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Resilience: Theory and Applications

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Executive Summary

There is strong agreement among policymakers, practitioners, and academic researchers that the concept of resilience must play a major role in assessing the extent to which various entities — critical infrastructure owners and operators, communities, regions, and the Nation — are prepared to respond to and recover from the full range of threats they face. Despite this agreement, consensus regarding important issues, such as how resilience should be defined, assessed, and measured, is lacking. The analysis presented here is part of a broader research effort to develop and implement assessments of resilience at the asset/facility and community/regional levels.

The literature contains various definitions of resilience. Some studies have defined resilience as the ability of an entity to recover, or "bounce back," from the adverse effects of a natural or manmade threat. Such a definition assumes that actions taken prior to the occurrence of an adverse event — actions typically associated with resistance and anticipation — are not properly included as determinants of resilience. Other analyses, in contrast, include one or more of these actions in their definitions. To accommodate these different definitions, we recognize a subset of resistance- and anticipation-related actions that are taken based on the assumption that an adverse event is going to occur. Such actions are in the domain of resilience because they reduce both the immediate and longer-term adverse consequences that result from an adverse event. Recognizing resistance- and anticipation-related actions that take the adverse event as a given accommodates the set of resilience-related actions in a clear-cut manner. With these considerations in mind, resilience can be defined as: "*the ability of an entity — e.g., asset, organization, community, region — to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance.*"

Because critical infrastructure resilience is important both in its own right and because of its implications for community/regional resilience, it is especially important to develop a sound methodology for assessing resilience at the asset/facility level. This objective will be accomplished by collecting data on four broadly defined groups of resilience-enhancing measures: preparedness, mitigation measures, response capabilities, and recovery mechanisms. Table ES-1 illustrates how the six components that define resilience are connected to the actions that enhance the capacity of an entity to be resilient. The relationships illustrated in Table ES-1 provide the framework for developing a survey instrument that will be used to elicit the information required to assess resilience at the asset/facility level.

Table ES-1: Relationship between Components of Resilience and Resilience-Enhancing Measures

Anticipate	Resist	Absorb	Respond	Adapt	Recover
Preparedness	**Mitigation**		**Response**		**Recovery**
Activities taken by an entity to define the hazard environment to which it is subject	Activities taken prior to an event to reduce the severity or consequences of a hazard		Immediate and ongoing activities, tasks, programs, and systems that have been undertaken or developed to manage the adverse effects of an event		Activities and programs designed to effectively and efficiently return conditions to a level that is acceptable to the entity

The resilience of a community/region is a function of the resilience of its subsystems, including its critical infrastructures, economy, civil society, governance (including emergency services), and supply chains/dependencies. The number and complexity of these subsystems will make the measurement of resilience more challenging as we move from individual assets/facilities to the community/regional level (where critical infrastructure resilience is only one component). Specific challenges include uncertainty about relationships (e.g., the composition of specific supply chains), data gaps, and time and budget constraints that prevent collection of all of the information needed to construct a comprehensive assessment of the resilience of a specific community or region. These challenges can be addressed, at least partially, by adopting a "systems approach" to the assessment of resilience. In a systems approach, the extent to which the analysis addresses the resilience of the individual subsystems can vary. Specifically, high-level systems analysis can be used to identify the most important lower-level systems. In turn, within the most important lower-level systems, site assessment data should be collected only on the most critical asset-level components about which the least is known.

Implementation of the strategies outlined here to assess resilience will facilitate the following four objectives:

1. Develop a methodology and supporting products to assess resilience at the asset/facility level,

2. Develop a methodology and supporting products to assess resilience at the critical infrastructure sector level,

3. Provide resilience-related information to critical infrastructure owners/operators to facilitate risk-based resource decision making, and

4. Provide resilience-related information to State and local mission partners to support their risk-based resource decision making.

The first objective will be accomplished by modifying the current version of the Infrastructure Survey Tool (IST) developed by Argonne National Laboratory (Argonne). Modification of the IST will result in an enhanced version of Argonne's Resilience Index (RI). The second objective will be accomplished by analyzing data collected with the new versions of the IST and the RI to better understand the primary resilience-related characteristics of each critical infrastructure sector and to identify each sector's resilience-related strengths and weaknesses. The third objective will be accomplished by identifying and developing the types of resilience-related information critical infrastructure owners and operators need to make informed resource allocation decisions and developing an effective means of providing them with that information. Finally, the fourth objective will identify the types of resilience-related information that State and local mission partners currently lack, as well as the most effective methods for displaying and sharing this information with them.

1 Overview

Over the past several years, publications ranging from government-produced policy documents to analyses in scholarly outlets have provided varying perspectives on the role of *resilience* in policies and programs that are designed to address natural and man-made threats.[1] A review of those documents and reports reveals that there is strong agreement among policymakers (The White House 2011; DHS 2010, 2009; NIAC 2009), practitioners (Opstal 2007), and academic researchers (Kahan *et al*. 2009; Norris *et al*. 2008; Fiksel 2006) that the concept of resilience must play a major role in assessing the extent to which various entities — critical infrastructure, networks (e.g., electricity generation, transmission and distribution), communities, regions, and the Nation — are prepared to deal with the full range of threats they face. Agreement regarding the importance of resilience notwithstanding, there is a lack of consensus regarding important issues associated with the concept, including how resilience should be defined and how resilience on various scales should be assessed and measured.[2]

The analysis presented here is part of a broader research effort to develop and implement a set of instruments to assess resilience at the asset/facility and community/regional levels. This paper examines the theoretical and applied literature on resilience, focusing on the definition, characteristics/determinants, and assessment of resilience at the asset/facility (including organizations such as hospitals) and community/regional levels. Sources include scholarly publications; trade organization publications (e.g., the Council on Competitiveness; National Institute of Building Sciences [NIBS]); and research reports produced by governmental and educational organizations, such as the Community and Regional Resilience Institute (CARRI) at Oak Ridge National Laboratory and The Center for Resilience at The Ohio State University, among others. This paper also addresses practical issues, including the availability of data needed to measure resilience at different levels, and the willingness or motivation for private entities, as well as local and regional governments, to assist in data collection efforts and invest in increased resilience.

This paper is structured as follows. In section 2, we present a brief overview of the emergence of resilience as an integral component of a comprehensive risk management strategy and consider definitions of resilience that have been proposed or applied in various documents. We also provide a rationale for the definition of resilience that is employed in the remainder of this paper and that will underlie the subsequent development and implementation of a set of instruments to measure resilience at different levels. In section 3, we consider a range of issues related to the measurement of resilience at the infrastructure and community/regional levels, and present the basic framework we employ. Section 4 addresses the issue of how to motivate private enterprises, communities, and regions to participate in the assessment of resilience and invest in increased resilience. Section 5 concludes with a discussion of how the results of sections 2 through 4 of the paper will facilitate the achievement of specific objectives associated with the assessment of resilience at the asset and community/regional levels.

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[1] The terms “threat,” “hazard,” and “event” are often used interchangeably in discussions concerning homeland security issues. That will be the case in this paper as well.

[2] As the National Research Council has noted, “[t]he meaning of ‘resilience,’ however, is far from clear. Numerous definitions of ‘resilience’ exist, and the term is often used loosely and inconsistently” (NRC 2011, p. 27).

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2 Definition and Properties of Resilience

Although the concept of resilience has been applied in a variety of settings (e.g., psychology, psychiatry, ecology, social science, economy, and engineering) for several decades (Renschler *et al*. 2010, Rose 2009), it has received an increasing amount of attention in the area of risk management over the past several years. In the case of natural and man-made threats, analyses of resilience have focused on critical infrastructures, communities, and regions and on the resilience of various subsystems (e.g., a community's or region's economy, governmental units, emergency services sector, the civilian population). As we discuss in Section 2.1, the assessment of resilience varies according to the object of analysis. In addition, certain measures of resilience, such as critical infrastructure resilience and economic resilience, are important both in their own right and in their roles as determinants of resilience measured at a broader level, such as community or regional resilience.

Ultimately, the goal of efforts to assess such properties as protection (vulnerability), resilience, criticality, and so forth is to enable decision makers to make informed choices that will result in cost-effective reductions in the risks associated with the range of natural and man-made threats we face. Viewed from this perspective, we find that where we draw the line between such indicators as vulnerability and resilience is less important than being able to develop a process for measuring those indicators that will produce results that are consistent, reproducible, and useful to decision makers. Having a clear and consistent process for distinguishing and measuring resilience is a necessary element of a comprehensive approach to risk management. The initial step in developing that process is to establish a working definition of resilience.

2.1 Defining Resilience

As the review of the literature presented here clearly demonstrates, there is considerable variation in how different authors have defined resilience. For example, definitions vary depending on the object of analysis (e.g., asset, facility, system, community/region, system of systems). Even when attention is focused on a specific object of analysis (e.g., community), definitions vary in substantive ways. The definition of resilience, however, should be independent of the object of analysis and, in the interest of facilitating the formulation of compatible policy goals in both the public and private sectors by a range of actors — private decision makers (e.g., business owners and managers) and local, State, and national government decision makers — the same definition should be used in all decision-making processes. Establishing a uniform definition is critically important. Our definition of resilience will affect how we distinguish between resilience and other measures — specifically, protection and vulnerability— of our ability to withstand the adverse effects of natural and man-made threats.[3]

[3] The importance of distinguishing between vulnerability and resilience notwithstanding, as a practical matter there are certain aspects of protection and resilience that overlap. For example, the use of blast curtains has the potential to reduce the probability of a terrorist attack — which implies an increased level of protection — because the anticipated benefits to the terrorist in the form of damage to the facility, deaths, injuries, etc., are considered to be too small to warrant the expenditure of resources on an attack. In addition, in the event an attack occurs, the blast curtains might protect certain features of the asset (e.g., telecommunications equipment) that, in turn, enhances the rapidity of recovery of the asset's full functioning subsequent to the attack — which implies increased resilience.

Equally important, the definition of resilience has important implications for how resilience is measured or assessed. To appreciate the differences in how resilience has been defined in the literature, we have divided the definitions into three broad categories: general definitions, definitions of infrastructure resilience, and definitions of community resilience.

2.1.1 General Definitions

Several documents discuss the concept of resilience in very broad terms and without reference to a specific object of analysis (e.g., a critical asset/facility, community, or region). As the set of definitions included here demonstrates, there is a clear break in opinion regarding how resilience should be defined. To be specific, in describing the components or determinants of resilience, several of the definitions considered here focus on what happens "*after* the adverse event" (i.e., an adverse natural or man-made event), whereas others include one or more "*before* the adverse event" components, including resistance, protection, anticipation, and preparedness.[4]

2.1.1.1 Resilience Definitions That Include Only "After-Event" Components

- [Resilience is] "the capacity of a system to absorb disturbance, undergo change, and retain essentially the same function, structure, identity, and feedbacks" (Longstaff *et al*. 2010, p. 2).

- "We define resilience as: a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation *after* [emphasis added] a disturbance…. resilience emerges from a set of adaptive capacities" (Norris *et al*. 2008; p. 130, 135).

- "The capacity of a system to survive, adapt and grow in the face of change and uncertainty" (Fiksel 2006, p. 21).

- "Resiliency is defined as the capability of a system to maintain its functions and structure in the face of internal and external change and to degrade gracefully when it must" (Allenby and Fink 2005, p. 1034).

- [Resilience is] "[t]he ability of systems to absorb changes... and still persist" (Holling 1973, p. 3).

2.1.1.2 Resilience Definitions Containing Both "Before" And "After Event" Components

- "The term 'resilience' refers to the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies" (The White House 2011, p. 6).

- [Extended definition of resilience as the] "[a]bility of systems, infrastructures, government, business, communities, and individuals to resist, tolerate, absorb, recover

[4] This difference is readily apparent when we consider competing definitions of both infrastructure resilience and community resilience.

from, prepare for, or adapt to an adverse occurrence that causes harm, destruction, or loss" (DHS 2010, p. 26).

- "*Resilience* is defined as the ability to minimize the costs of a disaster, to return to a state as good as or better than the *status quo ante*, and to do so in the shortest feasible time… *Resistance* is used to mean the ability to withstand a hazard without suffering much harm. *Resilience* in this paper will include resistance but will also include the ability to recover after suffering harm from a hazard" (Gilbert 2010, p. 11).

