

Critical Infrastructure Protection and Resource Allocation Policy
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1. Introduction and Overview

Social and economic consequences of a terrorist attack on critical infrastructure are a key component of resource allocation policy and risk management. The NYU projects for CREATE develop analytical methods focused on the implications of attacks on critical infrastructures to provide inputs into resource allocation choices, decisions, and policies including the protection of infrastructure and its users.

The research focus has been the development of 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. During Year 4 probability density estimation methods were used to measure infrastructure density around anonymous vulnerable sites in California provided by CREATE. High hazard dams were used as the infrastructure to develop and illustrate the methodology.

Resource allocation methods were also developed using the distribution of electricity generation capacity at state and county levels.

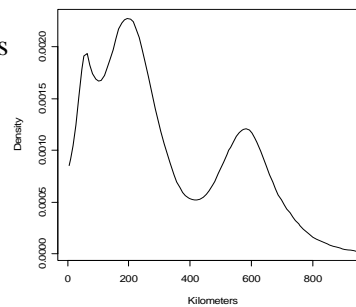
Other research areas focusing on consequences of disabling infrastructure included an analysis of the recovery of transit infrastructure following the September 11, 2001 attacks, the cost consequences of disabling hazardous liquid pipelines.

2. Research Accomplishments

2.1. Resource Allocation

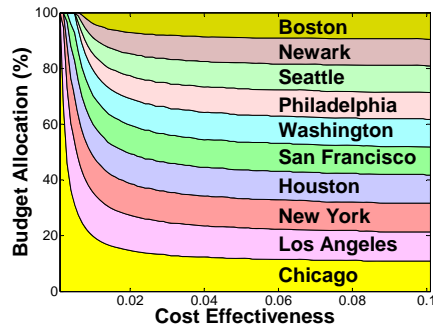
2.1.1. Estimates of Infrastructure Density Around Vulnerable Targets.

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 natural belief 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. Dams and vulnerable sites in California are used as a platform for developing and applying this risk management methodology.

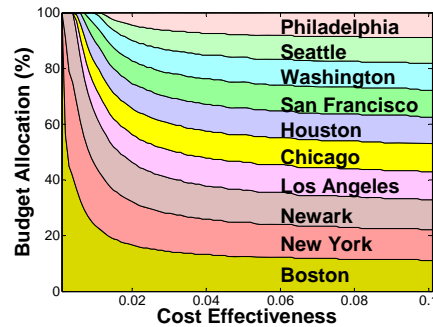


2.1.2. Infrastructure Inputs for Models to Optimize Resource Allocation

The research by Bier, Haphuriwat, Menoyo, Zimmerman and Culpen in *Risk Analysis* 2008 uses two measures of critical infrastructure protection (for bridge and airport traffic) provided by NYU-ICIS as inputs for a computational model for the optimal defensive resource allocation among potential terrorist targets by the University of Wisconsin team. According to the abstract in Bier et al. (*Risk Analysis*): “The model postulates that the optimal allocation of resources depends on attacker and defender strategies and in particular how they value those strategies, in particular those related to the value of the targets. Target attractiveness is measured in part our study explores how the optimal budget allocation depends on the cost effectiveness of security investments, the defender’s valuations of the various targets, and the extent of the defender’s uncertainty about the attacker’s target valuations. We use expected property damage, expected fatalities, and two metrics of critical infrastructure (airports and bridges) as our measures of target attractiveness. Our results show that the cost effectiveness of security investment has a large impact on the optimal budget allocation. Also, different measures of target attractiveness yield different optimal budget allocations, emphasizing the importance of developing more realistic terrorist objective functions for use in budget allocation decisions for homeland security.” Below is the hypothetical ranking of cities when airport and bridge usage is incorporated as a measure of target attractiveness.



Total air departures as a measure of target attractiveness



Highest average daily bridge traffic as a measure of target attractiveness

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2.1.3. Population, Income and Simple Vulnerability Indicators for Infrastructure as a Basis for Distributing Federal Anti-Terrorism Funds to States in the U.S.

Greenberg and Zimmerman (in *Global Terrorism: Issues and Developments*, 2008) developed a need-based method of allocating resources based on how electric power generation, population and population income are distributed at the state level.

2.1.4. Resource allocations based on county level distributions of electric power generation

Greenberg and Zimmerman in a paper under review also computed allocations of electric power generation at the county level data as a basis for vulnerability assessments for resource allocation policy.

