NEW PARADIGMS TO SIMULTANEOUSLY ACHIEVE ENVIRONMENTAL SUSTAINABILITY AND SECURITY FOR INFRASTRUCTURE*

By: Rae Zimmerman, Ph.D

Introduction

Security and environmental sustainability are not only compatible goals, but security is also a critical component and integral part of sustainability. Sustainability has been considered the broader, more encompassing category, and the role and importance of security as an element of sustainability is often not explicitly recognized. The two concepts, security and sustainability converge specifically in the area of urban infrastructure. Society cannot financially afford to consider these two important social goals separately.

First, I will explore the issues and solutions within each of the two areas – security and sustainability – separately, and then evaluate how a more integrated perspective provides reinforcement and synergy for the particular issues that each area faces. I will review some illustrations of New York City’s reaction to the security problems created by the September 11, 2001 World Trade Center attacks as well as the emphasis on environmental sustainability as development moves forward in New York.

Second, in the conclusion, I will identify key issues that need to be addressed in implementing such new paradigms.

Security

Issues

Security connotes protection from harm, for example, from natural disasters, terrorism or accidents, and though it is related to other concepts such as safety, it is distinct from them (Zimmerman 2008, forthcoming).

Security issues arise with respect to infrastructure in part due to highly dispersed, but interconnected facilities that are not easily amenable to surveillance. Development patterns and economies of production of infrastructure services—particularly in the provision of electric power that is utilized by other infrastructure sectors—have resulted in large distances between consumers and producers of...
the services that infrastructure provides, which makes these facilities difficult to protect.

The larger metropolitan regions in the country now consume land at a faster rate than the rate at which the population is growing (Yaro and Hiss 1986: Figure 34). In other words, the per-capita consumption of land is increasing, yet many of the production sites for conventional infrastructure services remain concentrated, underscoring the increasing distances between infrastructure consumption and production.

A few examples of the extensiveness of infrastructure distribution facilities are noteworthy: The U.S. has over 4 million miles of highways in the interstate system, 600,000 bridges, and 880,000 miles of major water distribution lines. On the production side, the U.S. has 80,000 dams, 5,000 electric power production facilities, 726 gas processing plants, and 121 oil refineries (NRC 2002). Many of these facilities are concentrated in relatively few locations, creating potential security problems. For example, about half of the ridership on transit systems (which are critical environmental sustainability infrastructure) is concentrated in only two states (Zimmerman 2002, 2006).

**Solutions**

Truly (2002: 1, 2) has suggested the following general characteristics of secure infrastructure:

- Independence from main systems (e.g., energy systems not connected to the grid or easily disconnected from it);
- Mobility/portability;
- Flexibility in deployment;
- Small in size for ease of transport and deployment;
- More conservative of resource utilization;
- Close to users and less vulnerable to destruction by virtue of fewer distribution lines;
- Reliance on less-vulnerable sources since they are ubiquitous or abundant, and/or natural—e.g., the sun, wind, water, biological materials, gases;
- Inaccessible to criminals (perpetrators, intruders).

The adaptability of physical systems in light of these attributes has been a common focus of security. The manner in which infrastructure in New York City responded to the attacks on the World Trade Center on September 11, 2001 illustrates many of the attributes cited above for secure infrastructure. Attempts to provide water for fire fighting made use of fire boats and piping extending from the Hudson River into the site; electric power lines were drawn over the streets in order to tap substations that were still functioning for power to the affected area; cell towers and electric generators were able to be brought into the area quickly.
from reserves throughout the country; the transit system was able to reroute trains to continue service by bypassing the affected area (Zimmerman 2003b, c).

**Sustainability**

General attributes for sustainability are very extensive and too numerous to list here, as are the areas in which the natural environment has come into conflict with infrastructure. General principles of sustainability, however, are noteworthy as a context for an evaluation of infrastructure in light of sustainability.

Sustainability has been defined in a number of different ways that underscore balancing the environment, development, and social equity goals. First, the Brundtland Commission report, *Our Common Future*, defines it as: to ensure that humanity "meets the needs of the present without compromising the ability of future generations to meet their own needs" (National Research Council 1999: 23, citing World Commission on Environment and Development 1987).

Second, over a decade later, the National Resource Council’s Board on Sustainable Development defined it as “the reconciliation of society’s developmental goals with its environmental limits over the long term” (National Research Council 1999: 22), and emphasizes that the elements to be sustained are in the areas of nature, life support systems, and community (National Research Council 1999: 23).

Third, sustainability became the foundation for or was operationalized in a number of accounting frameworks. "Ecological footprints" analysis has been an important application area, defined as “the land (and water) area that would be required to support a defined human population and material standard indefinitely” (Wackernagel and Reis 1996: 158) and generally takes into account “the flows of energy and matter to and from any defined economy and converts these into the corresponding land/water area required from nature to support these flows” (Wackernagel and Reis 1996: 3).

