earthquake

- Hypothetical earthquake in Southern California near Los Angeles with no specified time of year
- Estimates were derived from assumptions regarding ground shaking and intensity measures and progress of electric power restoration and clean-up
- The center of the earthquake tracks from Lancaster down to Baja California and west toward Los Angeles
- Densely populated urban areas included in the affected region



Results: Baseline REAcct Output

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Total GDP reduction by State

State	Direct ($billion)	Total ($billion)
California	$19.12	$6.08

Total GDP reduction by industry for selected industries

Industry Sector	Total GDP Reduction ($billion)
Real estate and rental leasing	$6.08
Information	$4.86
Health care and social assistance	$3.97
Professional, scientific, and technical services	$3.96
Wholesale trade	$3.53
Government (federal and local)	$3.22
Finance and insurance	$3.02
Retail trade	$2.57
Construction	$1.70
Administrative and waste management services	$6.08
Total	$34.59

Distribution of direct GDP reduction by county

Results: Supplemental Analysis, IIM Output

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Industry	Direct Loss ($billion, 2013)	IIM ($billion, 2013)	Direct + IIM (% of Direct)
Wood Products	$0.011	$0.034	421%
Primary Metals	$0.041	$0.066	259%
Nonmetallic Mineral Products	$0.026	$0.040	255%
Printing and Related Support Activities	$0.047	$0.068	243%
Mining	$0.128	$0.175	236%
Paper Products	$0.036	$0.035	197%
Textile Mills and Textile Product Mills	$0.028	$0.027	194%
Electrical Equipment, Appliances, and Components	$0.050	$0.042	183%

Results: Quarterly REAcct Output

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- Quarters 3 and 4 are most appropriate scenario comparisons

Rank	Industry	Q2 Direct Loss ($billion, 2013)	Q4 Direct Loss ($billion, 2013)	Annual Direct Loss ($billion, 2013)
1	Real estate and rental leasing	$3.14	$3.24	$3.18
2	Information	$1.81	$1.87	$1.77
3	Professional, scientific, and technical services	$1.51	$1.56	$1.50
4	Wholesale trade	$1.42	$1.47	$1.44
5	Health care and social assistance	$1.42	$1.46	$1.44
6	Finance and insurance	$1.11	$1.10	$1.19
7	Government (federal and local)	$1.89	$0.47	$1.11
8	Retail trade	$1.01	$1.04	$1.04
9	Durable goods manufacturing	$0.97	$0.99	$0.97
10	Nondurable goods manufacturing	$0.88	$0.91	$0.86
11	Administrative and waste management services	$0.62	$0.65	$0.63
12	Construction	$0.56	$0.58	$0.58
	All Industries	**$19.37**	**$18.20**	**$18.60**

Results: Quarterly REAcct Output Contd.

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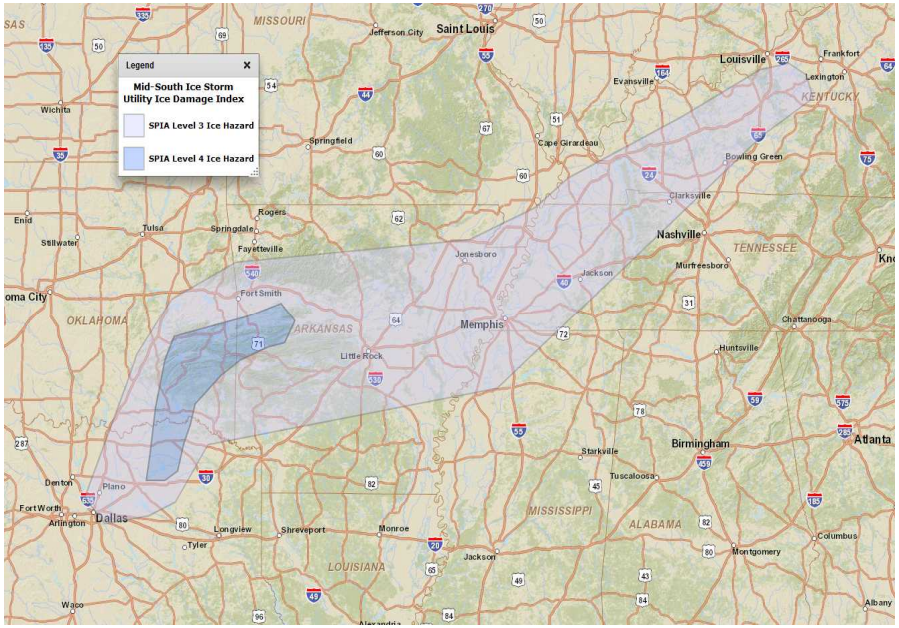
Rank	Industry	Q2 Total Loss ($billion, 2013)	Q4 Total Loss ($billion, 2013)	Annual Total Loss ($billion, 2013)
1	Real estate and rental leasing	$6.02	$6.21	$6.08
2	Information	$4.96	$5.12	$4.86
3	Health care and social assistance	$3.91	$4.03	$3.97
4	Professional, scientific, and technical services	$3.99	$4.12	$3.96
5	Wholesale trade	$3.48	$3.60	$3.53
6	Government (federal and local)	$5.50	$1.38	$3.22
7	Finance and insurance	$2.81	$2.79	$3.02
8	Durable goods manufacturing	$2.68	$2.74	$2.68
9	Retail trade	$2.50	$2.56	$2.57
10	Nondurable goods manufacturing	$2.44	$2.51	$2.37
11	Real estate and rental leasing	$6.02	$6.21	$6.08
	All Industries	**$49.51**	**$46.09**	**$47.29**