2.2. Risk Management: Consequence Assessment

2.2.1. Consequence Analysis Models Developed from Unintended Releases from U.S. Hazardous Liquid Pipelines

Restrepo, Simonoff and Zimmerman (*International Journal of Critical Infrastructure Protection* 2009) analyze a database obtained from the U.S. Department of Transportation’s Office of Pipeline Safety (OPS) of 1,582 accidents related to U.S. hazardous liquid pipelines for the period 2002-2005 using regression models, and demonstrate that consequences vary substantially depending on the factors that caused them and other characteristics. Regression model results are then used as inputs to accident scenarios to show how different causes can alter the expected magnitude of the value of product lost, property damages, and cleanup and recovery costs; such analyses show that expected costs vary greatly depending on the underlying characteristics of the accident. The research focuses on economic consequence measures related to accident cost: the value of the product lost, public, private, and operator property damage, and cleanup, recovery, and other costs. Logistic regression modeling is used to determine what factors are associated with nonzero costs, and then for the accidents associated with nonzero values for these consequence measures (weighted) least squares regression is used to understand the factors related to them.

2.2.2. Infrastructure Resiliency Estimation Techniques

Resiliency of transit after the September 11, 2001 attacks is a key input for risk management. Simonoff and Zimmerman (*Journal of Applied Security Research* 2008) show that the vulnerability of infrastructure to attack is influenced by how rapidly it can rebound after being disabled. A statistical model that compared observed transit ridership in NYC and the region to what would be expected had 9/11 not occurred is applied to the period before and after the damages and other forms of disablement to bus and rail transit after 9/11. Results showed that a relatively rapid recovery of the city and regional systems occurred, and this can in part be attributed to the matrix-like structure of transit, where more than one way of providing transit services exists.

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*.

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. Optimal Resource Allocation Incorporating Critical Infrastructures

For the optimal resource allocation modeling by Bier et al. (2008), critical infrastructure is used in selected transportation sectors (bridge and airport usage) provided by the NYU-ICIS team to the U. of Wisconsin, as inputs into a model for ranking the relative attractiveness of different U.S. cities as targets of terrorism. This enables critical infrastructure to be directly incorporated into a ranking model to prioritize areas with respect to vulnerability for resource allocation by DHS and other agencies.

3.3. Consequence Assessment Tools

The evaluation of causes and consequences of hazardous liquid pipeline spills by Restrepo, Simonoff and Zimmerman (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.

4. Collaborative Research

Collaborative research was undertaken with the U. of Wisconsin on optimal resource allocation (Bier et al. 2008) and with 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.”

5. Research Products

Research Products		#
7a	# of peer-reviewed journal reports published	4
7a	# of peer-reviewed journal reports accepted for publication	4
7a	# of non-peer reviewed publications and reports	9
7a	# of scholarly journal citations of published reports*	Estimated 1700
7b	# of scholarly presentations (conferences, workshops, seminars)	20
7b	# of outreach presentations (non-technical groups, general public)	34**
7c	# of products delivered to DHS, other Federal agencies, or State/Local	1

*Estimated for all publications for Simonoff – 1200, Zimmerman – 450, Restrepo – 50 (through March 30, 2008).

**Includes an estimated 30 outreach efforts to the international, national, and local news media.

5.1. Publications and Reports

	Ref	Not Ref
1. Restrepo, C., Simonoff, J., Zimmerman, R., “Causes, Cost Consequences, and Risk Implications of Accidents in U.S. Hazardous Liquid Pipeline Infrastructure,” <i>International Journal of Critical Infrastructure Protection</i> , accepted for publication, forthcoming, 2009	x	
2. Zimmerman, R., “Understanding the Implications of Critical Infrastructure Interdependencies for Water,” <i>Wiley Handbook of Science and Technology for Homeland Security</i> , Voeller, J. (ed.) accepted for publication, forthcoming, 2009	x	
3. Zimmerman, R., “Making Infrastructure Competitive in a Changing World Through Investment,” <i>The Annals of the American Academy of Political and Social Science</i> , Wachter, S., Birch, E. (eds.) Philadelphia, PA: AAPSS, forthcoming, 2009	x	
4. Greenberg, M., Irving, W., Zimmerman, R., “Allocating U.S. Department of Homeland Security Funds to States with Explicit Equity, Population, and Energy Facility Security Criteria,” being revised, resubmitted and subsequently accepted for publication by <i>Socioeconomic Planning Sciences</i> , 2008	x	
5. Zimmerman, R, Simonoff, J., “Transportation Density and Opportunities for Expediting	x	