- "We see resilience as the aggregate result of achieving specific objectives in regard to critical systems and their key functions, following a set of principles that can guide the application of practical ways and means across the full spectrum of homeland security missions… The objectives (or end states) of resilience that underpin our approach are *resistance, absorption, and restoration*" (Kahan *et al.* 2009, p. 9).

- [Resilience is] "[t]he capacity of a system, community, or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures" (SDR 2005, p. 17).

- "The term 'resilience,"… implies both the ability to adjust to 'normal' or anticipated stresses and strains and to adapt to sudden shocks and extraordinary demands. In the context of hazards, the concept spans both pre-event measures that seek to prevent disaster-related damage and post-event strategies designed to cope with and minimize disaster impacts" (Tierney 2003, p. 3).

2.1.2 Definitions of Infrastructure Resilience

Infrastructure resilience (or what in some circles is referred to as organizational resilience (Stephenson 2010)) is important both in its own right and because it contributes to the resilience of other objects of analysis, such as communities and regions. As Stephenson (2010) has argued:

> "To be resilient, communities rely on services and employment provided by organisations, to enable them to plan for, respond to, and recover from emergencies and crises. However, organisational and community resilience are two sides of the same coin; if organisations are not prepared to respond to emergencies and crises, communities too are not prepared" (p. iii).

Stephenson's position reflects the commonly held view that the resilience of a community's infrastructure is a key determinant of the community's overall resilience. As such, if the infrastructure in a particular community is not resilient, the community's overall resilience will be undermined, all else remaining constant.

- "The QHSR [Quadrennial Homeland Security Review] offers the homeland security enterprise a strategic framework for understanding protection and resilience. The QHSR describes protection efforts as being focused on stopping an attack or disruption from occurring, while resilience efforts are centered on minimizing the consequences of a disaster. As such, it implies that protection and resilience are distinct, complementary, and necessary elements of a comprehensive risk management strategy for the critical infrastructure mission" (SLTTGCC 2011, p. 3).

- "*Resilience* is defined as the ability to minimize the costs of a disaster, to return to a state as good as or better than the *status quo ante*, and to do so in the shortest feasible time… In order to effectively measure and improve resilience, we need to define what bad thing it is we are trying to avoid. That is, we need to know what it is we are trying to protect. Protecting physical infrastructure means limiting damage to buildings and structures, including most lifeline infrastructure" (Gilbert 2010, pp. 11–12).

- "Infrastructure resilience is the ability to reduce the magnitude, impact, or duration of a disruption. Resilience is the ability to absorb, adapt to, and/or rapidly recover from a potentially disruptive event" (NIAC 2009, p. 12).

2.1.3 Definitions of Community Resilience

Risk management at the community level requires consideration of both the risks faced by critical infrastructure and the community's ability to recover from a disruptive event. The latter can be captured by measuring the community's resilience. As was the case when considering both general definitions and definitions of infrastructure resilience, the definitions of community resilience considered here reveal disagreement over whether one or more pre-event actions (e.g., resistance, protection, anticipation, preparedness) should be included in the definition and, consequently, measurement of community resilience as well.

- "***Disaster Resilience*** for regions and communities, refers to the capability to prepare for, prevent, protect against, respond to or mitigate any anticipated or unexpected significant threat or event, including terrorist attacks, to adapt to changing conditions and rapidly recover to normal or a "new normal," and reconstitute critical assets, operations, and services with minimum damage and disruption to public health and safety, the economy, environment, and national security." (TISP 2011, p. 7).

- "The sub-factors of resilience defined in the DHS Risk Lexicon — *resist, absorb, and recover or adapt* — can be … used to describe subordinate objectives (*outcomes*) against which preparedness capabilities (*outputs*) could be measured. Thus, capabilities developed to prevent, protect, and mitigate strengthen our ability to resist hazards; response capabilities enable us to absorb impacts; and recovery capabilities support a return to normalcy — or adaptation to a new norm which may mitigate future impacts… The objective is to strengthen the capacity to 'resist,' through strategies to thwart intentional attacks or other man-made disasters; through protective measures that reduce the probability of failure, like access controls or protective barriers; and by taking steps to reduce the consequences of failure, through measures such as provision of back-up power

or ensuring that critical facilities are not located in areas known to be vulnerable to adverse events" (HSAC 2011, pp. 10–11).

- "A disaster-resilient nation is one in which its communities, through mitigation and pre-disaster preparation, develop the adaptive capacity to maintain important community functions and recover quickly when major disasters occur" (NRC 2011, p. 29).

- [Community resilience is] "[t]he capacity of a system to absorb disturbance, undergo change, and retain the same essential functions, structure, identity, and feedbacks… Resilience in a community setting is the ability of a community to absorb a disturbance while retaining its essential functions" (Longstaff *et al*. 2010, pp. 3,4).

- "We define resilience as: a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation *after* [emphasis added] a disturbance…. community resilience [emerges] from a set of networked adaptive capacities" (Norris *et al*. 2008, p. 130, 135).

- "Efforts should therefore be focused on the promotion of [societal] resilience, i.e., the ability to 'bounce back' after suffering a damaging blow" (Boin and McConnell 2007, p. 54).

- [Community resilience is] "[t]he capacity of a community, its members and the systems that facilitate its normal activities to adapt in ways that maintain functional relationships in the presence of significant disturbances" (Paton 2007, p. 7).

2.2 Synthesis of Different Definitions

As the range of definitions of resilience listed above demonstrates, the most significant difference concerns the timing of specific actions, that is, actions that are taken prior to the occurrence of the adverse event versus those actions that are taken after the event has occurred. The majority of the documents we reviewed define resilience as the ability of an entity to recover, or "bounce back," from the adverse effects of a natural or man-made event.[5] In addition, those same documents take the position, either explicitly or implicitly, that actions taken prior to an adverse event's occurrence (i.e., actions that are typically associated with resistance, protection, anticipation, or preparedness) are not part of resilience. Rather, resistance, protection, anticipation, preparedness-related measures, and resilience-related actions are distinct elements of an overall strategy to address various threats. This view is advocated by Rose (2009), who argues that "[m]y view is that vulnerability is primarily a pre-disaster condition, but that resilience is the outcome of a post-disaster response. Resilience is one of several ways to reduce vulnerability, the others being adaptation and the entirely separate strategy of mitigation" (p. 3).

The preceding observation notwithstanding, several of the documents we reviewed (NRC 2011; HSAC 2011; TISP 2011; DHS 2010; Tierney 2003) include one or more of the concepts of

[5] A review of the literature by Norris *et al*. (2008) yielded results similar to our own; they found that 16 of the 21 studies they examined define resilience as capacities/actions that occur *after* some type of disturbance, stress, or adversity has occurred.

resistance, protection, anticipation, and preparation in their definitions of resilience. This approach is that taken by the U.S. Department of Homeland Security (DHS) (2010) and the Homeland Security Advisory Council's (HSAC's) Community Resilience Task Force (HSAC 2011). Kahan *et al*. (2009) also include resistance in their definition of resilience, observing that,

> Most definitions of resilience do not address the issue of resistance, which we see as integral to a holistic perspective. Of the several definitions we have found in our research, the only one that specifically links resistance-related activities to resilience is that proposed by DHS in its Risk Lexicon document (p. 10).

In fact, Bruneau *et al*. (2003) also include resistance in their definition of resilience, asserting that:

> Resilience can be understood as the ability of the system to reduce the chances of a shock, to absorb a shock if it occurs (abrupt reduction of performance) and to recover quickly after a shock (re-establish normal performance). More specifically, a resilient system is one that shows the following:
>
> - Reduced failure probabilities
> - Reduced consequences from failures, in terms of lives lost, damage, and negative economic and social consequences
> - Reduced time to recovery (restoration of a specific system or set of systems to their "normal" level of performance) (p. 736).

Clearly, actions that contribute to reducing the chances of a shock or reducing failure probabilities would be viewed as protection-related or resistance-related actions. Bruneau *et al*. (2003) also identify a set of properties that further define resilience. One of those properties is *robustness*, which they define as "strength, or the ability of elements, systems, and other units of analysis to withstand a given level of stress or demand without suffering degradation or loss of function" (p. 737). Considering the context in which Bruneau *et al*. (2003) are writing (i.e., seismic resilience), their definition of robustness implies resistance-related activities. This interpretation is supported by Tierney (2009): "robustness refers to the ability to resist disruption and failure and continue functioning effectively…" (p. 6).[6]

The question, then, is whether resistance, anticipation/preparation, or protection should be included as components of resilience. To answer this question, it is instructive to consider the relationships among resistance, anticipation,[7] and protection. First, we assume that resistance, anticipation, and protection involve actions that are taken prior to the occurrence of an adverse event. Second, we assume that certain resistance- and anticipation-related actions are properly viewed as a subset of a broader set of protective measures. This subset of resistance- and anticipation-related actions consists of those actions that are predicated on the assumption that an

[6] It is worth pointing out that Tierney is one of the co-authors of the study by Bruneau *et al*. (2003).

[7] From this point on, we treat anticipation and preparedness as synonymous.

adverse event is going to occur. Such actions are designed to reduce the adverse consequences, both immediate and longer term, that result when an adverse event does occur. For example, building a flood wall to absorb the impacts of anticipated record flood levels would be an action within this subset. Other resistance- and anticipation-related actions that are intended solely to prevent an adverse event from occurring — for example, installing gates at a facility with the goal of *preventing* a terrorist act — are not part of this subset of resistance- and anticipation-related actions.[8] Table 1 lists additional examples of actions predicated on the assumption that an adverse event is going to occur and of actions that are intended solely to prevent an adverse event from occurring.

Distinguishing resistance- and anticipation-related actions from the broader set of protective measures on the basis of whether they take the occurrence of an adverse event as a given provides a straightforward means for distinguishing among the broader set of such actions. Moreover, this distinction reduces the degree of difference among the definitions considered here. Obviously, all of the definitions in which resilience is a function of what happens after an adverse event occurs take the adverse event as a given. Adding in resistance and anticipation-related actions that take the adverse event as a given simply expands the set of resilience-related actions in a clear-cut manner.

Table 1: Distinguishing among Resistance- and Anticipation-Related Actions

Examples of Actions that Assume an Adverse Event is Going to Occur	Examples of Actions Intended to Prevent an Adverse Event from Occurring
▪ Install and monitor closed circuit television (CCTV) ▪ Develop a response/emergency action plan ▪ Install bollards to increase standoff distance ▪ Maintain stockpiles of inputs to production (raw materials) ▪ Develop an evacuation plan ▪ Establish an emergency operations center	▪ Employ entry controls (e.g., guards), perform visitor screening ▪ Install a fence around a facility ▪ Establish procedures for dealing with suspicious packages ▪ Conduct employee background checks ▪ Add razor wire or barbed wire to perimeter fencing

2.3 Our Definition

On the basis of the literature review and the preceding argument, we define resilience as: "the ability of an entity — asset, organization, community, region — to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance." This definition underlies our analysis and proposed approach to the measurement and evaluation of resilience at the facility/asset and community/regional levels. The relationship between the different components of resilience and the occurrence of an adverse event are illustrated in Figure 1. As shown, anticipation-, resistance-, and absorption-related actions are undertaken prior to the occurrence of an adverse event, whereas response, adaptation, and recovery occur afterward. The heavy line in the figure

[8] In the remainder of this paper, the terms resist, resistance, anticipation, and preparation refer specifically to the subset of actions that are taken prior to an adverse event's occurrence on the assumption that an adverse event is going to occur.

represents the level of activity (e.g., production in the case of a manufacturing plant) or of the well-being (e.g., a population's psychological health in the case of a community or region) of the object of analysis. Subsequent to the occurrence of an adverse event, activity/well-being declines. The resilience of the object of analysis determines both the amount by which the activity/well-being declines and the amount of time required to return to the pre-event equilibrium (or some other new equilibrium).

