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# ESTIMATING ECONOMIC IMPACTS OF HOMELAND SECURITY MEASURES

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# ESTIMATING ECONOMIC IMPACTS OF HOMELAND SECURITY MEASURES

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## 1. Introduction

The terrorist attacks of Sept. 11, 2001 have prompted the federal government to adopt a number of different measures that are intended to reduce the probability of future successful terrorist attacks and/or reduce the impact of any future attacks should they occur. These measures are grouped together under the broad rubric of preserving and increasing homeland security.

Public policies that increase the level of homeland security require that government, individuals, and businesses devote more time and money to protective measures, which exacts an economic cost. Using a broad definition of “homeland security” to consist of “all expenditures possibly aimed at either preventing damage due to terrorist attacks or at preparedness for the response to potential attacks,” the Federal Reserve Bank of New York (FRBNY) has estimated that in 2003 total public and private sector outlays on increased security equaled just over \$70 billion or just under 0.7% of the nation’s gross domestic product. In addition, the FRBNY report estimates that “indirect costs” such as travel delays related to heightened airport security added an additional \$12 billion, for a total estimated cost of more than \$80 billion.

Whether costs of this magnitude are viewed as “large” or “small” depends on one’s perspective. On the one hand, as noted in the FRBNY article, when viewed against the landscape of a \$11 trillion national economy, the estimated costs of attaining homeland security are relatively small; and clearly, measures of macroeconomic performance such as economic growth and employment indicate that the national economy has been able to take these additional costs in stride.

Yet this does not mean that such costs should be ignored in the design, implementation and evaluation of homeland security policies.

- The magnitude of the aggregate costs associated with homeland security are quite comparable in size to estimates that have been made by OMB and others of the economic cost of environmental and social regulations, and there is general agreement that there is a public interest to be served in ensuring that such regulations achieve the maximum social benefit at minimum social cost. Presumably the same logic should apply to homeland security measures.
- There has been criticism that outlays made with the ostensible purpose of fostering greater homeland security have been wasteful. Focusing more attention on the economic cost and economic impact of proposed homeland security measures can help reduce such wasteful expenditures, just as more careful analysis of these factors has led to more cost-effective governmental regulatory policies in other areas (as documented by the Office of Management and Budget).
- Although the impact of a single, or multiple homeland security measures may seem “small” in the context of the national economy, these costs are typically concentrated on certain stakeholders, such as local governments, specific business sectors, or consumers of particular goods and services. To these stakeholders, the cost of

achieving greater homeland security can be quite palpable and substantial, and should receive their proper due in the design and evaluation of homeland security measures.

- At a practical policy level, unlike national defense, policies intended to promote homeland security, are not exempt from OMB requirements that government regulatory programs with cost of impacts of \$100 million or greater be subject to regulatory analysis which requires a careful analysis of the costs of such such measures in relation to the benefits to be derived.

## **1.1 Economic Impacts and Decision-Making**

There are two related, yet also distinct sets of questions that one might seek to answer in undertaking an economic analysis of a particular homeland security measure. The first set has to do with whether a particular policy or intervention is “socially cost-effective.” In the case where the policy choice is whether to adopt a particular program or not, the issue is whether the proposed program produces social benefits that are commensurate with the social value of the scarce resources that are used to implement the policy. In the case where the policy choice is among alternative means of achieving a particular objective, the issue is that of determining which of the alternatives achieves the stated objective at minimum cost to society. A different set of questions seeks to trace out the how a particular policy might affect the profits of specific industries or regional employment, as consumers, businesses, and government adjust their behavior in response to a particular policy or set of policies.

### 1.1.1 Assessing Social Efficiency and Cost-Benefit Analysis

Consider for example the case of a policy that until recently has prohibited the use of Reagan National Airport by general aviation. The social costs of such a policy would consist of the increased time and money that users of general aviation have been required to spend as a consequence of journeying to the Washington DC area either by alternative means (e.g. commercial instead of general aviation), or by flying into regional airports other than Reagan National. From the standpoint of social cost effectiveness, the question is whether such a policy provides benefits, in the form of a reduction in the probability that a terrorist attack could successfully be mounted against the nation’s capital, that justify the imposition of such costs on users of general aviation. In the case where the policy choice involves alternative means of reducing the probability of terrorist attacks from general aviation, such as, for example, prohibiting the use of Reagan National Airport entirely, vs. a policy, such as the one that has been recently adopted, of allowing general aviation to use Reagan National, subject to certain restrictions, the question would be that of which of these alternatives accomplished the objective --- reduced probability of terrorist attack from general aviation – at the lowest overall social cost.

The accepted analytical framework for addressing questions of this type is that of Cost-Benefit Analysis (CBA). CBA has become an increasingly important element in the design, implementation, and evaluation of a wide range of public programs in areas such as water resources and wide range of environmental and social regulations. All water resource projects undertaken by the United States Army Corps of Engineers are required to undergo a CBA, and all government regulations with a cost impact of \$100 million or greater are required by the

Office of Management and Budget to undergo a regulatory impact analysis which in principle involves a comparison of the costs and benefits of the proposed regulation.

CBA has proved to be useful as an aid to public decision-making because it provides a coherent and comprehensive social accounting framework. The framework is coherent because it draws on a consistent set of economic principles, derived from welfare economics, for defining social benefits and costs. It is comprehensive because its objective is to arrive at a “bottom-line” based on the concept of *social* benefit and cost that is broader than *private* revenue and cost normally be used to assess the performance of profit-making enterprises.

Although the estimated bottom line that is reached by applying CBA to a particular activity is itself a useful input into the decision process, it is widely recognized that the process of arriving at that bottom line is at least, if not more valuable than the bottom line number. The basic reason is that careful application of the social accounting framework requires the analyst to specify clearly the essential features of the policy being analyzed, and to account fully for its effects on all stakeholders. This process often provides valuable insights about ways in which specific policies can be improved in ways that either lower their costs and/or increase their potential benefits.

### 1.1.2 Economic Impact Analysis

Clearly the social costs and benefits of a policy represent a form of economic impact. However, in the parlance of economic analysis, the term “impact analysis” is typically used to describe how particular policies affect variables such as profits and employment, as various stakeholders, such as business, individuals, and government adjust their behavior to the imposition of costs and/or the creation of benefits.

