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Using Infrastructure Density for Resource Allocation Policy

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Using Infrastructure Density for Resource Allocation Policy
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1. Introduction and Overview

Social and economic consequences of a terrorist attack on a vulnerable site can magnify impacts by indirectly damaging nearby critical infrastructure systems. Alternatively, an attack on an infrastructure facility can indirectly damage or disable a vulnerable site. New metrics and models are necessary to approach this problem. During Year 4 infrastructure density around vulnerable sites in California provided by CREATE was measured using probability density estimation, a type of smoothing method. High hazard dams were used as the infrastructure to test the methodology. During Year 5 the foundation was developed for extending this work to transportation systems such as Amtrak and BART rail systems. The results of the research and its relevance to public policy and security will be disseminated at conferences and papers will be written and submitted for publication.

Objectives: This research work has developed methodologies to enhance the ability of decision-makers to distribute resources for security by (a) estimating critical infrastructure densities around hypothetical vulnerable sites as a basis for risk-based resource allocation; and (b) summarizing and evaluating the conceptual and practical soundness of critical infrastructure density estimates applicable to a wide variety of infrastructures.

The methodology to estimate infrastructure density used in this work can also be applied to the distribution of resources for mutual-aid agreements among counties or other neighboring geographical areas. A high density of infrastructure facilities suggests a greater potential for an event requiring emergency response to occur and the area of operations for response organizations often extends beyond county and other geographical borders.

Other research areas focusing on consequences of disabling infrastructure included an analysis of the recovery of transit infrastructure following the September 11, 2001 attacks and the cost consequences of disabling natural gas transmission and distribution systems, which was a companion piece to costs and consequences of disabling hazardous liquid pipelines completed in Year 4.
2. Research Accomplishments


Simonoff, Restrepo, Zimmerman and Naphtali (2008) analyzed the proximity of infrastructure to vulnerable sites in California. The usefulness of such measures is based on the premise that the higher the density of infrastructure around these sites and the nearer they are to those sites, the greater the social and economic consequences that would result from a terrorist attack on those proximate infrastructures. Alternatively, an attack on the vulnerable sites makes the proximate infrastructure vulnerable to damage, which could potentially greatly exacerbate the economic and social consequences of such an attack. GIS is used to compute distances between infrastructure and vulnerable sites. Based on these distances, a statistical smoothing technique is used to estimate the density of infrastructure around each vulnerable site. These density estimates allow for resource allocation strategies that account for this sort of collateral damage. Since this methodology provides a metric of infrastructure density around sites regardless of geographical borders it is superior to infrastructure counts within buffers or counties and can inform decisions about mutual-aid agreements for emergency response among counties and other geographical areas. Dams and vulnerable sites in California were used as a platform for developing and applying this risk management methodology.

2.2. Risk Management: Consequence Assessment

2.2.1. Consequence Analysis Models Developed from Unintended Releases from U.S. Natural Gas Transmission and Distribution Systems

Simonoff, Restrepo, and Zimmerman (Journal of Loss Prevention in the Process Industries 2009) analyze a database obtained from the U.S. Department of Transportation’s Office of Pipeline Safety (OPS) related to U.S. natural gas transmission and distribution pipeline accidents:

Abstract: “A critical aspect of risk management in energy systems is minimizing pipeline incidents that can potentially affect life, property and economic well-being. Risk measures and scenarios are developed in this paper in order to better understand how consequences of pipeline failures are linked to causes and other incident characteristics. An important risk measure for decision-makers in this field is the association between incident cause and cost consequences. Data from the Office of Pipeline Safety (OPS) on natural gas transmission and distribution pipeline incidents are used to analyze the association between various characteristics of the incidents and product loss cost and property damage cost. The data for natural gas transmission incidents are for the period 2002 through May 2009 and include 959 incidents. In the case of natural gas distribution incidents the data include 823 incidents that took place during the period 2004 through May 2009. A two-step approach is used in the statistical analyses to model the consequences and the costs associated with pipeline incidents. In the first step the probability that there is a nonzero consequence associated with an incident is estimated as a function of the characteristics of the incident. In the second step the magnitudes of the consequence measures, given that there is a nonzero outcome, are evaluated as a function of the characteristics of the incidents. It is found that the important characteristics of an incident for risk management can be quite different depending on whether the incident involves a transmission or distribution pipeline, and the type of cost consequence being modeled. The application of this methodology could allow decision-makers in the energy industry to construct
scenarios to gain a better understanding of how cost consequence measures vary depending on factors such as incident cause and incident type.” © 2009 Elsevier Ltd. All rights reserved