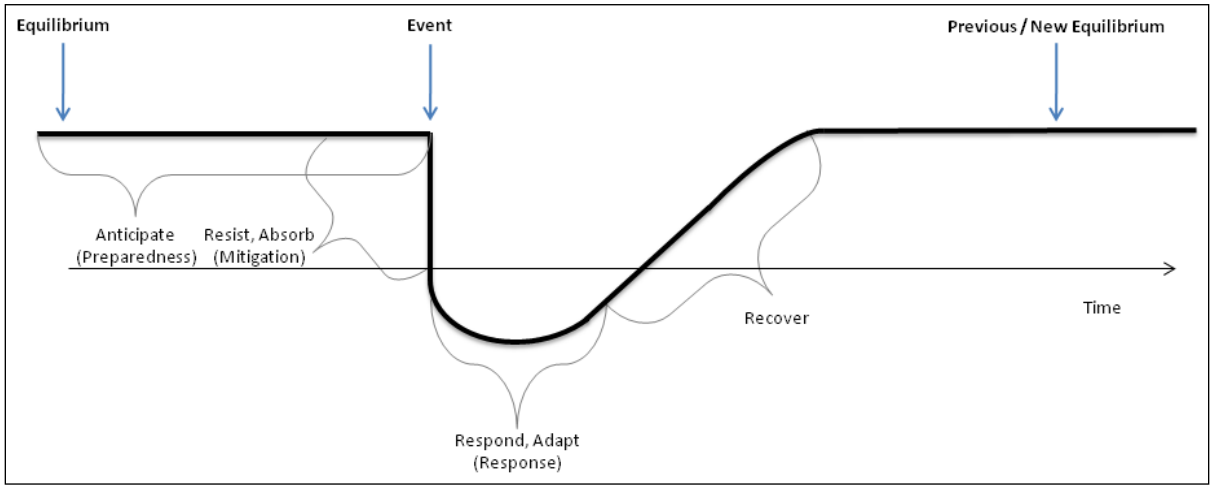

Figure 1: Components of Resilience and the Timing of an Adverse Event

3 Measurement and Evaluation of Resilience

The measurement of resilience at all levels — for example, critical infrastructure, community, region — entails considerable challenges. Moreover, measuring resilience becomes more challenging as we move from critical infrastructure resilience, which focuses on individual assets and facilities, to higher-level aggregates, for example, community or regional resilience (of which critical infrastructure resilience is only one component). This pattern follows from the fact that as we move to the community or regional level of analysis, the determinants of resilience (e.g., supply chain resilience, governance resilience, civil society resilience) become increasingly difficult to quantify. This is a result of such factors as uncertainty about specific relationships (e.g., the composition of specific supply chains [because firms may not be willing to divulge information about specific suppliers]), and data gaps (e.g., measurement of sociological and psychological factors that influence civil society resilience). In addition, time and budget constraints may simply make it impossible to collect all of the information that would be needed to construct a comprehensive assessment of the resilience of a specific community or region. Thus, it is quite likely that as the scope of the object of analysis increases — from critical infrastructure to community/region — so will the gap between theory and practice.

In this section, we address three topics: (1) the systems approach to the assessment of resilience, (2) an improved framework for the measurement and evaluation of resilience at the asset/facility level, and (3) a model for the assessment of resilience at the community/regional level. We begin by briefly describing how a systems approach can be used to effectively prioritize resilience assessment efforts. Next, we discuss how the current version of the Infrastructure Survey Tool (IST) that has been developed by Argonne National Laboratory (Argonne) will be modified to assess the resilience of individual critical infrastructures more accurately. We then present a framework for the assessment of resilience at the community/regional level, which is based in part on the Department of Homeland Security's Regional Resilience Assessment Program (RRAP). The RRAP — which was developed and piloted by DHS in FY2009 and emphasizes infrastructure "clusters," regions, and systems — is designed to identify critical infrastructure dependencies, interdependencies, cascading effects, resiliency characteristics, regional capabilities, and security gaps. [9] In our model, community/regional resilience is a function of the resilience of five subsystems: the local economy, critical infrastructure, governmental/institutional units, civilian population, and relevant supply chains. In addition to providing justification for the inclusion of each of these subsystems, we identify possible data sources that can be used to measure the resilience of each subsystem.

[9] The RRAP process also includes information from tools that are used to measure both the protective measures and resilience measures in place at individual facilities. Reducing the risks associated with natural and man-made events faced by a facility includes both protection against an event happening and resilience once the event has happened. Thus protective measures and resilience measures are all determinants of a facility's ability to reduce risk.

3.1 Systems Approach to the Assessment/Measurement of Resilience

Recognizing budget realities and the need for a process that effectively prioritizes resilience assessment efforts, personnel at DHS have proposed a "systems approach" to the assessment of resilience. Briefly stated, the approach is based on the assumption that a critical asset or facility can be viewed as a system (DHS 2011a).[10] Higher-level constructs (e.g., a community or a region) are composed of several different systems. As such, a community or a region is a "system of systems." Viewed within this framework, "high-level systems analysis informs the identification of the most important lower level systems, within which *site* assessment data on only the most critical asset-level components about which the least is known should be collected." (DHS 2011a, p. 3) An underlying assumption of the discussion that follows is that a "system of systems" approach should be employed in identifying the appropriate scope of a resilience assessment, as well as the specific assets and/or subsystems for which resilience-related information should be collected. In the parlance of systems engineering, this means that we must focus on the "states of the system."

The underlying principle of the system of systems approach is that, to make effective decisions, one must understand the various states of the system in order to influence system outcomes, for example, resilience. According to Haimes (2011):

> The behavior of the states of the system, as a function of time, decision, exogenous and random variables, and inputs, enables modelers to describe, under certain conditions, its future behavior for any given inputs (random or deterministic). For example, to determine the safety of drinking water from a reservoir (as a system), one must determine the states of the water in the reservoir: its acidity, turbidity, dissolved oxygen, bacteria, and other pathogens. To determine the functionality and reliability of a bus, one must know the *states of* the bus's fuel, oil, tire pressure, and other mechanical and electrical components. To treat a patient, a physician first must know the temperature, blood pressure, and other states of the patient's physical health (p. 6).

Using this approach, analysis would consider the high-level context (e.g., a geographic region or an industry sector) and the associated states of these systems, ultimately represented by the most critical assets to inform the scope and focus of a resilience assessment — including the most critical assets from which to collect resilience data.

3.2 Critical Infrastructure Resilience

Because critical infrastructure resilience is a component of community and regional resilience(as are the resilience of social, economic, and other subsystems), it is appropriate to focus first on

[10] A system can be defined as "[a]n organized, purposeful structure regarded as a whole and consisting of interrelated and interdependent elements (components, entities, factors, members, parts, etc.). These elements continually influence one another (directly or indirectly) to maintain their activity and the existence of the system, in order to achieve the goal of the system." http://www.businessdictionary.com/definition/system.html, accessed on December 6, 2011.

the development of a sound approach to its measurement that can stand alone and also serve as an input to the calculation of those other measures. In 2010, Argonne National Laboratory, in collaboration with the DHS Protective Security Coordination Division, developed a measure of the resilience of critical infrastructure. (Argonne 2010) The Resilience Index (RI) was based on the approach recommended by the National Infrastructure Advisory Council, which argued for analyzing the resilience of an organization or system by considering three major components: *robustness, resourcefulness,* and *rapid recovery.* Briefly stated, the RI was constructed from data collected via the IST, which was modified to address various determinants of robustness, resourcefulness, and rapid recovery. The data were weighted and summed to produce an index number that ranges between 0 and 100.

This new task will build on the current RI to construct an improved measure of critical infrastructure resilience by revising the current question set in the IST to conform to our definition of resilience (*the ability of an entity — asset, organization, community, region — to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance*). This effort will consist of deleting, reworking, or adding new questions to the existing question set to produce a more comprehensive infrastructure resilience index, the Resilience Measurement Index (RMI), that will assist in feeding into the broader community/regional resilience assessment discussed in Section 3.3 of this paper.

On the basis of the questions concerning resilience in the current IST, we have categorized four general groupings of measures that together provide a measure of the resilience of a facility (i.e., its ability to withstand and rebound from an event). The proposed major components of the RMI, and the characteristic(s) of resilience to which they correspond, include the following:

- Preparedness (anticipate),
- Mitigation measures (resist, absorb),
- Response capabilities (respond, adapt), and
- Recovery mechanisms (recover).

These major components align closely with the four strategic elements of resilience identified in the DHS (2010) *Quadrennial Homeland Security Review Report*: enhanced preparedness, hazard mitigation, effective emergency response, and rapid recovery.

Table 2 illustrates how the six components found in the definition of resilience are connected to the actions that describe the capacity of an entity to be resilient to a man-made or natural event. The relationships illustrated in Table 2 provide the framework for developing a survey instrument that will be used to elicit the information required to assess resilience at the asset/facility level. In the discussion that follows, we consider each of the major components designed to capture facility resilience, the sub-components that contribute to each major component, and the characteristic(s) of resilience that each sub-component is meant to capture.

Table 2: Relationship between Components of Resilience and Resilience-Enhancing Measures

Anticipate	Resist	Absorb	Respond	Adapt	Recover
Preparedness	**Mitigation**		**Response**		**Recovery**
Activities taken by an entity to define the hazard environment to which it is subject	Activities taken prior to an event to reduce the severity or consequences of a hazard		Immediate and ongoing activities, tasks, programs, and systems that have been undertaken or developed to manage the adverse effects of an event		Activities and programs designed to effectively and efficiently return conditions to a level that is acceptable to the entity

The proposed major components present a more intuitive view of the resilience of a facility. The expanded focus on the components that contribute to the resilience of a facility will provide a more complete calculation of RI and provide better insight on the resilience of some of the Nation's most critical infrastructure. Strengthened understanding of a facility's resilience will enable greater understanding of the items that must be considered when looking beyond the individual asset level — that is, when considering the resilience of the collective — to the community, region, and/or the Nation.

3.3 Community/Regional Resilience

On the basis of our review of the literature (see, e.g., Norris *et al*. 2008; Stewart *et al*. 2009; Longstaff *et al*. 2010; and Cutter *et al*. 2010), we find that community/regional resilience is a function of the resilience of several subsystems, including but not necessarily limited to, the community/region's economy, civil society, critical infrastructure, supply chains/dependencies, and governance (including emergency services). Figure 2, which depicts the process employed in the Department of Homeland Security's RRAP,[11] illustrates a framework that facilitates consistent assessment of community/regional resilience while allowing the specifics of the assessment process to be driven by the scope of the individual assessment. In particular, the figure illustrates steps in the process of identifying the specific scope of a community/regional resilience assessment project. Certain pieces (e.g., site assessments, facilitated discussion/community outreach events) should be part of all community/regional resilience assessments; however, depending on the scope of the analysis in question, the specific facilitated discussion/ community outreach mechanism would change; thus, how the analysis addresses the resilience of the five community subsystems would also change. For example, in certain analyses, analysts might choose to place a heavy emphasis on critical infrastructure, civil society, and governance and thus choose to use multiple analysis tools within those subsystem categories. In other cases, we might expect to see an in-depth analysis of the supply chain/dependencies subsystem so that we could not only determine the resilience of the supply chain but also evaluate how the supply chain contributes to overall community/regional resilience. The basic premise is that, in each analysis, all of the subsystems should be considered as they all contribute

[11] This approach is similar to, and is based in part on, Sandia National Laboratories' Complex Adaptive System of Systems Process, http://www.sandia.gov/CasosEngineering/, accessed on December 1, 2011. For more information on the DHS RRAP, see http://www.dhs.gov/files/programs/gc_1265397888256.shtm.

to community/regional resilience; however, there should be flexibility regarding the depth of analysis and the tools that are used.