To continue the example of banning general aviation at Reagan National Airport, the effects of such restrictions would presumably be to lower employment and profits of business enterprises supplying general aviation services using Reagan National, while at the same time increasing employment and profits of businesses providing substitute services, which might include other airports in the region, as well as commercial aviation. There would, in short, be both “losers” and “winners” from the adoption of such a policy.

The analytical framework for addressing these issues would generally be regional economic models which enable one to trace out how changes in demands for various goods and services affect employment and output in specific sectors and regions. Unlike cost-benefit analysis, which is required to be conducted by law for certain kinds of public programs, there are no similar requirements that economic impact analyses be undertaken for public programs. Nonetheless the issue of how public policies affect variables such as profits and employment is likely to be factor in the political discourse about policies, and is worth analyzing and understanding for that reason.

## **1.2 Relation Between Cost-Benefit and Impact Analysis**

As noted above, cost-benefit analysis and impact analysis are best understood as examining different facets of how the adoption of a policy affects the economy. In the Reagan National Airport example, the social costs of the ban would be the estimated increase in time and money costs of flying to Washington DC by other means. The question posed by cost-benefit analysis is whether imposing such costs is warranted based on the social benefit to be achieved. Impact analysis would focus on how the behavioral adjustments that “are behind the higher costs” such as shifting to commercial carriers and to alternative regional airports, affect profits, incomes, and employment of those providing either general aviation services, or substitutes for such services. Such estimates might serve as inputs into the estimation of social costs, but would not in and of themselves constitute estimates of either social cost or social benefit as these terms are commonly understood in the application of benefit cost and/or regulatory impact analysis.

## **2. Gross and Net Costs of Homeland Security Policies**

Current and potential homeland security policies span a wide range of government actions. A number of these are described in more detail in the appendix to this report. In addition Text boxes 1-3 provide brief summaries of three examples of such measures: the Container Security Initiative, the US Visit Program, and the Terror Threat Alert level program.

These actions impose costs on society to the extent that they cause more scarce resources to be devoted to homeland security than would otherwise be the case. These costs can come in several different forms.

### **2.1 Government Expenditures**

Many actions require governments to make additional investments in capital and labor, as illustrated by the examples in the text boxes.

- In order to implement the container security program, the U.S. government may need to provide funds to foreign governments to help defray the cost of screening containers at foreign ports, plus provide resident staff from the U.S. Customs and Border Protection agency at these ports. In addition, government funded research is currently underway to develop tamper-proof container seals.
- Implementing the U.S. visit program requires the installation at both entry and exit ports of digital cameras, fingerprint scanners, and exit machines, and additional staff will be needed within the Department of State and the U.S. Customs and Border Protection agency to review documents during the process of issuing visas.
- Raising the terror alert level causes both federal and state and local governments to spend funds on additional protective measures, such as initiating twelve-hour work days for police, and the placement of physical protective barriers.

### **2.2 Private Costs**

Homeland security policies also impose costs on private persons and businesses. Consider for example, a regulation that would require airlines to install missile defense systems on commercial airliners. Estimates suggest that the cost of installing the defense systems would cost roughly \$1 million per airliner. Since there are 6,800 airliners in U.S. fleets, the total cost of the installation would be \$6.8 billion. Presumably private airlines would attempt to shift the added cost of these systems forward to consumers in the form of higher ticket prices. If airlines were successful in shifting forward all of the added costs to consumers, then the costs of installing these missile defense systems would be borne entirely by consumers in the form of higher ticket prices. If, however, market conditions permitted airlines to shift forward only a portion of the added cost, then the costs would be shared by both consumers and producers. Similarly, if suppliers of electricity were required to install additional redundant capacity in order to harden such systems from attack, the added costs of such hardening would be borne either by

the consumers of electricity or both consumers and suppliers of electricity. [Note, we plan to add a text box on this measure based on reports in the press, and material posted on the USC website, and we will probably have one on the general aviation ban at National Airport].

A common feature of both of these examples, which involve government regulation of private producers, is that the lion's share of the cost of implementing the policy is ultimately borne by private parties and not the government, unless an additional decision is made to subsidize these costs from the public fisc. Providing such subsidies (for example by granting tax credits to defray some or all of the costs of installation) would shift the costs from private parties to the government, but the social costs of compliance with the regulation would remain the same.

### **2.3 Costs of Time and Delay**

A number of homeland security measures involve creating security checkpoints at which people and goods are screened. Such screening increases the travel time of individuals. For example, the FRNY analysis of the costs of homeland security estimated that increased security standards at airports have resulted in the average passenger facing an extra hour of waiting time. Because time is a scarce resource, "time is indeed money" and the FRBNY study estimates that the added hour translates into a monetary cost equivalent of approximately \$11.8 billion. (Hobijn, 2002).

In addition to costs experienced by travelers, businesses also can experience additional time and delay costs for shipping goods across borders. Especially in an era of just-in-time production, such costs can be considerable, and in some cases may lead to relocation of production activities. Estimates for the manufacturing sector (described more fully below) suggest that a days worth of delay at the border of bringing goods into the United States is equivalent to a tariff of 0.8%

### **2.4 Joint or Dual Benefits of Homeland Security Measures**

In addition to imposing costs, a distinctive feature of many homeland security policies is that they may also provide dual or joint benefits that lower their net cost. As in the case of the costs described above, these ancillary benefits can be experienced by governments, private persons, and private business. For example, enhanced container security developed in response to homeland security concerns can also make it easier to monitor the inflow of illegal goods into the country, providing cost savings to both federal and local governments. Raising terror alert levels increases costs of policing, but the added police that are put into the streets as a result may also result in reductions of certain types of crime. Requiring that electrical systems build in redundancy to minimize power disruption in the event of a terrorist attack also reduces the likelihood of experiencing power disruptions caused by storms.

The existence of such dual or joint benefits have two implications for potential homeland security measures. One is that such ancillary benefits can be seen to lower the "net cost" to society of increased homeland security. The other is the combination of homeland security benefit and a dual benefit may the margin that makes an otherwise "uneconomic" security policy worth undertaking.

## Container Security Initiative

Much of the world's trade is transported in cargo containers, many of which arrive in U.S. seaports each day, creating a need to secure the shipping process. Aiming to push the U.S. zone of security outward, the Container Security Initiative (CSI) uses intelligence to identify and target containers that pose a risk for terrorism. These identified containers are then pre-screened in the foreign port of departure using detection technology before they are shipped to the United States. Smarter, tamper-evident containers are also required to avoid tampering during trip to the United States. With 37 ports currently enrolled in the CSI program it is important to examine the costs imposed on the U.S. government, industry and individuals.