Recovery to Promote Security,” <i>Journal of Applied Security Research</i> , Vol. 4 (1) 48-59, 2009		
6. Zimmerman, R., “Managing Infrastructure Resiliency, Safety and Security,” <i>Encyclopedia of Quantitative Risk Analysis and Management</i> , Everitt, B., Melnick, E., (eds.) New York, NY: John Wiley, 1033-1040, 2008		x
7. Bier, V. Haphuriwat, N., Menoyo, J., Zimmerman, R. , Culpen, A., “Optimal Resource Allocation for Defense of Targets Based on Differing Measures of Attractiveness,” <i>Risk Analysis</i> , Vol. 28 (3) 763-770, 2008	x	
8. Zimmerman, R., Simonoff, J., Naphtali, Z., Restrepo, C., Willis, H., “Infrastructure Density around Vulnerable Sites and Resource Allocation,” policy brief for internal use only, NYU, ICIS, June 2008		x
9. Zimmerman, R., Simonoff, J., Naphtali, Z., Restrepo, C., Willis, H., “Proximity Analysis of Vulnerable Facilities to Infrastructure Facilities Using Density Estimation: California Facilities,” draft report, May 6, 2008		x
10. Zimmerman, R , Restrepo, C., Simonoff, J., “Infrastructure Disruptions and Recovery Rates in Disasters,” ASCE Metropolitan Section Infrastructure Group Technical Seminar, <i>New York City Infrastructure Critical Needs</i> , Polytechnic University, March 24-25, 2008		x
11. Greenberg, M., Zimmerman, R., “Distribution of Federal Anti-Terrorism Funds to States in the United States: A Comparison of Population, Income, and Simple Vulnerability Indicators with Infrastructure Applications,” <i>Global Terrorism: Issues and Developments</i> , Larche, R. (ed.) Hauppauge, NY: Nova Science Publishers, Inc., 101-120, 2008		x
12. Simonoff, J., Restrepo, C., Zimmerman, R., Naphtali, Z., “Analysis of Electrical Power and Oil and Gas Pipeline Failures,” Chapter 27, <i>Critical Infrastructure Protection: Issues and Solutions</i> , Goetz, E.D., Sheno, S. (eds.) New York, NY: Springer, 381-394, 2008	x	
13. Zimmerman, R., “New Paradigms to Simultaneously Achieve Environmental Sustainability and Security for Infrastructure,” Public Entity Risk Institute (PERI) Web Symposium, “Infrastructure Risk and Renewal: The Clash of Blue and Green,” paper posted at www.riskinstitute.org/PERI/SYMPOSIUM , 2007		x
14. Zimmerman, R., Restrepo, C., Nagorsky, B., Culpen, A., “Vulnerability of the Elderly During Natural Hazard Events,” <i>Proceedings of the Hazards and Disasters Research Meeting</i> , Boulder, CO: Natural Hazards Center, 38-40, http://www.colorado.edu/hazards/workshop/hdrm_proceedings.pdf , 2007		x
15. Greenberg, M., Mantell, N., Lahr, M., Felder, F., Zimmerman, R., “Short and Intermediate Economic Impacts of a Terrorist-Initiated Loss of Electric Power: Case Study of New Jersey,” <i>Energy Policy</i> , Vol. 35 (1), 722-733, 2007	x	
16. Simonoff, J., Restrepo, C., Zimmerman, R., “Risk Management and Risk Analysis-Based Decision Tools for Attacks on Electric Power,” <i>Risk Analysis</i> , Vol. 27 (3), 547-570, 2007	x	
17. Schuler, R. E., “Two-Sided Electricity Markets: Self Healing Systems,” Richardson, H., Gordon, P., Moore II, J. (eds.) <i>The Economic Costs and Consequences of Terrorism</i> , Cheltenham, UK: Edward Elgar Publishers, 317-333, 2007		x

5.2. Presentations

Conferences:

- Zimmerman, R., Simonoff, J. S., Naphtali, Z. S., Restrepo, C. E., Willis, H., “Measures of Critical Infrastructure Density around Vulnerable Facilities,” *Society for Risk Analysis Annual Meeting*, Boston, MA., December 8, 2008
- 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
- Rosenzweig, C., Zimmerman, R., “Integrating Transportation, Population and Hazards Data for Risk Avoidance During Emergencies,” NYC Dept. of Health and Mental Hygiene/Office of Emergency Management, New York, NY, July 15, 2008
- Zimmerman, R., Restrepo, C. E., Simonoff, J. S., Naphtali, Z. S., Culpen, A. M., “Hazards, Infrastructure Incidents and Social Equity in Urban Areas,” *Association of Collegiate Schools of Planning (ACSP), Association of European Schools of Planning (AESOP) World Planning Congress*, Chicago, IL, July 8, 2008
- Zimmerman, R., paper presentation for *Security: Advancing a Framework for Enquiries (SAFE)*, Istanbul, Turkey, sponsored by the European Science Foundation and NATO, Workshop 4: Management of Security: Successes and Failures, May 21-23, 2008
- Restrepo, C. E., Naphtali, Z. S., Zimmerman, R., “Using GIS to Evaluate the Distribution, Concentration and Level of Risk Posed by Dams in the United States,” *The Association of American Geographers’ (AAG) Annual Meeting*, Boston, MA, April 15-19, 2008
- Zimmerman, R., Restrepo, C. E., Simonoff, J. S., “Infrastructure Disruptions and Recovery Rates in Disasters,” *ASCE Metropolitan Section Infrastructure Group Technical Seminar New York City Infrastructure Critical Needs*, Polytechnic University, New York, NY, March 24, 2008
- Zimmerman, R., Restrepo, C. E., Simonoff, J. S., “Regression Modeling and Prediction of Causes and Consequences of Oil and Gas Pipeline Accidents and Electric Power Outages,” *Second Annual Homeland Defense and Security Education Summit*, University of Maryland, College Park, MD, March 19, 2008
- Zimmerman, R., “An Educational Initiative Combining Security and Global Climate Change (GCC) Needs for Critical Infrastructure Protection,” *Second Annual Homeland Defense and Security Education Summit*, University of Maryland, College Park, MD, March 18, 2008
- Culpen, A., “Infrastructure Needs of Vulnerable Populations in Catastrophes,” New York University, Wagner School, U.S. Department of Homeland Security, *University Network Summit and Student Day*, Washington, DC, March 18, 2008
- Restrepo, C. E., Zimmerman, R., Simonoff, J. S., “Risk Communication in Support of Energy, Transportation and Water Services,” *2008 Risk Symposium*, Santa Fe, NM, March 11, 2008
- Zimmerman, R., “New Paradigms to Simultaneously Achieve Environmental Sustainability and Security for Infrastructure,” *Public Entity Risk Institute (PERI) Web Symposium, Infrastructure Risk and Renewal: The Clash of Blue and Green*, www.riskinstitute.org/PERI/SYMPOSIUM, January 14-18, 2008
- Zimmerman, R., Restrepo, C. E., “Research Directions for Analytical Tools to Portray and Monitor Infrastructure Vulnerability for Resource Allocation,” Panel on Securing Critical Infrastructures in New York State: Directions for Research and Application, Conference on protecting New York from terrorism and disaster, *Taking Stock, Setting Directions, Looking Forward, Protect New York Society*,

Levin Institute of SUNY, New York, NY, <http://protectnewyork.org/images/PNY-DraftProgram-1-4-08.pdf>, January 11, 2008

- Zimmerman, R., Simonoff, J. S., “Transportation Density and Opportunities for Expediting Recovery to Promote Security,” Panel on Transportation Security in New York, Conference on Protecting New York from Terrorism and Disaster: *Taking Stock, Setting Directions, Looking Forward, Protect New York Society*, <http://protectnewyork.org/images/PNY-DraftProgram-1-4-08.pdf>, Levin Institute of SUNY, NY, NY, January 10, 2008
- Restrepo, C. E., Simonoff, J. S., Zimmerman, R., “Risk and Vulnerability Measures for Infrastructure Asset Protection: Bridges and Dams,” *Society for Risk Analysis Annual Meeting*, San Antonio, TX, December 20, 2007
- Zimmerman, R., Restrepo, C. E., Simonoff, J. S., “Infrastructure Impacts of Global Climate Change,” sponsored by the Society for Risk Analysis (SRA) NY Metro Chapter and Columbia Students for Environmental Action, co-sponsored by The Louis Berger Group Inc., New York, NY, November 15, 2007
- Zimmerman, R., “Status of Recovery in New York Since the World Trade Center Attacks,” Disasters Roundtable Workshop, *Recovering from Disaster*, National Academies, Washington, DC, October 17, 2007
- Zimmerman, R., Restrepo, C., Naphtali Z. S., Simonoff, J. S., “Impact of Infrastructure Trends & Issues on Public Transportation for a Sustainable Future,” *American Public Transportation Association Annual Meeting*, Charlotte, NC, October 9, 2007
- Zimmerman, R., “Risk-Related Challenges for Ecosystem Damage and Restoration,” The Society for Risk Analysis Metro Chapter; NY, NJ, CT, New York, NY, October 4, 2007