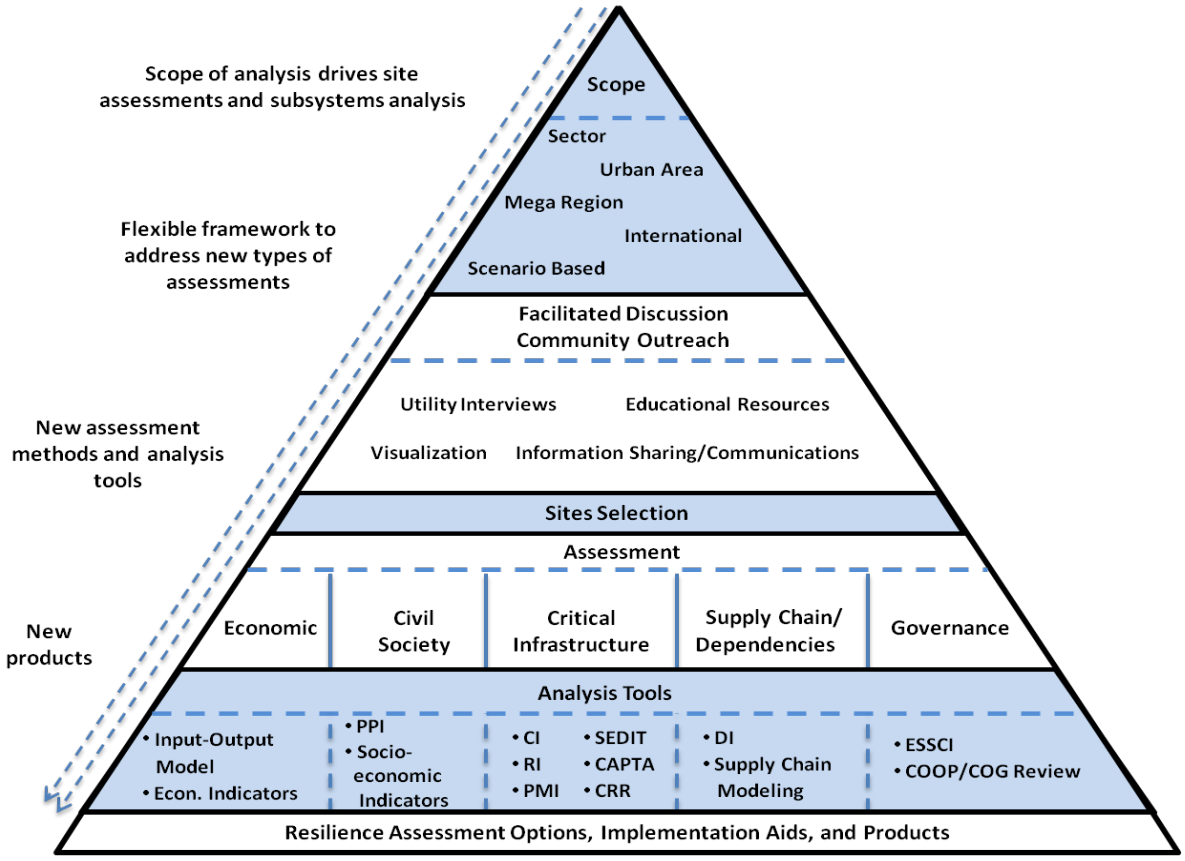

Figure 2: Community/Regional Resilience Framework[a]

[a] CAPTA = Costing Asset Protection: An All Hazards Guide for Transportation Agencies; CI = criticality index; COOP/COG = continuity of operations/continuity of government plans; CRR = Cyber Resiliency Review; DI = Dependencies Index; ESSCI = Emergency Services Sector Capabilities Index ; PPI = Public Preparedness Index; PMI = Protective Measures Index; RI = Resilience Index; SEDIT = Special Events and Domestic Incidents Tracker.

Figure 3 illustrates the relative contribution that the proposed approach can potentially provide to our overall understanding and analysis of the five subsystems of community/regional resilience identified in Figure 2. For example, a site assessment of a critical infrastructure (e.g., a water treatment plant) can provide a significant amount of data to inform resilience given that the community/region has a strong dependency on the water plant. However, a site assessment of a water treatment plant would provide less information about civil society resilience.[12] Information on civil society resilience can be more appropriately obtained through indices such as the Public Preparedness Index (PPI) (Petit *et al.* 2011) and open source data (e.g., American Community

[12] It is important to note that we did find direct ties between existing and/or potential new site assessment questions and each of the five subsystems of community resilience (e.g., we can go into a water treatment plant and ask at least a few questions that would inform the civil society subsystem analysis).

Survey[13]). The relative size of the blue bubbles shows that, for example, if we wanted to assess the civil society subsystem of a community at the same level as the critical infrastructure subsystem analysis, we would need to make use of additional data collection methods and tools outside of the site assessments. Examples of these additional tools are identified in the bottom row of Figure 2.

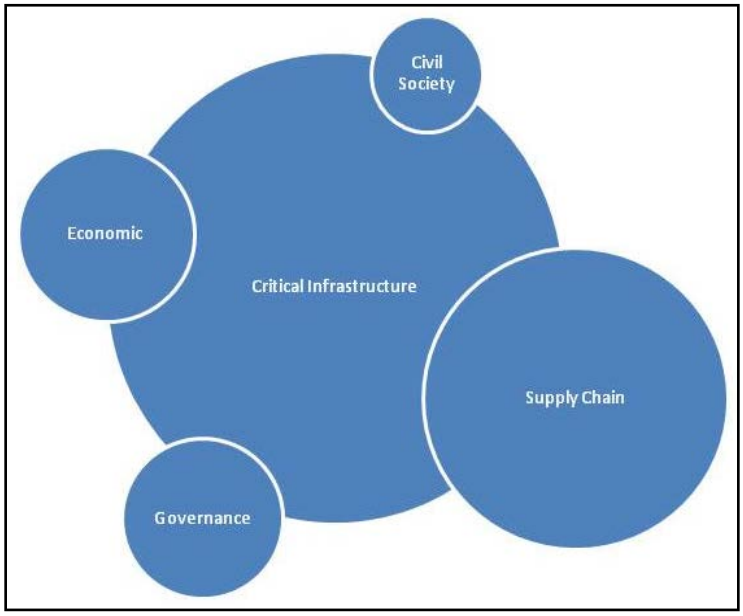

Figure 3: Site Assessment Contribution to Community Resilience Analysis

[13] http://www.census.gov/acs/www/, accessed December 1, 2011.

3.3.1 Definition and Measurement of Components of Community/Regional Resilience

As we have stated, in our model, community/regional resilience is a function of the resilience of the following five subsystems: the community's economy, the civilian population, critical infrastructure, supply chains, and governmental and institutional units. Definitions and approaches to the measurement of each of these components are presented below.

3.3.1.1 Economic Subsystem

Economic resilience is defined variously as (1) a function of the fairness of risk and vulnerability to hazards, the level and diversity of economic resources, and the equity of resource distribution (Norris *et al*. 2008); (2) the ability of a system to recover from a severe shock and includes both inherent and adaptive resilience (Stewart *et al*. 2009); (3) being composed of people, firms, and institutions that interact to accomplish the production, distribution, and consumption of goods and services (Longstaff *et al*. 2010); and (4) a measure of the economic vitality of communities based on housing capital, equitable incomes, employment, business size, and physician access (Cutter *et al*. 2010). Considering these definitions, economic resilience clearly has important implications for all five of the properties of resilience (anticipate, resist, absorb, respond/adapt to, and recover).

Potential tools/approaches/variables that might be used to measure economic resilience at the community/regional level include the following:

- Building Resilient Regions Resilience Capacity Index (RCI)[14] : Specific RCI indicators that could be apportioned to Economic Resilience are listed in Appendix B.
- Shannon Diversity Index (which can also be used to measure the level of diversification of the local economy).
- Input-output modeling of critical infrastructure interdependencies.
- 360-degree review of CI sectors and cascading risks (Macaulay 2009).

3.3.1.2 Civil Society Subsystem

It should be clear that the public's inability to adapt to, respond to, and recover from a disturbance will seriously limit the ability of a community or region to bounce back, regardless of the resilience of the other subsystems considered here. Longstaff *et al*. (2010) define *civil society* as the formal and informal modes of social organization and collective action outside of governmental authority (i.e., nongovernmental and philanthropic organizations, health and human service organizations, faith-based organizations, unions, associations). Cutter *et al*. (2010) define *community capital resilience* as the relationships that exist between individuals and their larger neighborhoods and communities. Norris *et al*. (2008) define *social capital* as a

[14] http://brr.berkeley.edu/rci/, accessed on November 6, 2011.

function of received (enacted) and perceived (expected) social support; social embeddedness (informal ties); organizational linkages and cooperation; citizen participation, leadership, and roles (formal ties); a sense of community; and attachment to place. Stewart *et al*. (2009) define social resilience as social systems within which communities build relationships among people and businesses, as well as communication channels for gathering and disseminating information.

Potential tools/approaches/variables that might be used to measure civil society resilience at the community/regional level include the following:

- Argonne's PPI (Petit *et al*. 2011).
- Building Resilient Regions RCI: Specific RCI indicators that could be apportioned to civil society resilience are listed in Appendix B.
- The Federal Emergency Management Agency (FEMA) Emergency Planning for First Responders and their Families (FEMA 2011).
- FEMA Personal Preparedness in America: Findings from the 2009 Citizen Corps National Survey[15] (FEMA 2009).

3.3.1.3 Critical Infrastructure Subsystem

As we have discussed earlier in this report, critical infrastructure resilience is a critical determinant of community/regional resilience. Stewart *et al*. (2009) define *critical infrastructure resilience* to include the actual infrastructure and the owner/operator capabilities needed to create a positive trajectory of functioning and adaptation after a disturbance has occurred. Longstaff *et al*. (2010) define *physical infrastructure subsystems* as:

> …the substructure or underlying foundation or network used for providing goods and services; especially the basic installations and facilities on which the continuance and growth of a community depend, including roads, water systems, communications facilities, sewers, sidewalks, cable, wiring, schools, power plants, and transportation and communication systems. (p. 12)

Cutter *et al.* (2010) define *infrastructure resilience* as "mainly an appraisal of community response and recovery capacity (e.g. sheltering, vacant rental housing units, and healthcare facilities) (p. 9)."

[15] The survey script found in Appendix B of this document might also be adapted to fit infrastructure owner/operators. Currently, the questions are designed for use in collecting data from individual households.

Potential tools/approaches/variables that might be used to measure critical infrastructure resilience at the community/regional level include the following:

- Argonne's infrastructure RI (Argonne 2010).
- Electric System Reliability Indices, for example, the System Average Interruption Duration Index (SAIDI) and the Customer Average Interruption Duration Index (CAIDI).[16]
- The U.S. Department of Energy Local Government Energy Assurance model/questions and plan development steps[17] (see Energy Assurance Plan Steps A, B, and C in Appendix A).
- The U.S. Environmental Protection Agency's Community-Based Water Resiliency (CBWR) Initiative and assessment tool.
- The National Institute of Standards and Technology Contingency Planning Guide for Information Systems.[18]
- National Communications System's (NCS) Route Diversity Project/Tools.
- NCS questions/data used to form Regional Characterization reports.
- National Cooperative Highway Research Program Costing Asset Protection: An All-Hazards Guide for Transportation Agencies (CAPTA) (NCHRP 2009).
- Population commute times, travel patterns, and traffic congestion from the U.S. Census.
- Various Metropolitan Planning Organization travel demand models.

3.3.1.4 Supply Chain/Dependencies Subsystem

The study by Stewart *et al*. (2009) is the only one that explicitly includes supply chain resilience, which they define as:

> [t]he capability of supply chain operators to manage the consequences, which impact their ability to exchange value with supply chain partners located within and outside the impact area. Supply chains exist in both private and public sectors and often involve collaboration across sectors.

[16] Electric System Reliability Indices available at http://l2eng.com/Reliability_Indices_for_Utilities.pdf, accessed on November 28, 2011.

[17] http://www.pti.org/docs-sust/LocalGovernmentEnergyAssuranceGuidelines.pdf, accessed on November 28, 2011.

[18] http://csrc.nist.gov/publications/nistpubs/800-34-rev1/sp800-34-rev1_errata-Nov11-2010.pdf, accessed on November 28, 2011.

This definition is included in their list of the determinants of community resilience. Stewart *et al*. (2009) suggest measures of supply chain resilience, including redundancy (establishment of reserves or back-up options that can be deployed in times of disruption), flexibility (sensing capabilities that enable enterprises to identify potential threats and respond accordingly), density (number and geographical spacing of supply chain nodes), complexity (number of supply chain nodes and interconnectedness of the nodes), node criticality (ability to prioritize post-disaster action around nodes that are important to the recovery of the chain), and public-private partnerships (legal bonds, operational linkages, information exchange mechanisms, cooperative norms, and relational contracts). Supply chain resilience should also consider the physical, geographical, cyber, and logical dependencies/interdependencies existing between critical nodes and links.