Host nations are responsible for determining who pays the direct costs of screening and unloading containers and the port is required to have non-intrusive inspectional equipment and radiation detection equipment prior to be eligible for the CSI program. However, the Department of Energy's Megaports Initiative often supplies some of this equipment. The cost of equipment supplied to CSI ports by the Department of Energy should be included in this analysis.

The CSI requires a small team of U.S. Customs and Border Protection agents to be located at each of the CSI ports to observe the security screening conducted by host country officials. The calculation of personnel costs for stationing agents overseas goes beyond the individual's salary and benefits. These costs also must include housing, a post differential, and depending on the port, hazard pay.

The U.S. Customs and Protection agency are currently working on testing technology to create tamper-evident seals to protect containers after been inspected in their home ports. The costs of the research to develop these seals, as well as testing them, should be included in the analysis. Additionally, once a product has been selected for use, the costs supplying the tamper-evident seals should be included, unless the host country is responsible for these costs.

It is anticipated that the CSI will not cause delays in the movement of containers through the ports. In fact, it is believed that CSI will make this process more efficient by using the time that the containers normally sit in ports waiting to be exported to screen and clear the containers. Now that the process is underway in many ports, this belief should be tested. If the initiative adds time to the process of clearing a container, then that time should be measured using the rule of thumb describe in the "Delays in Shipping of Goods" section, by increasing the cost of goods by 0.8% per day.

## Homeland Security Advisory System

The Homeland Security Advisory System (HSAS) is a color-coded system, ranging from green or a low level of threat to red or a severe risk of terrorist threat. The system was designed to measure and evaluate terrorist threats and communicate these threats to federal, state and local governments; and to the public. Compliance with the HSAS is mandatory for federal agencies, and recommended for states, localities, and private industry. Each time the system is raised from yellow to orange federal, state and local governments, along with private industry are burdened with additional costs to secure the nation.

These costs include additional protective measure employed by law enforcement and private security forces; increased screening of vehicles and people at government facilities and near critical infrastructure and key assets; increased wait time at security check points; and decreased luxury travel, especially air travel.

When the alert is raised, governments who decide to raise their own alert levels, typically do so by enacting protective measures. Police increase security patrols, which generally requires overtime. Some cities initiate a twelve-hour workday, rather than eight-hour shifts, to ensure adequate coverage. Other cities report double-checking critical locations during each shift and closely monitoring public events with crowds or put barriers in place to prevent vehicles from approaching high-risk buildings. Personnel costs and the costs of purchasing physical protection devices should be counted, along with the operating costs of the devices (i.e., moving barriers into position and non-personnel costs of operating magnetometers, etc.).

When the national terror alert is raised from yellow to orange, security checkpoints pop up all over the place from airports, to entering businesses or government agencies, to crossing bridges and approaching landmarks. Checkpoints such as these can slow traffic and cause delays. Estimations of the value of time and delay should be used to determine the aggregate cost of society's lost time while standing in line or sitting in traffic because of increased security.

Raising the terror alert tends to cause a decrease in tourism. Even though officials have tried to persuade the public to carry on with their normal lives, residual fear of airplanes or concern over being in public places cause individuals to cancel trips and possibly avoid scheduling them. This affects American travelers in terms of lost opportunities, but it also affects American companies relying on both foreign and domestic tourism. To determine the social opportunity costs of decreased tourism it is necessary to determine the reduction in profits to the tourism industry and the loss of utility to travelers that forgo there plans or postpone travel during an orange alert.

## U.S. VISIT

U.S. Visit is an initiative designed to enhance security for United States citizens and visitors to the United States while promoting legitimate travel across America's borders. U.S. VISIT applies to individuals holding non-immigrants visas traveling to and from the United States. The program involves the collection of biometric information (finger prints from both index fingers and a digital photograph) from visa applicants before processing the visa. When the visa holder arrives in the U.S. an inkless digital finger scanner is used to capture scans of the individual's index fingers and another digital picture is taken. This information is verified with the individual's travel documents and checked against the Terrorism Watch List. Assuming verification of documents and satisfactory answers to biographic questions, the individual is allowed to enter the country. Exit procedures currently vary based on a pilot program currently underway. Typical exit procedures require the individual to use an exit station, which scans the visa, the individual's fingerprints and takes a digital photo. This information is verified and the individual is issued an exit receipt. Some alternatives of the exit procedure involve a U.S. VISIT agent to verify the exit receipt at the departure gate. While this program will increase security and allow better monitoring of non-immigrants while they are traveling in the United States, it also imposes a variety of costs. These costs include the costs of equipping all ports with the necessary technology; creating a secure database; personnel costs; and the effects of fewer non-immigrants coming to the United States, either as tourists or as students.

In order for the U.S. VISIT program to function as intended each entry and exit port will need to be equipped with the appropriate numbers of digital cameras, fingerprint scanners, exit machines, along with other necessary supplies. Additionally, costs attributed to the design, development, and maintenance of a secure database that is capable of interacting with many government agencies will be included in the initial costs of the program. Finally, to ensure proper functioning of the program, additional staff will be needed within the Department of State and the U.S. Customs and Border Protection Agency to review documentation during visa issuance, populate the database with necessary information, and to process individuals entering and exiting the United States. The current market rate can be used to estimate costs of supplies and the database. The appropriate wage rate should be utilized for determining personnel costs.

It is likely that the additional security procedures involved in U.S. VISIT will deter some foreign tourists from choosing the United States as their destination for travel. This may be as a result of additional procedures involved in the visa application process, or because they are unwilling to provide their biometric information. If foreign tourists choose to spend their money elsewhere, the American tourist industry will likely suffer economic losses. This cost can be measured by the loss of producer surplus to the American tourist industry.

It is also possible that a more complicated visa process will deter some foreign students from coming the U.S. educational purposes. Although the cost to students themselves from the lost opportunity of a U.S. education would not be counted in a national analysis, because foreign students do not have standing, there is still a measurable cost related to this change of behavior. Often students assist faculty in research activities during their tenure in academia. This lack of productivity would be a social opportunity cost that should be included in the analysis. Also, in

the long run, individuals who come as students opt to stay in the U.S. after they have finished their degrees and become productive members of the society. If students decided to go to colleges and universities elsewhere in the world, there is a loss to the American economy that should be measured in the analysis.