2.2.2. Aging Infrastructure

The relevance of aging infrastructure to security and the need to address it as a part of risk management was presented at a U.S. DHS co-sponsored workshop at Columbia University. The resulting paper has subsequently been accepted to the workshop proceedings and was invited to contribute an article in the George Mason University Civil Infrastructure Protection Report in October 2009. Zimmerman, R., Restrepo, C.E. and Simonoff, J.S., “Infrastructure Age, Security and Natural Hazards,” The CIP Report, Volume 8, Number 4, October 2009, p. 18, 28, 29.

Abstract: “The age of U.S. infrastructure connects in subtle ways with many other threats such as terrorism, natural hazards, and climate change that these facilities and services face. Many new infrastructure initiatives being introduced to address these threats are also likely to address many of the condition and performance problems of aging infrastructure. This paper evaluates a number of infrastructure areas to identify how measures of condition are associated with age as well as other factors such as environmental stresses, usage, design, and operations and maintenance practices. This type of knowledge is an important prerequisite to understanding how infrastructure age relates to infrastructure resilience in the face of extreme events.” Zimmerman, R., Restrepo, C.E. and Simonoff, J.S., “The Age of Infrastructure in a Time of Security and Natural Hazards,” Proceedings of the DHS Aging Infrastructures Workshop, forthcoming.

2.2.3. Risk Management: Factors Influencing Infrastructure Resiliency

A number of investigations were undertaken to identify the factors that lead to infrastructure resiliency in the face of multiple hazards. For example, when water systems are controlled by information technologies, this potentially creates vulnerabilities in the face of cyber attacks (Zimmerman forthcoming 2009 in the Wiley Handbook of Science and Technology for Homeland Security). In another chapter, overall resiliency factors influencing infrastructure vulnerability were reviewed for the Encyclopedia of Quantitative Risk Assessment and Analysis. Both of these were modified and finalized during Year 5.

An invited paper for an IEEE homeland security conference presented an overview of various project studies on resiliency.

Abstract: “The age of U.S. infrastructure connects in subtle ways with many other threats such as terrorism, natural hazards, and climate change that these facilities and services face. Many new infrastructure initiatives being introduced to address these threats are also likely to address many of the condition and performance problems of aging infrastructure. This paper evaluates a number of infrastructure areas to identify how measures of condition are associated with age as well as other factors such as environmental stresses, usage, design, and operations and maintenance practices. This type of knowledge is an important prerequisite to understanding how infrastructure age relates to infrastructure resilience in the face of extreme events.”

3. Applied Relevance

3.1. Resource Allocation Based on Proximity of Infrastructure to Vulnerable Targets

The Proximity project (Simonoff, Restrepo, Zimmerman and Naphtali 2009) enables decision makers to:

- Visualize infrastructure proximity to vulnerable sites
- Rank vulnerable sites according to their proximity to critical infrastructure systems
- Rank counties or other geographical areas with respect to the risk of collateral damage and associated economic and social consequences to high hazard dams (with the methodology transferable to other infrastructure) as a result of an attack on a randomly chosen vulnerable site
- Form meaningful groupings of counties or other geographical areas, which can guide resource allocation and highlight similarities and differences across areas

For example, one can take into account two kinds of variations in considering the relative eligibility of counties: two counties might have an equal amount of nearby infrastructure but one has a larger number of vulnerable sites making that county a stronger candidate for more funding to prevent collateral damage to high hazard dams due to an attack on the vulnerable sites; alternatively, two counties might have an equal number of vulnerable sites, but one county may have more nearby infrastructure than another thus making it a stronger candidate for funding.