Potential tools/approaches/variables that might be used to measure supply chain resilience at the community or regional level include the following:

- Various Argonne models:
  - Dependencies Index.
  - EPFast (model for simulating uncontrolled electric grid islanding and for performing load flow analysis)
  - NGFast (model for natural gas pipeline breaks and downstream impacts).
  - POLFast (model for estimating impacts on U.S. petroleum industry).
  - Restore© (model of the complex set of steps required to accomplish a goal, such as repair of a ruptured natural gas pipeline).

- Sandia's Complex Adaptive Systems of Systems Applications (Glass and Ames 2008):
  - Petrochemical supply chains.
  - Food Defense: Detailed Topological Mapping of Food Supply Chains.
  - Strategic Recovery Model.

3.3.1.5 Governance/Institutional Subsystem

Longstaff *et al*. (2010) define *governance resilience* as a function of the public organizations (political, administrative, legislative, and judicial institutions) that contribute to the administration of government functions of the community and the processes through which government institutions, or any group of people with a mandate or with a common purpose, make decisions. Cutter *et al*. (2010) define *institutional resilience* as a function of the capacity of communities to reduce risk, to engage local residents in mitigation, to create organizational linkages, and to enhance and protect the social systems within a community. The two studies cite the connectedness of the various units of government in times of disruption; the cost and quality of services delivered in relation to the resources collected from the citizens; the strength of the government's mandate to act on the citizens' behalf, government's capacity to institutionalize and adapt lessons learned, and the extent of discretionary authority granted to government officials during a crisis (Longstaff *et al*. 2010); and political fragmentation and the percent of municipal expenditures for fire, police, and emergency medical services (Cutter *et al*. 2010) as possible determinants of governance/institutional resilience. Emergency services will also have a

large impact on the community's ability to absorb, respond to, and recover from a disturbance and captures information and communication resilience as called for by Norris *et al*. (2008).

Potential tools/approaches/variables that might be used to measure governance/institutional resilience at the community/regional level include the following:

- Argonne's Emergency Services Sector Capabilities Index (Shoemaker *et al*. 2011).
- FEMA Emergency Planning for First Responders and their Families (FEMA 2011).
- Variables cited in the American Planning Association's Policy Guide on Security.[19]
- The National Oceanic and Atmospheric Administration (NOAA) Coastal Resiliency Index. Questions can be gathered from portions of that index, as detailed below. Specific examples are listed in Appendix C.
  - Community Plans and Agreements[20]
  - Mitigation Measures[21]

[19] http://www.planning.org/policy/guides/adopted/security.htm, accessed on November 6, 2011.

[20] http://www.seagrant.noaa.gov/focus/documents/HRCC/resiliency_index_7-15-08.pdf, accessed on November 6, 2011.

[21] Ibid.

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4 Making the Case for Participation in the Assessment of, and Investment in, Resilience

A strong case can be made for enhancing resilience at various levels — asset, community, regional, national — in terms of the social benefits that would accrue from such actions. Social benefits notwithstanding, investment in enhanced resilience can be costly in terms of both time and resources. Recognizing that more than 85%[22] of critical infrastructure is privately owned and operated, it is important to be able to convince owners and operators that investment in both the assessment and, where necessary, the enhancement of resilience is in their interest. At the community and regional levels, we must also acknowledge the fact that government budgets are severely strained in the current economic environment. Thus, local and regional governments must also be convinced that investment in assessment and enhancement of regional resilience will benefit their constituents, as well.

4.1 Infrastructure Resilience

Although owners/operators of privately owned critical infrastructure are ultimately concerned with the "bottom line," there is nevertheless growing awareness in the business community that enhanced resilience is part of a well-designed strategy to enhance a business's ability to withstand various shocks — for example, natural and man-made disasters, supplier outages, industrial accidents, or economic shocks — and thus enhance the business's competitive position. A variety of organizations and private sector firms, including Business Resilience Certification Consortium International (BRCCI), Business Continuity Institute (BCI), Stephenson Resilience, and IBM, have been offering assessments of business resilience services to prospective clients for several years. The partnership between Dow Chemical Company and Ohio State University's Resilience Center to develop the Supply Chain Resilience Assessment and Management tool[23] is another example of the move to enhance business resilience. This increased focus on resilience reflects a growing appreciation in the private sector of the importance of effectively managing risks that can range from natural and man-made disasters to market and regulatory shocks. As a recent report by IBM noted,

> Organizations are adapting to an increasingly complex global environment with more holistic approaches to business resilience planning. Traditional business continuity plans — typically with a strong IT focus — are still critical, but they are becoming part of a bigger picture, as senior executives strengthen their oversight of enterprise-wide risk management. To ensure business resilience, companies are moving toward a risk management process that both addresses the myriad types of risk that functions across the organization face, and encompasses all facets of risk management, from its identification through to mitigation (IBM 2011, p. 2).

[22] http://www.dhs.gov/files/partnerships/editorial_0206.shtm, accessed December 1, 2011.

[23] Dow Chemical Joins Resilience Program, http://resilience.osu.edu/CFR-site/pdf/Dow_Resilience.pdf, accessed December 5, 2011.

IBM defines business resilience as

> … the ability of enterprises to adapt to a continuously changing business environment. Resilient organizations are able to maintain continuous operations and protect their market share in the face of disruptions such as natural or man-made disasters. Business resilience planning is distinguished from enterprise risk management (ERM) in that it is more likely to build capacity to seize opportunities created by unexpected events. Another difference is that while ERM can be implemented as a management capability, an integrated business resilience strategy requires the engagement of everyone in the organization, and often means a change in corporate culture to instill awareness of risk (IBM 2011, p. 3).

This definition is very similar to the definition of community resilience as it relates to the involvement of everyone who could potentially be affected by an unexpected event.

Consistent with IBM's position that, while they are similar, business resilience planning and ERM are not the same thing, the BRCCI has taken the following position:

An effective business resilience program requires a concerted effort to achieve resilience objectives from different areas of expertise within an organization. The following three areas are essential for establishing a business resilience program:

- Business continuity planning (BCP),
- Business resilience strategy planning (BRSP), and
- Enterprise risk management (ERM).[24]

To secure the cooperation of private owners/operators of critical infrastructure, infrastructure analysts need to be able to present a convincing argument to the owner/operator that he/she will receive tangible benefits by allowing analysts to conduct a resilience assessment. To be persuasive, infrastructure analysts need to be able to:

- Explain how enhanced resilience can benefit the owner/operator;

- Explain how the completion of the resilience assessment will provide information that the owner/operator needs to improve the facility/asset's resilience in a cost-effective manner; and

- Demonstrate an understanding of the factors that must be considered in assessing the business resilience of individual facilities or assets, that is, factors that guide the development of an effective business resilience program.

[24] http://www.brcci.org/business+resilience+model.htm, accessed November 3, 2011.

Regarding the third bullet, a partial list of such factors includes the following:

- Characteristics of the business continuity management process.

- Risk management measures that businesses should consider, including:

  – Investment in new information technology solutions related to risk management, including:
    - Data and application security,
    - Data protection,
    - Infrastructure security,
    - Compliance management,
    - Security governance and risk management, and
    - Identity and access management. (IBM 2011, p. 3)

  – Creation of a business continuity plan.

  – Development of a communications or training program to enhance its business continuity or resilience strategies.

  – Establishment of a company-wide risk management team.

  – Development of an integrated business resilience strategy.

  – Discussion of business resilience issues with supply chain partners.

  – Response to the recent increase in natural disasters by re-thinking business continuity strategies.

  – Assignment of overall responsibility for risk management across the organization to a single executive.

  – Engagement of an external risk management advisor (IBM 2011, p. 6).

Additional factors that have been cited include:

- Emergency response planning,
- Risk and vulnerability assessments, and
- Supply chain resilience planning.[25]

[25] http://www.stephensonresilience.co.uk/ourservices, accessed November 6, 2011.

4.2 Community/Regional Resilience

As we noted in the introduction to this section, governmental units at all levels are facing increasingly strained budgets in the current economic environment. Therefore, suggestions that local governments should expend scarce resources on assessing and enhancing resilience are likely to be met with varying amounts of resistance. Thus, it is important to be able to demonstrate the benefits that increased resilience can be expected to yield.

As we discussed in Section 3.3.1.5, public organizations (e.g., emergency services, floodplain management) will have a large impact on the ability of a community or region to absorb, respond to, and recover from a disturbance (i.e., community/regional resilience). The Emergency Management Accreditation Program (EMAP) assesses a region's emergency management capabilities. EMAP has identified several benefits of achieving accredited status, including the following:

- Provides benchmarks for program management and operations,
- Focuses on comprehensive emergency management,
- Encourages the collaboration of state- and community-wide programs rather than focusing on individual agencies,
- Enhances operational continuity and resiliency,
- Validates professional capabilities,
- Demonstrates effective use of public resources and provides justification for resources, and
- Encourages intra- and interagency communication and team building through the assessment and accreditation process (EMAP 2006, p. 4).

In addition, the National Flood Insurance Program's (NFIP) Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from a community's actions. For communities participating in the NFIP's CRS, flood insurance premium rates are discounted on the basis of 18 creditable activities, which are organized under four categories:

- Public Information,
- Mapping and Regulations,
- Flood Damage Reduction, and
- Flood Preparedness (NFIP 2006).

Although the EMAP program is focused specifically on emergency planning and the NFIP's CRS is focused on floodplain management, the benefits listed above apply more generally to the

assessment and enhancement of community/regional resilience, as well. Additional benefits that communities and regions with higher levels of resilience should experience include smaller adverse impacts on such variables as employment, income, consumer and business spending, tax receipts, interruption of essential services, and higher levels of societal cohesion and well-being than communities and regions with lower resilience would have, all else equal.

We have observed over three years of conducting the DHS Regional Resilience Assessment Program in communities throughout the country that there is a need for, and opportunity to, institutionalize resilience considerations in the infrastructure development process (DHS 2011b). This objective can be accomplished through recognition of resilience factors "built in" to official foundational documents, such as local comprehensive plans, land use plans, zoning standards, building codes, transportation plans, and urban design guidelines. With direct guidance in local plans, it would be easier to interject resilience considerations into a project in such a way that these measures become part of the established scope of work and budget and receive appropriate agency representation in project stakeholder groups. Often, resilience measures can be designed into a project at minimal or even no cost if they are considered from the project's inception. As recently reported, however, by the State, Local, Tribal, and Territorial Government Coordinating Council (SLTTGCC), which was convened to facilitate a wider conversation among national critical infrastructure mission partners regarding infrastructure resilience, there is a significant amount of work that needs to be done to bring the planning/design community together with the emergency response/law enforcement community to facilitate successful development of resilient infrastructure. This gap is illustrated in the SLTTGCC's response to the 2010 Quadrennial Homeland Security Review Report's recommendation that "design of new infrastructure and infrastructure improvements anticipate change in the risk environment, incorporate lessons from past events and exercises, and consider and build in security and resilience from the start" (DHS 2010, p. 42). The SLTTGCC stated that opportunities to "design-in" resilience do not fall under its area of responsibility. However, recognizing the importance of resilient infrastructure design, Council members did recommend that the DHS Office of Infrastructure Protection consider convening forums with State, local, tribal, and territorial officials to explore design standards as an element of risk reduction (SLTTGCC 2011).

The emerging national resilience imperative is underscored by Presidential Policy Directive-8 (The White House 2011) and the Quadrennial Homeland Security Review's (DHS 2010) recognition of resilience as a foundational element essential to a comprehensive approach to homeland security. Both the June 2011 Homeland Security Advisory Council's *Community Resilience Task Force Recommendations* (HSAC 2011) and the November 2010 *Designing for a Resilient America: A Stakeholder Summit on High Performance Resilient Buildings and Related Infrastructure* (NIBS 2010) provide more explicit direction for carrying out this charge through collaboration with the planning/design community. Relevant portions of these two reports are summarized below.

The HSAC Community Resilience Task Force provides the following recommendations to build resilient communities.