Example Scenario: Mid-South Ice Storm

- Hypothetical Ice Storm is located in area spanning from Dallas, TX to Lexington, KY between the months of October and March
- Estimates were derived from assumptions regarding storm path, width, intensity, and progress of electric power restoration
- The center of the storm tracks near Arkansas, Oklahoma, and Texas
- Less risk to densely populated urban areas



Results: Baseline REAcct Output

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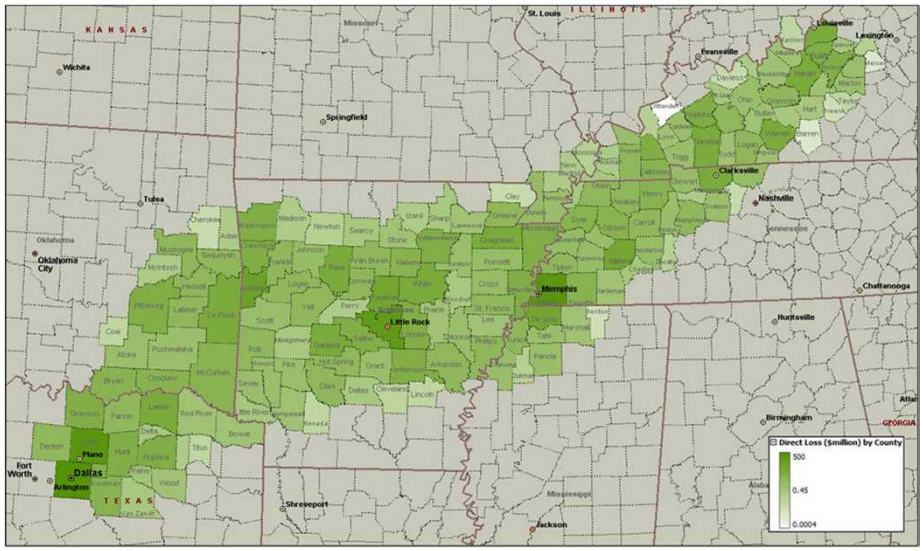
Total GDP reduction by industry for selected industries

Industry Sector	Total GDP Reduction ($billion)
Real estate and rental leasing	$0.52
Finance and insurance	$0.41
Government (federal and local)	$0.37
Health care and social assistance	$0.35
Wholesale trade	$0.32
Retail trade	$0.31
Professional, scientific, and technical services	$0.28
Information	$0.24
Construction	$0.22
Transportation and warehousing	$0.21
All Industries	**$4.56**



Distribution of direct GDP reduction by county

Results: Supplemental Analysis, IIM Output

Industry	Direct Loss ($billions, 2013)	IIM ($billions, 2013)	Direct + IIM (% of Direct)
Apparel and Leather and Allied products	$0.0002	$0.0030	1423%
Textile Mills and Textile Product Mills	$0.0006	$0.0027	581%
Printing and Related Support Activities	$0.0036	$0.0065	280%
Electrical Equip, Appliances, & Components	$0.0042	$0.0040	196%
Nonmetallic Mineral Products	$0.0046	$0.0037	179%
Primary Metals	$0.0085	$0.0061	172%
Wood Products	$0.0043	$0.0030	170%
Furniture and Related Products	$0.0021	$0.0011	153%