### **3: Models and Measures of Impacts: Cost-Benefit Analysis/Regulatory Impact Analysis**

As noted in Section 2, Cost Benefit Analysis (CBA) provides a coherent and consistent accounting framework that allows the social costs and social benefits of public policies to be estimated, and evaluated. Social costs consist of (1) scarce resources, both “economic” and “non-economic” in character that are reduced by, or used to implement the policy or program, and (2) reductions in economic well-being that are experienced by stakeholders who are negatively affected by the policy. Social benefits consist of (1) scarce resources that are saved if a policy is implement and (2) increases in economic well-being experienced by stakeholders who are positive affected by a policy or program.

There are two key conceptual building blocs of CBA. One is the concept of *social opportunity cost*, which is relevant for estimating the value of scarce resources either used up or saved as a result of the program. The other is *willingness to pay* which forms the basis for estimating changes in economic well being.

#### **3.1 Social Opportunity Cost**

Because resources in any society are finite and scarce, the decision to use resources in one way, such as to produce more homeland security means that these resources are not available for other uses.

- The manpower and equipment needed to implement the container security and the U.S. Visa program could either be used elsewhere in the government, or would be labor and capital that would be available for private production and consumption.
- The additional time that travelers either spend directly at security checkpoints, or in making sure that “enough time is allowed” to go through security checkpoint is time that could be used in productive activities or for leisure time.

In other words, the social opportunity cost of having more homeland security equals the value of what society must forego to implement homeland security policies (Boardman, et. al, p. 28). The modifier “social” that is placed before opportunity cost is meant to denote the fact that, while the value of what society must forego to implement a policy or program is often the same as what people would typically regard to be a financial cost or budgetary outlay, it need not be because the concept of social opportunity cost is broader. An example where the market value of a resource would be the same as its social opportunity cost would be that of the wage or salary paid to workers employed on a government project under conditions of full-employment. In such

a case, a payment of, say, \$10 per hour for a worker in a particular skill category would represent the wage that the a worker could command from employers other than the government. In that case the government program would use up scarce resources valued at \$10 per hour by society through the marketplace. A case in which the wage paid by the government would not necessarily equal the worker's social opportunity cost would be one in which there was widespread unemployment. In that case, the same payment of \$10 would not necessarily represent the value of the worker's time in its next best use because he/she would otherwise not be working.

Another case in which the two concepts would differ would be a situation in which a particular homeland security policy caused a government agency to shift staff from one set of activities to another, instead of spending more budgetary resources. In this case even though implementing the policy did not entail an overt budgetary cost, it would nonetheless impose a social opportunity cost equal to the value of the government employee's time in what would have been their next "best" use.

There are several widely-applied "rules of thumb" in both the academic and practical literature on cost-benefit analysis that can help guide the estimate of the opportunity cost of government actions.

- Except when there is widespread unemployment, budgetary outlays for manpower and equipment can be treated as good estimates of the social opportunity cost of those resources.
- The absence of a budgetary cost for a scarce resource does not mean that its use in the production of homeland security activities has no social opportunity cost. The example of the agency that re-deployed existing staff to homeland-security related activities without increasing its budgetary outlays would be one example.
- User fees or charges collected by the government from businesses and individuals to defray the added cost to the government of homeland security measures may provide a means by which different stakeholders bear a share of the added social opportunity costs of homeland security measures. However, such fees and charges do not reduce the actual social opportunity costs which equal the value of the scarce resources used up in the process of implementing such measures.
- In a fully employed economy, labor services and equipment purchased by the government to implement homeland security measures represent are scarce resources that could be employed in alternative uses in the private sector, or in alternative public activities. Hence, from the cost-benefit standpoint, "jobs" created by homeland security measures should be treated as costs of such measures, not as economic development benefits.

### **3.2 Willingness to Pay**

The objective of CBA is to weigh the value that society attaches to a policy's outcome(s), with the social opportunity cost of achieving the outcome(s). The social value in turn is defined to be the aggregation of what individual stakeholders are willing to pay to achieve the outcome. The more precise definition of "willingness to pay" is that it is the maximum amount of money that an individual or business would be willing to pay in order to have a favorable policy implemented. Willingness to pay can, however, also be "negative" in the case of a policy change with adverse consequences for an individual or business. In that case, the (negative) willingness to pay, is defined to be the minimum amount of money that an individual or business would have to be paid in order to "make them whole" after implementation of a policy that makes them worse off. Negative willingness to pay would be treated as a social cost of the policy, along with any social opportunity costs.

### **3.3 Measures of Willingness to Pay: Revealed Preference Measures**

There are two broad approaches to actually estimating the willingness to pay. The first, and preferred approach, is to rely on measures that are based on actual preference and choices of individuals and businesses that are revealed through their behavior in the marketplace. The approach is preferred because it is based on actual behavior, rather than on what people say they would be willing to pay in response to survey questions. A simple example of a revealed preference measure would be to use the difference in cost between flying into Reagan National airport by means of general aviation versus either using commercial aviation or using general aviation to fly to different airports in the Washington DC region. Suppose for sake of illustration that this cost difference equaled \$10,000 per trip. This amount would represent the minimum amount of money that would need to be paid to users of general aviation to make them economically whole after implementation of the ban, and hence would be a good estimate of negative willingness to pay. This estimate of willingness to pay would be a revealed preference measure because it would reflect actual market choices made by those affected by the policy (e.g. switching to commercial air carriers or to other regional airports).

As will be seen below, using revealed preference measures require that policies have outcomes whose effects can either be evaluated explicitly or implicitly from behavior in markets. There are, however, cases in which costs of policies might take the form of changes in the consumption of goods that are not easily evaluated in the marketplace. For example, the Jersey barriers that have been erected throughout Washington D.C. clearly detract from the experience to visiting sites such as the Capitol and the White House. There is no readily available market for assigning a monetary value to the loss in utility that occurs as a result. An alternative that has gained some acceptance in economics, but which also remains controversial is to attempt to estimate such monetary values by means of carefully constructed surveys. Such approaches are described as "stated preference measures" because they estimate willingness to pay based on what people state in survey responses.

#### 3.3.1 Consumer and Producer surplus

As noted in OMB Circular A-94, changes in consumers, and where appropriate, consumers and producers surplus, are widely regarded as providing the best measures of

willingness to pay when these magnitudes can be calculated. The use of these measures to estimate the social costs of a potential homeland security measure can be illustrated in the case of proposals to install missile defenses on commercial airliners.