- *Leverage existing Federal assets*. DHS, in conjunction with the General Services Administration and local officials, should develop a Resilient Community Initiative that leverages Federal assets and programs to enable community resilience.

- *Align Federal grant programs to promote and enable resilience initiatives.* DHS should review and align all grant programs related to infrastructure or capacity building and should support development of synchronized strategic master plans for improvement of operational resilience throughout the Nation.

- *Enable community-based resilient infrastructure initiatives.* DHS should transform its critical infrastructure planning approach to more effectively enable and facilitate communities in their efforts to build and sustain resilient critical infrastructures.

- *Enable community-based resilience assessment.* DHS should coordinate development of a community-based, all-hazards American Resilience Assessment methodology and toolkit (HSAC 2011, pp.4–5).

The *Designing for a Resilient America Stakeholder Summit on High Performance Resilient Buildings and Related Infrastructure,* was held on November 30–December 1, 2010, at the American Institute of Architects Headquarters in Washington, D.C. It was attended by 82 experts from the building industry, Federal agencies, State and local governments, universities, and professional and trade organizations (NIBS 2010). The goals of the summit were to bring the gathering's collective recommendations to the President, members of Congress, and senior representatives from Federal government departments and agencies and to issue a call for action by government and industry to address the critical requirements of resilience. Eighteen specific recommendations resulted from the Summit, including the following four recommendations most relevant to community resilience:

- DHS should support State and local planning and regulatory entities to advance the application and enforcement of resilient design for buildings and infrastructure in communities (NIBS 2011, p. 11).

- Urban and community planning and zoning organizations should develop strategies to build in resilience to all hazards for maintaining the functionality of infrastructure (NIBS 2011, p. 11).

- The Stafford Disaster Relief and Emergency Assistance Act[26] should be updated to include provisions for community resiliency planning and evaluation in an all-hazards approach as a prerequisite to receiving Federal grant monies, including establishing a national infrastructure bank to be used to finance resilience projects (NIBS 2011, p. 7).

[26] The Robert T. Stafford Disaster Relief and Emergency Assistance Act, signed into law November 23, 1988, constitutes the statutory authority for most Federal disaster response activities, especially as they pertain to FEMA and its programs.

- An interagency MOU should be implemented among all Federal agencies involved in urban planning, design, construction, and operations related to buildings and infrastructure. The MOU should establish an Interagency Resilience Working Group to identify and share tools and best practices and to coordinate the implementation of resilient design activities for Federal buildings (NIBS 2011, p. 11).

Because of the necessity of dealing with significant disasters ranging from terrorist attacks to catastrophic drought, certain areas of the country have already developed valuable resilience partnerships. Primary examples of communities/regions that have undertaken resilience initiatives include the following:

- With the 2002 National Capital Urban Design and Security Plan, the National Capital Planning Commission (NCPC)[27] led the Nation in finding innovative urban design solutions to meet heightened perimeter security requirements. Most recently, an NCPC-sponsored design competition is being used to inform the development of security alternatives for President's Park South that will be undertaken by the National Park Service and the United States Secret Service.[28] These alternatives will be examined through a Federal and local review and approval process, including a National Environmental Protection Act Environmental Assessment.

- Possibly because of its having experienced a series of severe droughts over the past decade, the City of Raleigh recognized water as a key planning issue in its 2030 Comprehensive Plan. The Plan made policy recommendations to establish the ability to provide interconnects with other water utility systems for use in times of drought or other emergency situations; it also promoted a series of water conservation measures even during periods of adequate supply. Water conservation saves energy and normalizes practices, which will help the City cope with the ups and downs of rainfall patterns.[29]

- The Hillsborough County, Florida, Metropolitan Planning Organization's (MPO) 2025 Long-Range Transportation Plan (LRTP) addresses security of the region's transportation system to meet Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) funding and authorization requirements.[30] SAFETEA-LU requires consideration of the security of a region's transportation system as a stand-alone planning factor. As part of the Hillsborough MPO's LRTP development, transportation planners actively engaged with emergency management and first responder agencies to ensure that considerations, such as hurricane evacuation and emergency access, were represented in the transportation project prioritization process.

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[27] http://www.ncpc.gov/ncpc/Main(T2)/Planning(Tr2)/PlanningStudies(Tr3)/Security.html, accessed July 17, 2011.

[28] President's Park South Design Competition, http://www.ncpc.gov/ppdc/index.html, accessed July 17, 2011.

[29] City of Raleigh 2030 Comprehensive Plan, http://www.raleighnc.gov/business/content/PlanLongRange/Articles/2030ComprehensivePlan.html, accessed July 18, 2011.

[30] Hillsborough County MPO 2025 Long Range Transportation Plan, http://www.hillsboroughmpo.org/pubmaps/pubmaps_folders/folderlrtp/lrtp_document/lrtp_document_files/LRTP_Ch_4%20Intermodal%20Trans_06-07.pdf, accessed July 17, 2011.

A strong case can be made for the benefits of increased resilience; however, the cost side of the equation must be addressed, as well. An important factor to consider in this regard, and one that community and regional leaders must be made aware of, is the variety of funding opportunities available at the Federal and State levels. Several such opportunities are listed and described in Appendix D.

5 The Path Forward

Implementation of the strategies described in Sections 2 through 4 — specifically, the adoption of a consistent definition of resilience, modification of the current IST to produce additional resilience-focused information/data at the facility level, and the development of a strong case for enhancing resilience at various levels (asset, community, region) — will facilitate realization of the following four objectives, namely, to:

(1) Develop a methodology and supporting products to assess resilience at the facility level,

(2) Develop a methodology and supporting products to assess resilience at the sector level,

(3) Provide resilience-related information to critical infrastructure owners/operators to facilitate risk-based resource decision making, and

(4) Provide resilience-related information to State and local mission partners that will support their risk-based, resource decision-making process.

As the discussion that follows demonstrates, the four objectives considered here are interdependent and sequential.

5.1 Develop a Methodology and Supporting Products to Assess Resilience at the Facility Level

This objective will be accomplished by modifying Version 3 of the IST to produce a new, enhanced version of the current RI. As was described in Section 3.2, Version 2 of the RI will include four major components:

- Preparedness,
- Mitigation Measures,
- Response Capabilities, and
- Recovery Mechanisms.

Questions in the current version of the IST will be assigned to each of these four components, and new questions will be added to ensure collection of the information required to compute the new RI.

Achieving this objective will yield two deliverables:

- Version 4 of the IST; and
- Version 2 of the RI.

These new tools will be used first in the Regional Resilience Assessment Program and then in other DHS programs (e.g., Enhanced Critical Infrastructure Protection and Site Assessment Visits). Version 2 of the RI will be developed and operational by January 2013. Accomplishing

this first objective will support objectives 2–4 and will constitute the basis for regional resilience assessments.

5.2 Develop a Methodology and Supporting Products to Assess Resilience at the Sector Level

The second objective is to develop a process for characterizing the resilience of each of the 18 critical infrastructure sectors. This process, which will employ the data collected with Version 4 of the IST and Version 2 of the RI, will support the analysis of critical infrastructure resilience within each sector.

Achieving this objective will yield two deliverables:

- An improved understanding of the primary resilience-related characteristics of each critical infrastructure sector, and
- Identification of sector strengths and weaknesses in term of resilience.

This objective may also support the development of resilience reports for each critical infrastructure sector for inclusion in the Infrastructure Protection Report Series. Because the development of the sector-level resilience assessments will require that the needed data be collected with Version 2 of the RI, there will be a delay between the implementation of Version 2 and the development of sector-level resilience assessments.

5.3 Provide Resilience-Related Information to Critical Infrastructure Owners/Operators to Facilitate Risk-Based Resource Decision Making

The third objective is to provide information that critical infrastructure owners and operators can use when deciding whether to enhance their facility's resilience. This objective will guide the selection of the format(s) in which the information that is collected and assessed will be presented to critical infrastructure owners/operators with the tools developed in the two first objectives. The formats for making information available to owners/operators will be adapted to their specific needs. Possible formats include interactive presentations (e.g., dashboards that allow the consideration of different options for increasing resilience) and more formal documents (e.g., reports, concept drawings[31], graphs). An illustrative dashboard screen is shown in Figure 4.

[31] That is, early-stage architectural or engineering drawings, which are generally referred to as "conceptual."

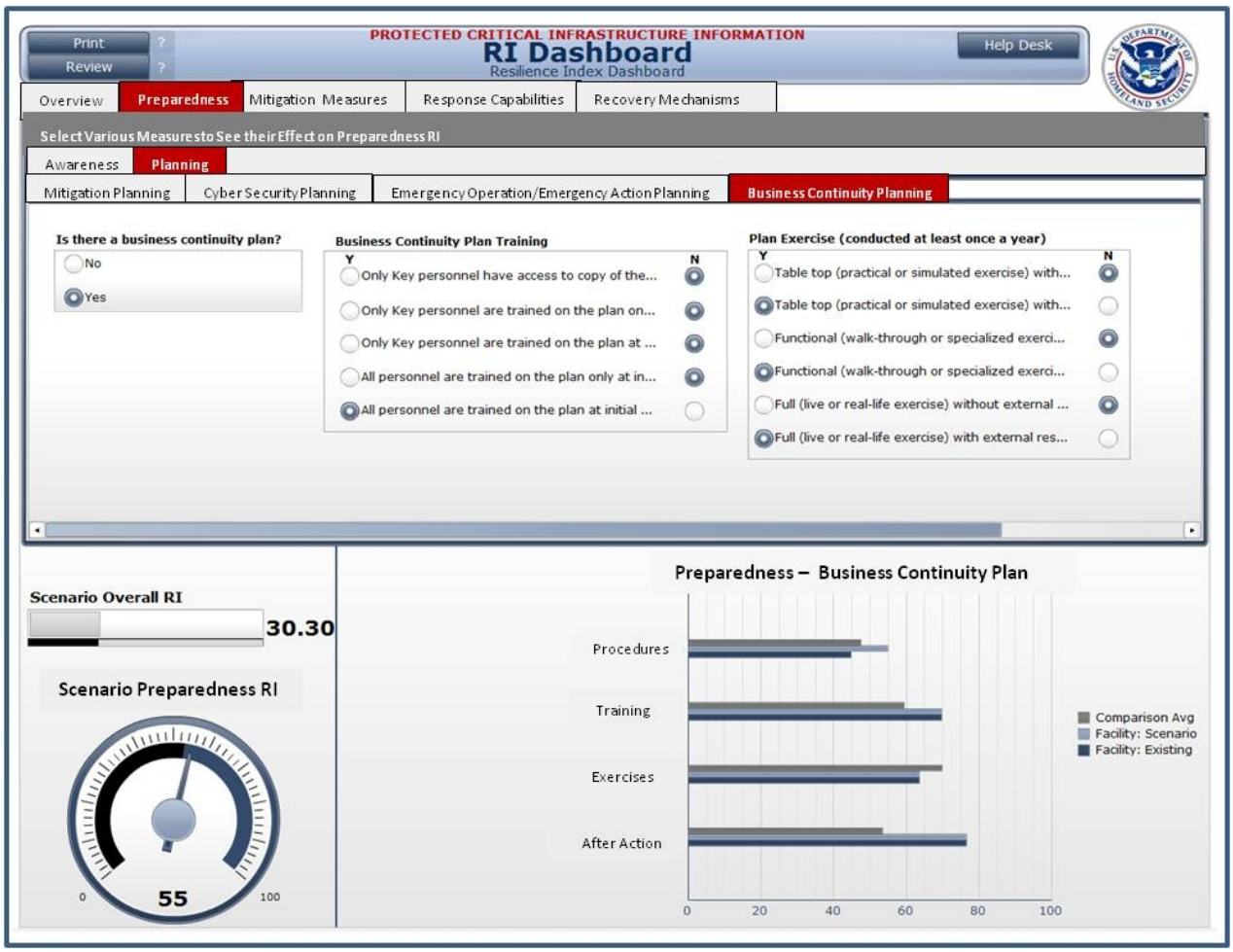

Figure 4: Representative Dashboard Presentation

Referring to Figure 4, different tabs at the top of the dashboard screen allow the user to select one of the four major Resiliency Index components: Preparedness, Mitigation Measures, Response Capabilities, and Recovery Mechanisms. When one of these components is selected, the corresponding subcomponents appear in the middle of the screen, which enables the user to choose the different characteristics that apply to his/her facility. At the bottom of the screen, the user can see — in real time — the repercussions of modifying each of these components in the different RI values that result. Three representations are used to support this functionality (moving clockwise from the bottom left of the screen):

- A gauge shows the value of the RI for the selected level 1 component (i.e., preparedness),
- A counter shows the value of the overall RI, and
- Bar charts show the values of indices for the lower-level components and compare them to the subsector averages.