Results: Quarterly REAcct Output

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Rank	Industry	Q2 Direct Loss ($billion, 2013)	Q4 Direct Loss ($billion, 2013)	Annual Direct Loss ($billion, 2013)
1	Real estate and rental leasing	$0.27	$0.28	$0.27
2	Finance and insurance	$0.15	$0.15	$0.16
3	Wholesale trade	$0.13	$0.13	$0.13
4	Government (federal and local)	$0.22	$0.05	$0.13
5	Retail trade	$0.12	$0.13	$0.13
6	Health care and social assistance	$0.13	$0.13	$0.13
7	Professional, scientific, and technical services	$0.11	$0.11	$0.11
8	Durable goods manufacturing	$0.10	$0.10	$0.10
9	Information	$0.08	$0.09	$0.09
10	Transportation and warehousing	$0.08	$0.08	$0.08
11	Construction	$0.07	$0.07	$0.07
12	Administrative and waste management services	$0.07	$0.07	$0.07
	All Industries	$1.84	$1.70	$1.76

Results: Quarterly REAcct Output

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Rank	Industry	Q2 Total Loss ($billion, 2013)	Q4 Total Loss ($billion, 2013)	Annual Total Loss ($billion, 2013)
1	Real estate and rental leasing	$0.52	$0.53	$0.52
2	Finance and insurance	$0.38	$0.38	$0.41
3	Government (federal and local)	$0.64	$0.16	$0.37
4	Health care and social assistance	$0.35	$0.35	$0.35
5	Wholesale trade	$0.31	$0.33	$0.32
6	Retail trade	$0.31	$0.31	$0.31
7	Professional, scientific, and technical services	$0.28	$0.30	$0.28
8	Durable goods manufacturing	$0.28	$0.27	$0.27
9	Information	$0.23	$0.23	$0.24
10	Construction	$0.21	$0.21	$0.22
11	Transportation and warehousing	$0.21	$0.21	$0.21
12	Administrative and waste management services	$0.19	$0.19	$0.19
	All Industries	$4.71	$4.28	$4.48

Conclusion

- Incorporating the IIM model into REAcct provides supplemental information which characterizes the indirect impacts of an acute disruptive event
  - Implementation requires minimal computational resources, preserving REAcct's speed
- With quarterly data we have additional operational reporting capabilities
  - Tradeoffs with increased temporal resolution

Next Steps

- Continue scenario testing for supplemental metrics and operationalize in software
  - **Extend comparisons –** complete testing of all proposed enhancements for each type of acute disruption
  - **Temporal resolution** – compare low, medium, and high output to the original model output
  - **Resilience metric** – test proposed resilience proxy metric and if successful then establish in software for operational use
  - **Geospatial resolution** – finalize data comparison, test for accuracy, and implement in software
  - **Data acquisition** – continue pursuing higher resolution industry data for all supplemental estimates and metrics. Future work may entail estimating desired data in-house.

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SUPPLEMENTAL SLIDES

Proposed Metrics for Resilience

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- Differing impacts to firms within an industry

$$DL_{irf} = \frac{Y_i^{US}}{365 * E_i^{US}} * E_i^r * \alpha_f d_{irf} \qquad \alpha_{rf} \in [0,1]$$

$$DL_{ir} = \frac{Y_i^{US}}{365 * E_i^{US}} * E_i^r * \sum_{f=1}^{F} \alpha_{rf} d_{irf} \qquad \alpha_r = \sum_{f=1}^{F} \alpha_{rf} = 1$$

- Differing impacts to industries in same disruption zone
  - Extent factor by region:

$$DL_r = F_r \sum_{i=1}^{I} \frac{Y_i^{US}}{365 * E_i^{US}} * E_i^r * d_{ir} \qquad F_r = RE_r * DE_r \in [0,1]$$

  - Redefine as:

$$F_{ir} = RE_r * DE_{ir} \qquad F_r = RE_r \sum_{i=1}^{I} DE_{ir}$$

  - Direct losses for region *r*:

$$DL_r = \left(RE_r \sum_{i=1}^{I} DE_{ir} \right) \left(\sum_{i=1}^{I} \frac{Y_i^{US}}{365 * E_i^{US}} * E_i^r * d_{ir} \right)$$

Further Extensions

- Geospatial resolution
  - As resolution increases the data quality decreases (in general) and not all of the necessary input data is reported by different agencies at the same levels and classifications
  - BLS data not available for region less than county
  - There are perhaps two obvious candidates for smaller regions, Census tracts and ZIP codes
- Resilience
  - The literature on the resilience of economic and infrastructure systems: the ability to relocate, substitute, and reschedule production can affect a firm or industry's ability to recover quickly
  - Postulated that identifying industries or firms could recover quickly following a shock will in turn lessen the recovery time for a particular industry sector
  - The proposition for REAcct is a simplifying method by which to account for inherent resilience for specific firms or industry types

- **Geospatial resolution** – provide increased specificity of scenarios and acute disruptive events
- **Resilience Metrics** – these are of increasing interest to policymakers and owners/operators of infrastructure