Outreach Events:

- Zimmerman, R., panel co-chair and program committee member for the U.S. Department of Homeland Security, Science & Technology Directorate, *Workshop on Future Directions in Critical Infrastructure Modeling & Simulation*, Virginia Modeling, Analysis & Simulation Center (VMASC), Suffolk, VA, October 28-30, 2008
- Zimmerman, R., presentation to visiting faculty from the Hanoi Architectural University, including the Dean of Infrastructure and Environmental Planning, Chief of Electricity Subject, NYU-Wagner School, April 7, 2008
- Zimmerman, R., presentation at a one day mobile workshop in *Urban Planning for the Young Planners Network Conference* at the Academy of Urban Planning, an urban planning themed high school in Bushwick, Brooklyn, April 4, 2008
- Zimmerman, R., Culpen, A., “DHS Student & Alumni Network News,” invited published interviews, <http://www.dhsnetwork.org/documents/DHSOct2007NetworkNewsletter.pdf>, 1-3, October 2007
- Zimmerman, R., several dozen network news and printed media presentations and citations on various aspects of critical infrastructure relevant to security, for example: Passenger Transport (American Public Transportation Association), The Brooklyn Paper, PM Network magazine, Gotham Gazette, The New York Times, Daily News, NY Sun, National Public Radio, Forbes.com Video Network, CNN, Fox 5, WLNYTV, The History Channel, See: <http://www.icisnyu.org/ICISintheNews.php>, August 1, 2007-September 30, 2008

5.3. Models, Databases, and Software Tools and Products

- Ordinary and weighted least squares regression to model and predict magnitudes of costs and consequences of infrastructure accidents and attacks from potential causes, including type of incident, underlying cause of incident, and location of incident.
- Logistic regression to model and predict the probability of nonzero costs due to infrastructure accidents and attacks from potential causes, including type of incident, underlying cause of incident, and location of incident.
- Count regression models (Poisson and negative binomial) to model the number of injuries or deaths due to infrastructure accidents and attacks from potential causes, including type of incident, underlying cause of incident, and location of incident.
- Infrastructure density measure based on a log-linear local likelihood density estimator used to construct a measure of the local proximity of infrastructure to vulnerable sites, thereby allowing for risk-based assessment of the potential for collateral damage, and risk-based cost allocation strategies that take such potential into account.
- Construction of predictive scenarios that allow for realistic assessment of how estimates costs and consequences of infrastructure accidents and attacks vary with differences in the underlying causes and characteristics of the incidents.

6. Education and Outreach Products

Education and Outreach Initiatives (Please detail below)	#
# of students supported (funded by CREATE)	2
# of students involved (funded by CREATE + any other programs)	8
# of students graduated	4
# of contacts with DHS, other Federal agencies, or State/Local (committees)	40 est.
# of existing courses modified with new material	3
# of new courses developed	0
# of new certificate programs developed	0
# of new degree programs developed	N/A

Details

of students supported (funded by CREATE): Alison Culpen (MUP May 2008) and Jung-Hsien Liao (MUP May 2008)

of students involved (funded by CREATE + any other programs): 2 funded by CREATE (see above); Funded by other programs (6) - Aurelien Pere, Pierre Delacoux des Roseaux, Clement Despres (ENTPE, Lyon, France; Wagner School MS 2008), Preston Mesick (Carnegie Mellon, DHS scholar), Jean-Claude Lupis (Columbia University, DHS scholar), Marine Lericolais (Doctoral Student, ENTPE, Visiting Scholar September 1, 2008-February 2009).

of students graduated (4 in 5/08): Culpen, Liao, Pere, Delacoux des Roseaux graduated in May 2008 (Masters degrees).

of contacts with DHS, other Federal agencies, or State/Local (committees): DHS – numerous contacts made (number of 40 is a rough estimate) through professional conferences, e.g., InfraGard, DHS summit meeting, and DHS S&T Modeling and Simulation Workshop October 2008; Other federal agencies - U.S.

Zimmerman, et al., CREATE Annual Report Year 4, New York University

EPA SAB Homeland Security Advisor Committee; others met through professional conferences;
State/Local committees include the NYU advisory committee for CREATE

of existing courses modified with new material: P11.2610 Environmental Impact Assessment (Fall 2007); P11.2612 Adapting the Physical City (Spring 2008); P11.2613 Sustainable Cities (Fall 2007)