The ability to change the parameters, the speed with which users can see the results, and the possibility for assessing different scenarios all serve to make the dashboard a very powerful tool and particularly relevant for helping to manage risk-related decisions about critical infrastructures.

Achieving this objective will yield one deliverable:

- Identification of effective means to provide resilience-related information to critical infrastructure owners/operators.

5.4 Provide Resilience-Related Information to State and Local Mission Partners That Will Support Their Risk-Based, Resource Decision-Making Process

The fourth objective is to assist State and local officials in the development of restoration and risk management programs. This objective will be accomplished by identifying the types of resilience-related information that State and local mission partners currently lack but that is critical to a well-informed decision-making process.

Achieving this objective will yield two deliverables:

- Determination of information needed by State and local officials to support their restoration and risk management programs; and

- Methods for displaying and sharing this information.

5.5 Summary

Two factors — the emergence of resilience as a critical component of a comprehensive risk management strategy and the acknowledgement that critical infrastructure is an important component of regional resilience — have necessitated the development of a sound methodology to assess the resilience of the Nation's critical infrastructure. On the basis of a review of the literature covering the basic concept, as well as the application of the concept of resilience at the critical infrastructure and community/regional levels, we developed a working definition for the measurement of resilience. A basic framework for measuring resilience at the infrastructure level with a single survey tool was then presented. As we move to the community/regional level, the assessment of the resilience becomes a much more complex task that involves investigation of the resilience of numerous aspects of the community or region, including the local economy, critical infrastructure, civil society, governance (including emergency services), and supply chains. The methodology required to capture resilience at the community/regional level is very complex and will involve not only surveys of individual assets but discussions with stakeholders, identification of critical community and regional capabilities, and identification of interdependencies among these entities.

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Appendix A: Energy Assurance Plan Steps A, B, and C

Checklist A: Facility Analysis

1. Inventory facilities
2. Identify facility ownership/management
3. Determine facility criticality
4. Prioritize facilities based on their functions/impacts
5. Identify required operations for critical and essential facilities
6. Identify energy sources for required operations
7. Calculate energy demand for required operations
8. Identify low-cost/no-cost back-up alternatives
9. Estimate energy demand contribution for alternatives
10. Identify current back-up systems, locations, and energy output
11. Calculate energy shortfall for each facility
12. Calculate reduced energy demand from alternatives and options
13. Identify and evaluate opportunities for meeting shortfall
14. Develop a strategic investment plan to harden facilities

Checklist B: Fuel Supply

1. Onsite generators are routinely exercised, fueled, and in stand-by mode.
2. Fuel storage capacity (diesel and gasoline) exists for multiple days for required operations.
3. Fuel supplies at numerous storage facilities located strategically around the city are regularly consumed and refreshed.
4. Capability exists to deliver fuel citywide via numerous tanker vehicles.
5. Refueling routes are in place and current.
6. Personnel (primary and alternate) to operate the refueling equipment and trucks are identified.
7. Inventory of roll-up generators with fuel are routinely exercised.
8. Fuel reserve sensors are in place to automatically alert suppliers and city personnel of impending needs.
9. Facilities with mission-required operations have uninterruptable power supply (UPS).
10. Decisions regarding fuel for required operations are in place.
11. Diverse portfolio of back-up energy technology is in place (renewables, etc.).
12. Plans for facility consolidation are in place and staff is aware of these alternate work sites.
13. Communication plans for all energy emergency operations are in place.
14. Emergency purchase authorizations are in place for fuel acquisition.
15. Contracts with fuel suppliers address that the city gets top priority, tankers can be located onsite, and fuel for a minimum of 72 hours of operation is mandatory.

Checklist C: Personnel

1. Onsite generators are routinely exercised including fueling, start-up, checking for functionality of stand-by mode, etc.
2. Plans are in place and practiced to deliver fuel on a citywide basis (i.e., there are numerous tanker vehicles, adequate number of trained personnel, etc.).
3. Refueling routes are in place, current, known, and practiced, if necessary.
4. Primary and alternate personnel have been identified to operate equipment (refueling, trucks, etc.).
5. Personnel routinely exercise inventory of roll-up generators, if applicable.
6. Personnel are aware of what fuel reserve sensors are and how they function.
7. Personnel are aware of how priority decisions regarding fuel for required operations are made.
8. Plans for facility consolidation are in place and staff is aware of these alternate work sites.
9. Communication plans for all energy emergency operations are in place and personnel regularly review and exercise these plans.

Appendix B: Building Resilient Regions Resilience Capacity Index (RCI) Indicators

Specific RCI Indicators that could be apportioned to *Economic Resilience* include the following:

- **Income Equality**. Income equality in the RCI is based on the metropolitan area Gini coefficient for income inequality calculated by the U.S. Census Bureau for metropolitan areas in 2009. So that high values signify high equality and high resilience, the RCI indicator is calculated as the inverse of the Gini coefficient for income inequality. Data are from the 2009 American Community Survey one-year estimates, Table B19083 (Gini coefficient for income inequality).

- **Economic Diversification**. Data for the RCI indicator are from the Bureau of Labor Statistics, Quarterly Census of Employment and Wages (QCEW), 2009. For metropolitan areas without 2009 QCEW data, the RCI indicator uses comparable data for a previous year. Data substitutions occurred for three metropolitan areas: Amarillo, Texas (data for 2008), Hartford, Connecticut (data for 2001) and Parkersburg, West Virginia (data for 2001).

- **Regional Affordability**. The RCI assesses regional affordability using the metropolitan area as the unit of analysis. It measures the percentage of households in the metropolitan area spending less than 35% percent of their income on housing, accounting for both owners (mortgage costs) and renters (monthly rent costs). Data come from the 2009 American Community Survey one-year estimates, tables B25070 (gross rent as a percentage of income) and B25091 (monthly owner costs as a percentage of income).

- **Business Environment**. As formulated and measured by the Indiana Business Center (2010) for its Innovation Index, an economically dynamic region is one with a proportionately high level of small businesses, high levels of business churn (starts and stops), residential high-speed Internet connections, change in the number of broadband holding companies, and ample venture capital (Indiana Business Center, http://www.statsamerica.org/innovation/). The RCI Business Environment indicator is the "Economic Dynamics" subcomponent of the Indiana Business Center's Innovation Index. Formulated as an index, it is a single number capturing the range of business conditions at the metropolitan region scale.

Specific RCI Indicators that could be apportioned to *Civil Society Resilience* include the following:

- **Educational Attainment**. Data come from the 2009 American Community Survey one-year estimates, table B15003 (educational attainment). Because of the unavailability of data, the RCI uses 2008 figures for the Hinesville-Fort Stewart, Georgia, metropolitan area.

- **Without Disability**. So that high scores translate to higher resilience, the RCI measures the inverse of disability, that is, the population that is without disability. It is calculated as

the percentage of a metropolitan area's civilian non-institutionalized population that report no sensory, mobility, self-care, or cognitive disabilities. Data come from the 2009 American Community Survey one-year estimates, table B18101 (disability status).

- **Out of Poverty**. So that high scores translate to higher resilience, the RCI measures the inverse of poverty, that is, the population that is out of poverty. Measured at the metropolitan-area scale, the indicator captures the percentage of the population with income in the past 12 months above the federally defined poverty line. Data come from the 2009 American Community Survey one-year estimates, table B17001 (poverty status in the past 12 months), from which the inverse measure is calculated.

- **Health Insured**. The RCI measures health-insured persons as the percentage of the metropolitan area's civilian non-institutionalized population that report having health insurance coverage, including both public and private insurers. Data come from the 2009 American Community Survey one-year estimates, table B27001 (health insurance coverage status).

- **Civic Infrastructure**. The RCI uses the number of civic organizations per 10,000 people in a metropolitan area to capture the concept of civic infrastructure. Organizational counts come from the 2008 County Business Patterns, 3-digit North American Industry Classification System (NAICS) code 813 ("religious, grant-making, civic, professional, and similar organizations"), from which the indicator includes voluntary health organizations, social advocacy organizations, social organizations, business associations and professional organizations, labor unions, and political groups. It excludes religious organizations (NAICS code 8131) and grant-making organizations (NAICS code 8132).

- **Metropolitan Stability**. The RCI indicator for Metropolitan Stability is the annual average percentage over a five-year period of a metropolitan-area population that lived within the same metropolitan area a year prior. It is calculated as the sum of persons who lived in the same house a year ago and those who lived in a different house in the same metropolitan area a year ago, divided by the population aged one year and older. Data come from the 2005–2009 American Community Survey five-year estimates, table C07201 (geographical mobility in the past year).

- **Home Ownership**. The RCI indicator for home ownership is the number of owner-occupied housing units as a percentage of total occupied housing units in a metropolitan area. Data come from the 2009 American Community Survey one-year estimates, table B25003 (tenure).

- **Voter Participation**. The RCI uses voter turnout data from the 2008 general election to gauge voter participation. The measure is the number of voters participating in the 2008 general election as a percentage of population age 18 and over in the metropolitan area. Voting data come from Dave Leip's Atlas of U.S. Presidential Elections at http://www.uselectionatlas.org/.

Appendix C: National Oceanic and Atmospheric Administration (NOAA) Coastal Resiliency Index — Sample Questions

In its Coastal Resiliency Index (Emmer *et al*. undated), the NOAA has developed a list of questions to gauge Community Plans and Agreements (available at http://www.seagrant.noaa.gov/focus/documents/HRCC/resiliency_index_7-15-08.pdf). For example, does your community:

- Have a certified floodplain manager?
- Participate in the Federal Emergency Management Agency (FEMA) Community Rating System?
- Use an early flood warning system?
- Have a certified floodplain manager?
- Have planning commissioners with formal training in planning?
- Have a planning staff with credentials from the American Institute of Certified Planners (AICP)?
- Have a mitigation plan that is approved by FEMA and the State emergency management system (EMS)?
- If you have an approved mitigation plan, has it been revised in the past two years?
- Have Memorandums of Understanding (MOUs) or Memorandums of Agreement (MOAs) with neighboring communities in place to help each other during times of disaster?
- Have a comprehensive plan or strategic plan that addresses natural disasters?
- Have a floodplain manager or planner who participates in the following organizations:
  - Association of State Floodplain Managers or State Floodplain Management Association?
  - American Planning Association (APA) or state APA chapter?
  - American Society of Civil Engineers (ASCE) or State or local section of ASCE?
  - American Public Works Association?
- Have first-hand experience with disaster recovery within the last 10 years?
- Have a communication system to use before, during, and after a disaster?

The NOAA's Coastal Resiliency Index (Emmer *et al*. undated) also includes questions to gauge use of mitigation measures (available at http://www.seagrant.noaa.gov/focus/documents/HRCC/resiliency_index_7-15-08.pdf). For example, has your community implemented the following mitigation measures?

- Compared the elevation of residential, nonresidential buildings, or infrastructure to National Flood Insurance Program standards for your community?
- Relocated buildings and infrastructure from flood-prone areas?
- Performed flood-proofing of nonresidential structures?
- Conducted education programs about mitigation options for your community?
- Acquired repetitive loss structures or infrastructure?
- Supported/funded incentives-based mitigation measures?
- Adopted the most recent International Building Codes?
- Hired certified building inspectors?
- Supported/funded staffing of an adequate number of people to enforce building codes?

Appendix D: Federal and State Funding Opportunities to Help Finance Improvements in Community and Regional Resilience

D.1 Federal Funding Opportunities

The Federal government awards grants to support the homeland security efforts of States, local governments, and public/private partnerships. Funding for projects in disaster mitigation, preparedness, planning, exercising, and other homeland security activities may support resilience initiatives. In addition, funding for other activities — such as transportation projects or community development — also may support resilience goals.