Similarly, sustainability has also been the foundation for reporting and accounting frameworks in the business environment. The “Triple Bottom Line” (TBL) standard was adopted in 2007 by the International Council for Local Environmental Initiatives (ICLEI), founded in 1990, and the origin of the term is attributed to John Elkington in 1994 (Wikipedia). TBL is considered to be an expansion of “traditional reporting framework to take into account environmental and social performance in addition to financial performance,” and has been abbreviated in terms of three concepts, “People (Human Capital), Planet (Natural Capital) and Profit (Economic Benefit)” (Wikipedia).

Changing environmental conditions have a number of effects on vital public services and the infrastructure that supports them, and potentially compromise security if not addressed in the initial stages of planning infrastructure. Global
warming is an important example that illustrates many of these threats, and has produced changes or refinements in the application of principles of sustainability.

Issues

Areas in which infrastructure has affected the natural environment have been known for a very long time and have been the centerpiece of U.S. environmental legislation. However, the boomerang effects—those pertaining to the effects of the environment on infrastructure—are less often noticed and articulated.

The issue of global warming has brought these issues to center stage. Effects associated with global warming, such as temperature increases and sea-level rise, pose a serious risk to the viability of infrastructure by straining the physical properties of the infrastructure as well as altering its use. A number of effects reviewed by the Center for Naval Analyses (CNA) (April 2007) include:

- Increasing severity and frequency of storms will compromise the physical integrity of some infrastructure.
- Changes in the use of and demand for infrastructure will be generated by changes in population location due to migrations, etc.
- Redistribution of water resources will occur due to rising temperatures and sea levels, changes in precipitation, increased evaporation, and increased droughts.

In addition, other factors associated with global warming will undermine infrastructure (Zimmerman 1996): Infrastructure facilities such as pipes, bridges, etc. are built with materials that withstand a certain temperature-tolerance limit—higher temperatures of longer duration can cause material degradation such as crumbling of concrete and melting of asphalt on road surfaces, reduced structural integrity of steel over time, and changes in electrical conductivity of transmission systems. Also, consistent with the work of CNA and the Intergovernmental Panel on Climate Change, it is well known that the location of existing transportation and electric power infrastructure, particularly in a large city such as New York City, is often in areas potentially prone to flooding (Zimmerman 2003a, Zimmerman and Cusker 2001).

Solutions

Placing infrastructure underground is a possible means of reducing exposure to temperature extremes, reducing impacts on the surface environment, and useful as a means to store and channelize floodwaters.

Temporary adaptation in the form of relocation of population and economic activity and the infrastructure that supports them, can work over the long term, as long as the adaptations take into account sea-level rise far into the future.
The introduction of new temperature-tolerant materials could reduce the risk of damage from extremes of heat.

Nanotechnologies may be applied in a variety of infrastructure sectors as solutions for energy storage problems that have stood in the way of the implementation of many renewable energy technologies.

Conventional water infrastructure has adapted to development patterns, and is now changing dramatically to address problems of flooding and drought. Plants, animals, and insects are cleverer than people in their ability to store and utilize water when they need it, and some of the new, innovative mechanisms for storm water capture are taking advantage of these mechanisms. In addition, water systems—commonly dependent on power for pumping, treatment, etc.—may benefit from use of renewable energy technologies.

**A Comprehensive Metric for Infrastructure: Simultaneous Optimization of Security and Sustainability**

Strategies are emerging to simultaneously address sustainability and security. Sustainability, especially environmental sustainability, takes the options for security further, and vice versa. Mapping the two together specifically with respect to infrastructure produces some noteworthy synergies that are described below. This is particularly critical given that limited public resources are not likely to be able to support both of these critical goals.

The key seems to be decentralization: distributed or dispersed, but non-interconnected systems for the provision of infrastructure services. This is not to be confused with the distributed nature of existing infrastructure utility distribution lines that are geographically dispersed but interconnected through central production locations.

In order for synergy to be realized, a stronger market potential for renewable resources is needed. Great strides have been made in promoting these new technologies. For example, according to the Energy Information Administration, between 2004 and 2005, the consumption of renewable energy increased by 2% and the number of alternative-fuel vehicles increased by about 20% between 2003 and 2005 (EIA 2007). In spite of these increases, the use of renewables still accounts for only a small share of infrastructure – only 7% (EIA 2007), and most of this is consumed in a limited number of sectors and in a limited number of locations where renewable resources or the technologies to use them are available.

In calculating common objectives, infrastructure interdependencies play a key role that is often not obvious. There are many intricate interconnections among infrastructure systems (Rinaldi, Peerenboom, and Kelly 2001) paralleled by an equally intricate and diverse management structure. In order to approach
infrastructure security and sustainability comprehensively, all of these interdependencies and connections need to be considered. Alternatively, generic, global or system-wide ways of measuring vulnerability must be sought to identify and manage the potential adverse effects of interdependencies (e.g., drops in pressure in water and electrical lines).