### Consumer Surplus

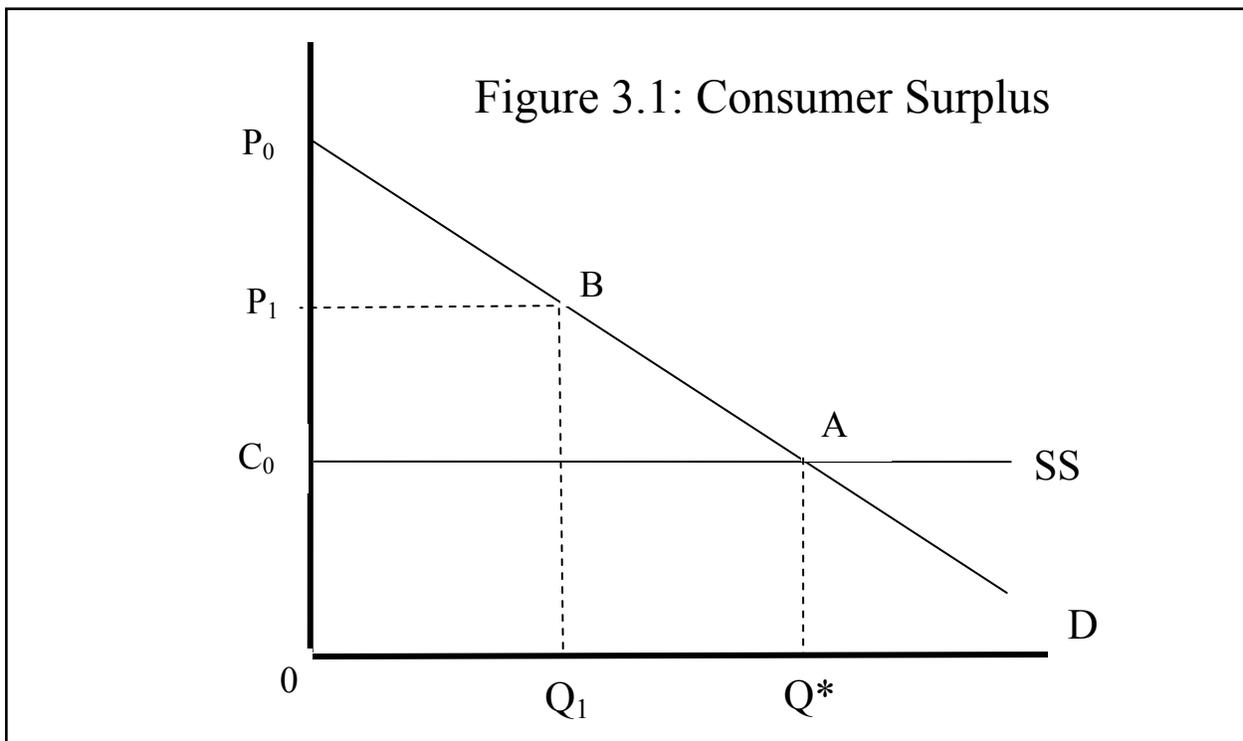
Figure 1 presents a simple supply and demand model of commercial air travel. In the absence of a requirement to install missile defenses on civilian aircraft, the cost per trip is represented by the supply curve  $S_1$ , and the demand per trip is represented by the demand curve  $D_1$ . Each point on the demand curve can be thought of as representing the maximum amount that consumers would be willing to pay for an additional trip. For example, the point at which the demand curve intersects the Y axis, corresponds to a situation in which the individual has consumed no trips, and would be willing to pay a price of  $\$P_0$  to take the first trip. If instead, a consumer were already consuming  $Q_1$  trips per year, then she would be willing to  $P_1$  for an additional trip. This amount would be less than at the point where no trips were consumed because the value of a marginal trip would generally be presumed to decline with the number of trips taken, based on the principle of diminishing marginal utility.

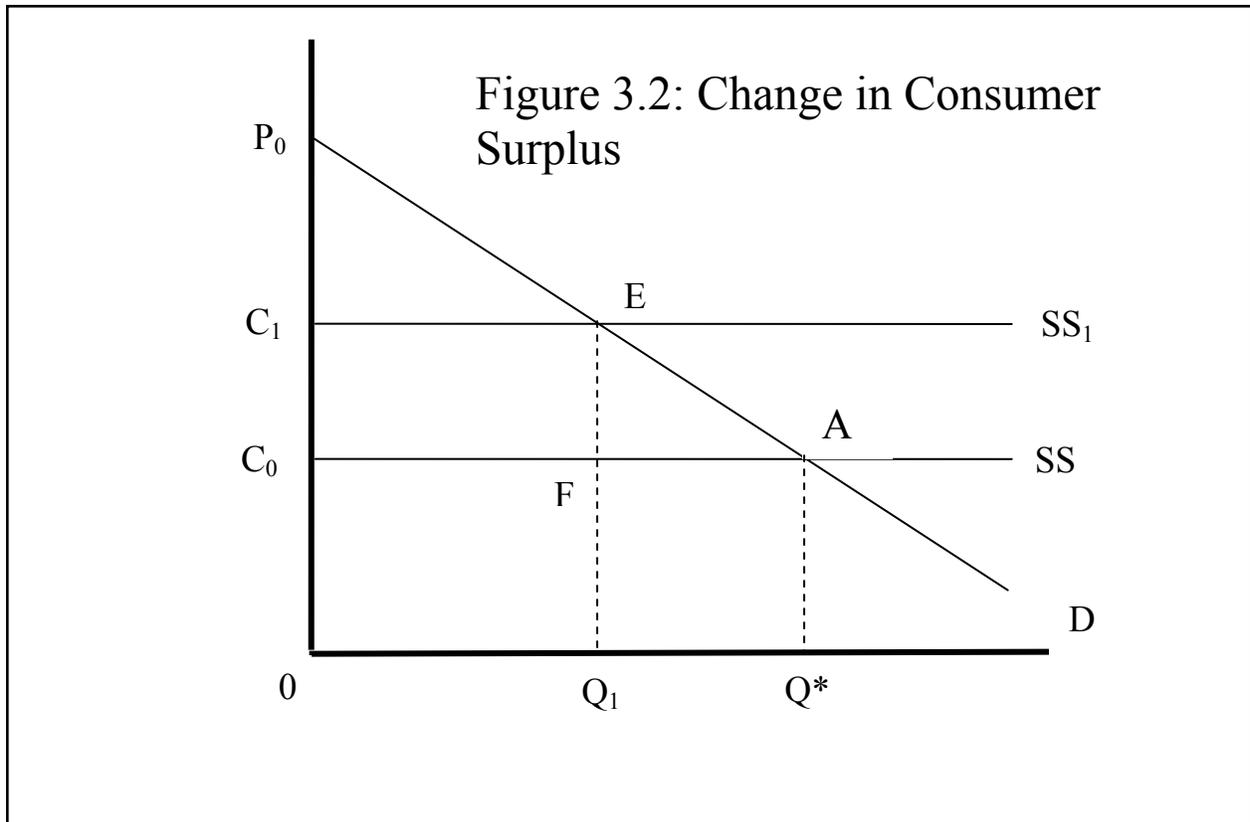
Assume for purposes of illustration that prior to the adoption of a regulation requiring airlines to install missile defenses on airliners consumers could take as many trips as they desired at a constant cost per trip of  $\$C_0$ . In that case, the market equilibrium quantity of trips taken would be  $Q^*$ . The consumer would be said to have captured a consumer surplus because although she was only required to pay a price of  $\$C_0$  for each trip taken, she would in fact have been willing to pay more for each trip taken up to the last or marginal trip. For example, although she would have been willing to pay  $\$P_0$  to take the first trip, she would only have been required to pay  $\$C_0$ , giving her a consumer surplus equal to the difference, or  $\$(P_0 - C_0)$ . Similarly the value of an additional trip at taken at  $Q_1$  would be  $P_1$ , providing a surplus of  $\$(P_1 - C_1)$ , and so forth. The total consumer surplus that the consumer would enjoy from having the ability to consume as many trips as she wishes at a cost of  $\$C_0$  would equal the sum of these consumer surpluses between the points 0 and  $Q^*$ . Mathematically, this amount would equal the shaded Area bounded by the points  $P_0AC_0$  in Figure 3.1.