The Catalog of Federal Domestic Assistance (CFDA) provides a full listing of all Federal programs available to State and local governments (including the District of Columbia); federally recognized Indian tribal governments; Territories (and possessions) of the United States; domestic public, quasi- public, and private profit and not-for-profit organizations and institutions; specialized groups; and individuals. There are more than 2,000 programs listed from 64 different agencies. The CFDA is available online at http://www.cfda.gov and provides application deadlines, current eligibility requirements, and information on the application process for each program.

Of the many programs in the CFDA, the ones listed below are some of the most closely aligned to potential resilience enhancement projects. Note that the funding landscape changes every year. The programs and initiatives described below may or may not be available in the future and are not presented as a comprehensive list of possible funding sources.

D.1.1 Homeland Security Grant Programs

The Homeland Security Grant Program (HSGP) umbrella includes several programs detailed below. The U.S. Department of Homeland Security (DHS) issues information and application guidance for the HSGP on an annual basis. The current guidance (*Fiscal Year 2011 Homeland Security Grant Program Guidance and Application Kit, May 2011*) includes funding guidelines and information on eligibility, the application process, and application review criteria. In addition to this general guide, DHS has numerous "supplemental resources" for particular types of programs, including cyber security, law enforcement information sharing, public-private collaboration, caring for children in disasters, and other topics. The HSPG office Web page, http://www.fema.gov/government/grant/hsgp/, includes these guides and other information on the HSPG application process. HSGP programs include the following:

- The State Homeland Security Program (SHSP) supports the implementation of State Homeland Security Strategies to prevent, protect against, respond to, and recover from acts of terrorism and other catastrophic events. In addition, SHSP supports implementation of the National Preparedness Guidelines, the National Incident Management System (NIMS), the National Response Framework (NRF), the National Strategy for Information Sharing, and the National Infrastructure Protection Plan. The

SHSP awards block grants to States, as administered by the designated State Administrative Agency. Subgrants are coordinated through the designated State or regional representative. Those considering applying should attend meetings and get on mailing lists to learn of and request consideration for available funds. New requests are generally considered in the Fall. Amounts vary and no match is required but matching may be encouraged.

- The Urban Areas Security Initiative (UASI) program funds address the unique planning, organization, equipment, training, and exercise needs of high-threat, high-density urban areas and assists them in building an enhanced and sustainable capacity to prevent, protect against, respond to, and recover from acts of terrorism.

- Operation Stonegarden (OPSG) funds are intended to enhance cooperation and coordination among local, Tribal, territorial, State, and Federal law enforcement agencies in a joint mission to secure the United States' borders along routes of ingress from international borders to include travel corridors in States bordering Mexico and Canada, as well as States and territories with international water borders.

- The Metropolitan Medical Response System (MMRS) program supports the integration of emergency management, health, and medical systems into a coordinated response to mass casualty incidents caused by any hazard. MMRS grantees reduce the consequences of a mass casualty incident during the initial period of a response by augmenting its existing, local operational response systems before an incident occurs.

- The Citizen Corps Program's (CCP) mission is to bring community and government leaders together to coordinate the involvement of community members and organizations in emergency preparedness, planning, mitigation, response, and recovery.

D.1.2 Hazard Mitigation Assistance

The Federal Emergency Management Agency (FEMA) has several programs aimed at "breaking the cycle" of disaster response (e.g., for communities that repeatedly suffer flooding) through disaster resilience. The FEMA Hazard Mitigation Assistance Web page (http://www.fema.gov/government/grant/hma/index.shtm) has extensive information. These programs include the following:

- The Hazard Mitigation Grant Program (HMGP) assists in implementing long-term hazard mitigation measures following Presidential disaster declarations. HMGP funding is available to implement projects in accordance with State, Tribal, and local priorities.

- The Pre-Disaster Mitigation (PDM) program provides funds on an annual basis for hazard mitigation planning and the implementation of mitigation projects prior to a disaster. The goal of the PDM program is to reduce overall risk to a grantee jurisdiction's population and structures, while at the same time reducing reliance on Federal funding from actual disaster declarations, as well.

- The Repetitive Flood Claims (RFCs) program provides funds on an annual basis to reduce the risk of flood damage to individual properties insured under the National Flood Insurance Program (NFIP) that have had one or more claim payments for flood damages. RFC provides up to 100% Federal funding for projects in communities that meet the reduced capacity requirements.

- The Severe Repetitive Loss (SRL) program provides funds on an annual basis to reduce the risk of flood damage to residential structures insured under the NFIP that are qualified as severe repetitive loss structures. SRL provides up to 90% Federal funding for eligible projects.

D.1.3 Other Federal Programs

A number of other programs administered by FEMA, the Transportation Security Administration (TSA), the U.S. Department of Transportation (DOT), the U.S. Department of Agriculture (USDA), and other agencies are potential sources for funding resilience enhancement initiatives.

- The Port Security Grant Program (PSGP) provides funding for transportation infrastructure security activities to implement Area Maritime Transportation Security Plans and facility security plans among port authorities, facility operators, and State and local government agencies required to provide port security services. PSGP's purpose is to support increased port-wide risk management; enhance domain awareness; conduct training and exercises; oversee expansion of port recovery and resiliency capabilities; and develop further capabilities to prevent, detect, respond to, and recover from attacks involving improvised explosive devices (IEDs) and other nonconventional weapons. Information may be found at http://www.fema.gov/government/grant/psgp/.

- The Emergency Management Performance Grant (EMPG) Program makes grants to States to assist State, local, Tribal, and territorial governments in preparing for all hazards, as authorized by Title VI of the Stafford Act. The Federal government, through the EMPG Program, provides necessary direction, coordination, guidance, and assistance as authorized in this title so that a comprehensive emergency preparedness system exists for all hazards. Information may be found at http://www.fema.gov/government/grant/empg/.

- Through the Transportation Security Grant Program, DHS provides security grants to mass transit and passenger rail systems, intercity bus companies, freight railroad carriers, ferries, and the trucking industry to help protect the public and the Nation's critical transportation infrastructure against acts of terrorism and other large-scale events. The grants support high-impact security projects that have a high efficacy in reducing the most risk to our Nation's transportation systems. Information is available on the TSA Web site at http://www.tsa.gov/what_we_do/grants/index.shtm.

- FEMA and the U.S. Environmental Protection Agency (EPA) have partnered on the Smart Growth Program to promote disaster resilience through smart growth. Smart growth strategies, such as creating flexible land use policies, targeting public investment

to catalyze private investment, and engaging the entire community in making decisions about the future, can help communities to recover from a disaster in a more resilient way, rebuild according to a shared community vision, and be prepared for the next natural disaster. Information may be obtained at http://www.epa.gov/smartgrowth/fema_moa.htm.

- The Homeland Defense Equipment Reuse (HDER) Program is implemented through a DHS and U.S. Department of Energy partnership. HDER's mission is to provide emergency responder agencies with access to items that are no longer needed by the Federal government. Items are refurbished and provided at no cost to the recipient. It provides surplus radiological, chemical, and biological detection and response equipment; detection instrumentation; and personal protective equipment, as well as training and technical support, to enhance homeland security preparedness capabilities. Information is available at http://hder.oro.doe.gov/.

- The long-term goal of the Disaster Resilience for Rural Communities Program is to advance basic research in engineering and in the social, behavioral, and economic sciences on enhancing disaster resilience in rural communities. As stated by the USDA, "There is much research on vulnerability and resilience in urban communities, but much less about how rural communities and their residents are responding to natural and man-made hazards." Information is available at http://nifa.usda.gov/funding/rfas/disaster.html.

- The Justice Assistance Grant (JAG) Program is the primary provider of Federal criminal justice funding to State and local jurisdictions. JAG provides States and units of local governments with funding to support law enforcement; prosecution and court programs; prevention and education programs; corrections and community corrections; drug treatment and enforcement; crime victim and witness initiatives; and planning, evaluation, and technology improvement programs. Information about this U.S. Department of Justice program is available at http://www.ojp.usdoj.gov/BJA/grant/jag.html.

D.2 State Funding Opportunities

A number of examples of innovative State programs are profiled in the 2008 report, *Innovative Programs in Funding State Homeland Security Needs*, by the Southern Legislative Conference (SLC). The three themes of the programs profiled in the SLC report are interagency coordination, public/private communication, and adoption of a regional approach. Examples are described below.

- *Illinois Private Sector Alliance Project.* This project consists of two interdependent programs: Infrastructure Security Awareness (ISA) and the Mutual Aid Response Network (MARN). The ISA was designed to facilitate information exchange among public and private security professionals through the Homeland Security Information Network (HSIN). Participants exchange information about potential threats, training opportunities, and organized crime through HSIN. MARN is designed to mitigate the impact of natural disasters and acts of terrorism by leveraging private sector response

assets. Through this project, Illinois is developing a clearinghouse of information detailing agreements with the private sector on the use of resources during a critical incident. Resources covered include facilities, equipment, transportation, medical supplies, and portable generators.

- *Indiana public/private initiatives.* Indiana is establishing a Special Interest Group on the InfraGard Web site for enhanced, secure public/private information sharing. Indiana also is in the beginning stages of a partnership with the Business Executives for National Security that will enhance public-private interactions and assist in the development of the State's critical infrastructure protection program.

- *Iowa multistate cooperation.* Iowa participates in the Multi-State Agriculture Consortium (MSAC) with Kansas and Nebraska. The MSAC allows representatives from these States, all with a strong agriculture segment in their economies, to develop quick-response teams, as well as to share response and recovery plans.

- *Minnesota regional organization.* Minnesota's 87 counties are organized into six homeland security and emergency management regions. Starting with the Minneapolis/St. Paul metro region, joint power agreements have been signed for each region providing for joint equipment procurement, training standards, exercise development and execution, and distribution of emergency response equipment within each region.

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Appendix E: List of Abbreviations

APA	American Planning Association
Argonne	Argonne National Laboratory
ASCE	American Society of Civil Engineers
BCI	Business Continuity Institute
BCP	Business Continuity Plan(ning)
BRCCI	Business Resilience Certification Consortium International
CAPTA	Costing Asset Protection: An All Hazards Guide for Transportation Agencies
CARRI	Community and Regional Resilience Institute
CFDA	Catalog of Federal Domestic Assistance
CI	Criticality Index
COOP/COG	Continuity of Operations/Continuity of Government plans
CRS	Community Rating System
DI	Dependencies Index
DHS	U.S. Department of Homeland Security
EMAP	Emergency Management Accreditation Program
EMPG	Emergency Management Performance Grant
EOC	Emergency Operations Center
ERM	Enterprise Risk Management
FEMA	Federal Emergency Management Agency
HDER	Homeland Defense Equipment Reuse
HMGP	Hazard Mitigation Grant Program
HSAC	Homeland Security Advisory Council
HSIN	Homeland Security Information Network
HSPG	Homeland Security Grant Program
ISA	Infrastructure Security Awareness
IST	Infrastructure Survey Tool
IT	information technology
JAG	Justice Assistance Grant
LRTP	Long-Range Transportation Plan
MARN	Mutual Aid Response Network
MMRS	Metropolitan Medical Response System
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding

MPO	Metropolitan Planning Organization
MSAC	Multi-State Agriculture Consortium
NAIC	North American Industry Classification System
NCPC	National Capital Planning Commission
NCS	National Communications System
NFIP	National Flood Insurance Program
NIAC	National Infrastructure Advisory Council
NIBS	National Institute of Building Sciences
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
PDM	Pre-Disaster Mitigation
PMI	Protective Measures Index
PPI	Public Preparedness Index
QCEW	Quarterly Census of Employment and Wages
QHSR	Quadrennial Homeland Security Review
RCI	Resilience Capacity Index
RFC	Repetitive Flood Claim
RI	Resilience Index
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
Sandia	Sandia National Laboratories
SEDIT	Special Events and Domestic Incidents Tracker
SHSP	State Homeland Security Program
SLC	Southern Legislative Conference
SLTTGCC	State, Local, Tribal, and Territorial Government Coordinating Council
SRL	Severe Repetitive Loss
TSA	Transportation Security Administration
USDA	U.S. Department of Agriculture

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