Sustainable systems may reduce the complexity somewhat at the end points but may be vulnerable at points of interconnection with more conventional infrastructure (e.g., the case of wells and septic systems being operated via electric pumps or the remote control of distributed communication systems). Interdependencies occur both functionally and geographically. Co-location is a common example of geographic proximity of infrastructure, bringing utility distribution lines closer together, magnifying the impacts of a single failure of one system, and hence, making them less secure.

**Conclusions**

Meeting the goals of both sustainability and security for infrastructure is possible if planned at the outset. These are not inconsistent goals; in fact security is an aspect of sustainability. Sustainable systems help achieve a certain amount of decentralization that can harden infrastructure for security as well.

Sustainability and security of infrastructure share in common the fact that local disturbances can have regional and even global impacts because of the symbolic or cascading nature of highly localized events. Many of the same solutions can meet both objectives, such as decentralization and undergrounding of infrastructure and relying on resources that are ubiquitous and difficult to disable, such as the sun and the wind for energy.

In order to achieve convergence for security and sustainability, substantial institutional changes will be required, since each of these areas are within the domain of very different government jurisdictions. Infrastructure providers typically have a more unified approach, but tend to be still highly specialized in their approaches to sustainability and security. At a governmental policy level, homeland security directives can incorporate sustainability among the security goals and strategies for their implementation. Likewise, environmental legislation and regulations should incorporate security goals as criteria for environmental protection.

With all of these technologies and the institutional mechanisms to implement them, the accounting has to be undertaken. This will be quite a challenge, since the results may vary geographically and for different types of urban development.
References Cited


References Cited to Author’s Works


**Acknowledgements and Disclaimer**

Part of this work was supported by the U.S. Department of Homeland Security through the Center for Risk and Economic Analysis of Terrorism Events (CREATE) under grant numbers N00014-05-0630 and 2007-ST-061-000001. This work was also supported by the U.S. Department of Homeland Security through the NYU Center for Catastrophe Preparedness and Response (CCPR).
grant number 2004-GT-TX-0001. However, any opinions, findings, and conclusions or recommendations in this document are those of the authors and do not necessarily reflect views of the United States Department of Homeland Security.

The use of this paper is limited to the PERI symposium (including subsequent archival of symposium materials on the PERI website). For all other uses, please contact the author at rae.zimmerman@nyu.edu.

**About the author**

Rae Zimmerman is Professor of Planning and Public Administration at the New York University Robert F. Wagner Graduate School of Public Service, and since 1998, Director of the Institute for Civil Infrastructure Systems (ICIS), initially funded by the National Science Foundation for interdisciplinary research, education and outreach. She has been leading research projects on the protection and adaptability of critical infrastructures in the context of terrorism and natural hazards through U.S. DHS funded centers including leading NYU's co-partnership in CREATE, the first Science & Technology center of excellence at the University of Southern California. Zimmerman is also co-principal investigator of the "South Bronx Environmental Health & Policy Study," funded by the U.S. EPA, a researcher for the World Trade Center Evacuation study led by the Columbia University School of Public Health, and risk analyst for infrastructure engineering for government infrastructure projects.

Her research and teaching areas incorporate urban infrastructure security, sustainability and socioeconomic dimensions of environmental, energy, and transportation infrastructure particularly in the context of extreme events, and risk communication. Her publications have appeared in numerous edited books as well as in planning, environmental and public administration journals including the Journal of Urban Health; Energy Policy; Risk Analysis; International Journal of Critical Infrastructures; Water Resources Research; Agriculture, Ecosystems and Environment; the Journal of Urban Technology; Regulatory Toxicology and Pharmacology; and the Policy Studies Journal. Under her direction ICIS co-produced Beyond September 11th (Boulder, CO, University of Colorado, 2003) and Zimmerman co-edited Digital Infrastructures (Routledge 2004) and Sustaining Urban Networks (Routledge, 2005). She is a Fellow of the American Association for the Advancement of Science and past president and Fellow of the Society for Risk Analysis, and is currently a member of the U.S. EPA Science Advisory Board Homeland Security Advisory Committee. Former professional appointments and memberships include the Committee on the Review and Evaluation of the Army Chemical Stockpile Disposal Program (National Academy of Sciences (NAS)), the U.S. EPA Board of Scientific Counselors, the U.S. EPA National Drinking Water Advisory Council (NDWAC) Working Group on Drinking Water Research, the Board on Infrastructure and the Constructed Environment (NAS), and the NYS Department of Environmental Conservation Comparative Risk Committee. She holds a B.A. in Chemistry from the University of California.
(Berkeley), a Master of City Planning from the University of Pennsylvania, and a Ph.D. in planning from Columbia University.

**About the Symposium**


The Public Entity Risk Institute provides these materials "as is," for educational and informational purposes only, and without representation, guarantee or warranty of any kind, express or implied, including any warranty relating to the accuracy, reliability, completeness, currency or usefulness of the content of this material. Publication and distribution of this material is not an endorsement by PERI, its officers, directors or employees of any opinions, conclusions or recommendations contained herein. PERI will not be liable for any claims for damages of any kind based upon errors, omissions or other inaccuracies in the information or material contained here.

* * *