Requiring commercial air carriers to install missile defenses on airliners would presumably increase the cost per trip, which in Figure 3.2 is represented by an upward shift in the supply/cost curve from  $\$C_0$  to  $\$C_1$ . After the increase in cost, the consumer would be able to take as many trips as desired, but a higher cost per trip. The consumer surplus received per trip would fall, and the total consumer surplus would be represented by area  $P_0BC_1$ .

The difference in consumer surplus would represent the amount by which the consumer's economic well-being was reduced by the increase in the cost of air travel. This amount, which mathematically would equal the difference between the larger triangular area  $P_0AC_0$  and the smaller triangular area  $P_0BC_1$ , would be the amount of money that would need to be paid to the consumer to offset the loss in well-being as measured by the drop in consumer surplus. This amount can be represented graphically in Figure 2 by the trapezoidal area  $C_1EAC_0$

For purposes of estimating the change in consumer surplus, it is useful to note that this amount can be broken down into two components, which in Figure 3.2 are represented by the areas  $C_1EFC_0$  and  $EFA$ . Area  $C_1EFC_0$  equals the change in the cost per trip multiplied by the number of trips taken after the cost increase. In other words it represents the decline in consumer well-being that results from the fact that the trips that they take cost more as a result of homeland security measure. Area  $EFA$ , which equals the change in cost multiplied by the change in the number of trips taken as a result of the price increase, represents the decline in consumer well-being that results from the fact that consumers not only spend more on the trips they take – e.g. area  $C_1EFC_0$  – but also take fewer airline trips – the area  $EFA$ . The sum of these two pieces equals the total loss in well-being. As is discussed more fully in Appendix 2, these magnitudes can often be estimated using market data.





### Producers Surplus

In the analysis above, the price paid by consumers is shown as rising by the full amount of the increased costs associated with the installation missile defenses on commercial aircraft. In this scenario, the cost of the homeland security measure would be borne entirely by consumers in the form of lower consumer surplus. If, however, market conditions did not permit suppliers to raise the price per trip by the full amount of the added cost, producers would also bear a portion of the burden of the homeland security regulation. Although the cost per trip would have increased due to the need to install missile defense systems, the price charged per trip would not increase by a commensurate amount.

The formal measure that would capture this impact is the change in producer's surplus, which is a concept that is analogous to that of consumer's surplus. We do not present a formal discussion of how producer's surplus is conceptually defined, but note that in practice it would be measured as the reduction in profit that the firm would incur due to the need to comply with the homeland security regulation.

### **3.4 Estimates from related markets**

Estimating changes in consumer and producer surplus requires data from explicit market transactions. Such transactions may not always be available when government policies affect goods that are not explicitly traded in markets.

It is often possible, however, to obtain estimates of the relevant cost or benefit by using data from related markets. We consider three examples: (a) costs arising from delay in travel time, (b) costs arising from delay in the shipment of goods and services, and (d) costs arising from the loss of amenities (such as a jersey-barrier-free city). We also discuss how this approach might be used to estimate the willingness-to-pay for reductions in the risk of harm due to terrorist attack.

### 3.4.1 Delay in Travel Time

It is well-documented that homeland security measures have increased time spent traveling by air, once the added waiting time at airports is factored in. These increased waiting times represent a loss in the economic well-being of air travelers, and hence they would have a willingness-to-pay to avoid having to incur such delays. Although there is no market in which “reductions” in air travel delay are bought and sold, there are several related markets in which individuals implicitly do attach values to their time, and these markets can be used to estimate willingness to pay for reductions in congestion and travel delay.

According to Boardman, et al (2001), the majority of the empirical literature on the value of time focuses on estimating the value of travel time, normally referred to as the value of travel time savings (VTTS). However, it is important to note that the VTTS will only provide a rough guide to the value of other time. For example, people typically experience more disutility from waiting time than pure travel time. The majority of studies examine VTTS on a country or regional basis and use local before-tax and after-tax wage rates to estimate VTTS. Boardman, et al, rely heavily on a meta-analysis conducted by William G. Waters II who reviewed estimates of VTTS from 56 empirical studies conducted between 1974 and 1990. These studies involved both revealed preference approaches and contingent valuation studies. Walters found that a shadow price between 40 and 50 percent of the after-tax wage rate is appropriate for travel by automobile. Finally, Boardman, et al note that it is useful to separate travel time savings into work time, commuting time, and leisure time. Work time should be valued at the before-tax wage rate plus benefits, while leisure time and commuting time should be valued based on the percentage of after-tax wage rate (pp. 401 – 402).