3.2. Consequence Assessment Tools

The evaluation of causes and consequences of natural gas transmission and distribution pipeline accidents by Simonoff, Restrepo, and Zimmerman (Journal of Loss Prevention in the Process Industries 2009) provides a statistical model and scenarios based on linkages between causes and consequences that enable decision makers to understand changes in costs associated with different kinds of accidents. This extends a similar application by Simonoff, Restrepo, and Zimmerman (International Journal of Civil Infrastructure Protection 2009)

4. Collaborative Research

Collaborative research has continued with Professor Michael R. Greenberg who at Rutgers University heads the Transportation portion of a new center of excellence, Professor Vicki M. Bier of the U. of Wisconsin and Rand through Henry Willis of Rand on infrastructure density estimates as a basis for resource allocation decisions. NYU’s CREATE research has also been conducted in collaboration with NYU’s the Center for Catastrophe Preparedness and Response project, “Public Infrastructure Support for Protective Emergency Services.”

A major collaborative effort is underway between NYU and the Polytechnic Institute of New York University which merged in July 2008. The NYU-Wagner members of CREATE received an NYU-Poly seed grant which established a cyber security center, Center for Interdisciplinary Studies in Security and Privacy (CRISSP). The Center has already obtained an NSF grant for security education, ASPIRE (A Scholarship for Service (SFS) Program (or Partnership) for Interdisciplinary Research and Education) with NYU/Poly – Computer Science and Electrical Engineering Departments as lead. The Center has held a research workshop and has an ongoing seminar series.

New York University’s activities have occurred directly in conjunction with a number of DHS sponsored or co-sponsored events, such as the:
- Aging Infrastructures Workshop, sponsored by the DHS S&T Directorate and Columbia University, New York, NY (July 21, 2009)
- Infrastructure Security Workshop, Rutgers University, New Brunswick, NJ (October 13-14, 2009)

5. **Research Products**

<table>
<thead>
<tr>
<th>Research Products (Please detail below)</th>
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<tbody>
<tr>
<td>7a # of peer-reviewed journal reports published</td>
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<tr>
<td>7a # of peer-reviewed journal reports accepted for publication</td>
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<td>7a # of non-peer reviewed publications and reports</td>
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<tr>
<td>7a # of scholarly journal citations of published reports*</td>
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<td>7b # of scholarly presentations (conferences, workshops, seminars)</td>
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<td>7b # of outreach presentations (non-technical groups, general public)</td>
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<tr>
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<td>7c # of patents issued</td>
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<td>7c # of products in commercialization pipeline (products not yet to market)</td>
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<td>7c # of products introduced to market</td>
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*This is the estimated sum for all publications for Simonoff – 1400, Zimmerman – 450, Restrepo – 50 (through October 2009).

**Does not include outreach efforts to the international, national, and local news media.

***These include invited presentations that were included in the proceedings of DHS co-sponsored events.

### 5.1. Publications and Reports

<table>
<thead>
<tr>
<th>Zimmerman, Rae</th>
<th>New York University</th>
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<tbody>
<tr>
<td>2. Zimmerman, R., Restrepo, C., Simonoff, J., “The Age of Infrastructure in a Time of Security and Natural Hazards,” from the proceedings of the <em>DHS Aging Infrastructures Workshop</em>, forthcoming, 2009</td>
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5.2. Presentations - Conferences


9. Zimmerman, R., “Public Investment in American Cities: Infrastructure, Services and Delivery,” invited presentation, subsequent paper, Shape of the American City, a conference co-sponsored by the Penn Institute for Urban Research and the American Academy of Political Science and Social Science, October 24-25, 2008

5.3. Presentations - Outreach


6. Education and Outreach Products

<table>
<thead>
<tr>
<th>Education and Outreach Initiatives (Please detail below)</th>
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<td># of students involved (funded by CREATE + any other programs)</td>
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<tr>
<td># of students graduated</td>
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<tr>
<td># of contacts with DHS, other Federal agencies, or State/Local (committees)</td>
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<tr>
<td># of existing courses modified with new material</td>
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<tr>
<td># of new degree programs developed</td>
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</table>

Details:
# of students involved (funded by CREATE + any other programs): 2 funded by other programs - Marine (Lericolais) Depigny (Ph.D student from ENTPE, Lyon, France)
# of contacts with DHS, other Federal agencies, or State/Local (committees): DHS – numerous contacts made through professional conferences, e.g., InfraGard, DHS conferences; others met through professional conferences;