In 1997, the U.S. Department of Transportation (DOT) issued “Department Guidance for the Valuation of Travel Time in Economic Analysis.” This report was updated in 2003 to provide more accurate estimates of hourly wage rates. The report suggests that there are two reasons to estimate the value of time saved from travel. First, that time may be devoted to other activities preferred by travelers such as earning income or leisure; therefore, traveling imposes an opportunity cost equal to the individual’s value of time in the foregone activity. Second, when travel is associated with unpleasant conditions such as crowding, waiting in line or driving in traffic, cutting travel time will be beneficial. Besides distinctions made between modes of travel and trip purpose (personal or business), DOT also differentiates between intercity travel and other local travel. The report notes that although some analysts have argued that shorter periods of time are more valuable than larger blocks of time because larger blocks of time can be put to other uses, the DOT claims that without strong empirical evidence to the contrary, they assume a

constant value per hour for large and small time savings. Finally, DOT recommends using regularly reported nationwide statistics for the wage rates of the traveling population (U.S. Department of Transportation, 1997). The value of travel time savings suggested by DOT are summarized in the tables below (U.S. Department of Transportation, 2003).

Category	Surface Modes	Air Travel	Truck Drivers
Local Travel			
Personal	50%	--	--
Range	35 – 60%	--	--
Business	100%	--	100%
Range	80 - 120%	--	100%
Intercity Travel			
Personal	70%	70%	--
Range	60 – 90%	60 – 90%	--
Business	100%	100%	100%
Range	80 - 120%	80 - 120%	100%

Category	Surface Modes	Air Travel	Truck Drivers
Local Travel			
Personal	\$21.10	--	--
Business	\$21.20	--	\$18.10
Intercity Travel			
Personal	\$21.10	\$33.30	--
Business	\$21.20	\$40.10	\$18.10

Category	Surface Modes	Air Travel	Truck Drivers
Local Travel			
Personal	\$10.60	--	--
Range	\$7.40 - \$12.70	--	--
Business	\$21.20	--	\$18.10

Range	\$17.00 - \$25.40	--	\$18.10
All Purposes	\$11.20		--
Range	\$7.90 - \$13.40	--	--
Intercity Travel			
Personal	\$14.80	\$23.30	--
Range	\$12.70 - \$19.00	\$20.00 - \$30.00	--
Business	\$21.20	\$40.10	\$18.10
Range	\$17.00 - \$25.40	\$32.10 - \$48.10	\$18.10
All Purposes	\$15.60	\$28.60	--
Range	\$13.20 - \$19.80	\$23.80 - \$35.60	--

W. Douglass Shaw critiques the use of an individual's wage rate as the value of travel time savings. He notes that this generalization is troublesome because it can be inferred that an individual earning no market wage puts no value on her or his leisure time. Shaw argues that economist should differentiate between the value of a person's time and the cost of their time. Specifically, he states that a low wage earner may have a low opportunity cost of time, but may value their time as highly as a high wage earner. Also, Shaw notes that using the wage rate to determine VTTS ignores an individual's decision to allocate time. Essentially the point in the year, week, or day might influence an individual's opportunity cost of time at different points in time, because the next best alternative to spend their time may be different in the summer than in the winter, for example. Although Shaw points to future directions of research that might resolve some of these issues in the future, he doesn't suggest any current alternatives to measuring the value of time (Shaw, 1992).

### 3.4.2 Delays in Shipping of Goods

Homeland Security measures at border crossings and ports increase the average time it takes exporters to get their goods to US markets, as well as, the variability in transit time. In an era of just-in-time inventory, when multiple countries may be involved sequentially in the production of a single good, these time delays create real costs that should be included in any cost-benefit analysis. For example, in the days following 9-11 wait times for trucks at the Ambassador Bridge border crossing between Detroit and Windsor, Canada increased from 6 hours to 11 hours. The delay halted production at six automobile plants in the Detroit area (Ross, 2002). These time costs are, in effect, tariffs creating barriers to trade. Time costs may also affect the country location decision of firms in the long run. Because time costs vary across types of goods, this implies that changes in transportation time and other transportation costs may affect the composition of trade in the long run.

In his working paper, "Time as a Trade Barrier" David Hummel monetizes these time costs in a way that may be particularly helpful for estimating the costs of security related delays at ports. His estimates are based on the trade-off an exporter makes between freight charges and time when deciding between air and ocean shipping. This trade-off reflects an exporter's willingness-to-pay for timesavings. Hummel estimates the exporter's willingness-to pay to reduce transportation time as a percent of the good's price. This allows the additional time costs

of security to be analyzed as an ad-valorem tariff. Hummel also examines the effects of time costs on the country location decisions of firms.

According to the theory underlying Hummel's estimates, exporters select a country location and decide between air and ocean shipping so as to minimize the total cost of producing and transporting their particular commodity type to the United States. Transportation costs include time costs, as well as, freight charges. Time costs consist of the interest on the value of goods in transit (pipeline inventory costs) and depreciation. Goods lose value during transit for a variety of reasons, meaning depreciation rates may vary substantially across categories of goods. Some agricultural goods spoil rapidly. Depreciation rates may also be very high when consumer tastes are highly specific and variable making it more difficult for exporters to accurately predict demand for specific product types. Examples of this phenomenon include computers, office equipment such as copiers, fashion items, and children's toys. Production stoppages caused by delay in the delivery of a component are another source of depreciation. In fact, with increasing vertical specialization in world trade and the growing reliance on just-in-time inventory, depreciation rates for some component parts may exceed 100%. In other words, the cost of production bottlenecks due to delivery delay may exceed the value of the awaited parts.

Hummel estimates the effect of time costs on trade using a two-stage selection corrected probit model. The first stage estimates the effect of transit time on the probability that a given commodity type will be exported to the United States conditional on a country's production endowments and distance to the US (a proxy for freight costs). He finds that an increase in shipping time of just one day for most commodity categories decreased the probability of observing exports from a given country by about 1%. For machinery, transport equipment and miscellaneous manufactures, an increase in shipping time of one day reduced the probability of observing exports from a given country by about 1.5%. Shipping time did not significantly affect the probability that a given country would export cork and wood, pulp and waste, natural gas, coal, animal oils, or fertilizers to the United States.

In the second stage, Hummel estimates the probability that air shipping will be chosen for a particular commodity conditional on the exporting country. The probability that an exporting country selects air shipping is a function of the difference between air and ocean freight charges and the number of shipping days for the transport mode selected. Air shipping is assumed to take one day from anywhere in the world. This specification allows Hummel to estimate the willingness-to-pay for time reductions. His results indicate that for machinery and miscellaneous manufactures an additional day's transit time results in the equivalent of an ad valorem tariff of 0.8%. According to this estimate, an increase in transit time of 3 days due to additional security would be the equivalent of 2.4% tariff. Within the machinery and miscellaneous manufactures group, office equipment had the highest per day tariff rate of 2.2%. However, for all other categories there is no statistically significant time effect.

There are some difficulties regarding the applicability of this study to the measurement of security related delay costs at borders. First, the study does not estimate the costs of increases in the variability of transit time, only increases in the average transit time. Security measures are likely to increase the variability of transit time, as well as, the average duration. It may well be

that the variability in shipping times created by increased security screening poses the greater cost to firms with just-in-time inventory systems. Second, the estimated ad-valorem tariff rate of 0.8% only applies to machinery and miscellaneous manufactures and this study does not provide estimates for hourly costs of time at land border crossings. Finally, the willingness-to-pay for time saving estimates from this study were estimated conditional on country location. In the long run, time costs affect country selection. Given that time costs vary over types of good, it is possible for increased security time costs to ultimately change the composition of trade.

Nonetheless, Hummels “back of the envelope” estimate that a days worth of delay at a border translates into an effective increase in the cost of imported goods of 0.8% offers the best available “rule of thumb” for gauging the order of magnitude of the costs imposed by time delays in the shipment of goods and services.

### 3.4.3 Loss of Amenities

Both threats of terrorist attacks, and responses to such threats may affect the amenity value of living in certain locations. These amenity value are not directly traded in markets, however as OMB Circular A-94 notes, in such cases, willingness to pay can sometimes be inferred indirectly by observing changes in land values or variations in wage rates, that can be linked analytically to the policy change whose costs and benefits are being evaluated.

Certain regional models can be used to quantify the effects of government policies and other factors that affect welfare of individuals but for which observations of explicit market transactions are not available. In order to grow, a region must attract labor and capital – the mobile factors of production. While labor is primarily motivated by differential wages, taxes, and observable living costs, amenity differences are also important. Workers trade off differences in wages, housing cost, and amenity so that, in equilibrium, the utility from the package of these characteristics in one location must equal that attainable in other locations. Capital is attracted by profit that is higher whenever wages and rents of real property are lower.

These insights have led directly to the Rosen-Roback model of regional equilibrium that is the basis for the implicit markets model of regional development.<sup>2</sup> Figure 3 shows a region in Rosen-Roback equilibrium where the function  $V(W, R; A^*)$  that reflects combinations of wages, and rents that leave workers equally well off assuming that the region has amenity  $A^*$  and the function  $\Pi(W, R; \alpha^*)$  reflects combinations of wages and rents that leave firms with equal profits assuming amenity of the business environment is  $\alpha^*$ .<sup>3</sup> Note that households are willing to pay higher rents (housing costs) if wages are higher and firms are willing to pay higher rents if wages are lower. An equilibrium combination of wages and rents at  $W^*, R^*$  is achieved for given level of household amenity,  $A^*$ , and business amenity,  $\alpha^*$ .

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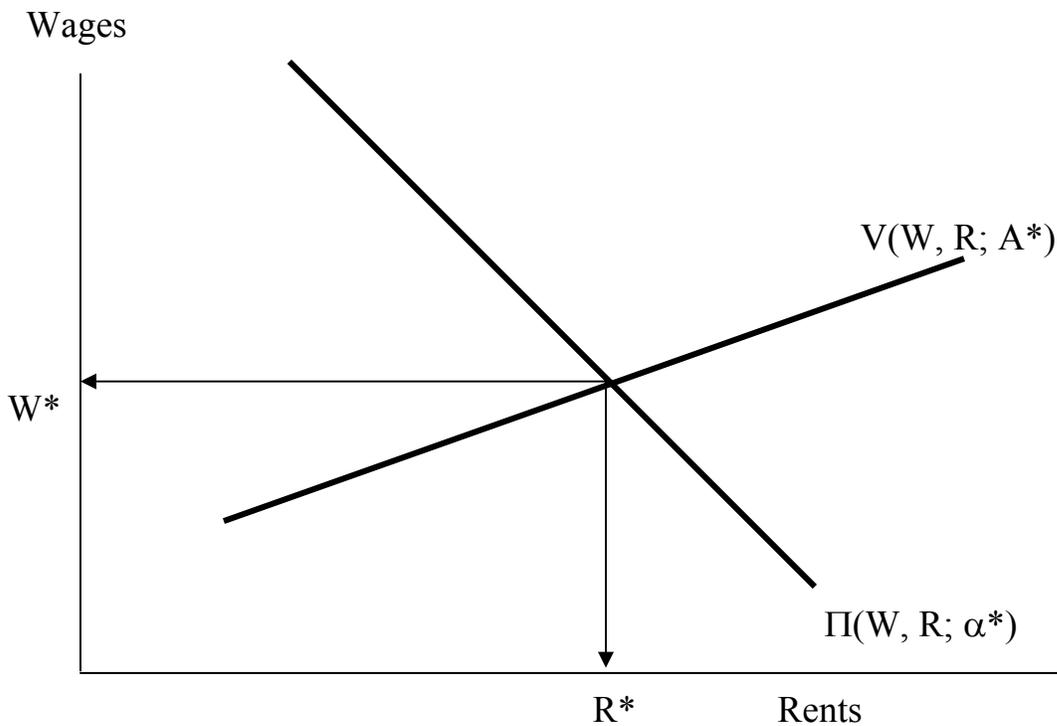
<sup>2</sup> For a more detailed discussion, see: Jennifer Roback, "Wages, Rents and Amenities: Differences Among Workers and Regions," *Economic Inquiry*, (January 1988) and Jennifer Robak, "Wages, Rents and the Quality of Life," *JPE*, (Dec 1982).

<sup>3</sup> Technically  $V(\cdot)$  is an indifference curve based on an indirect utility function and  $\Pi(\cdot)$  is an iso-profit function.

It is instructive to observe what happens in a Rosen-Roback model if there is a change in amenity. For example, assume that the threat of terrorism lowers  $A^*$ , household amenity, down to  $A' < A^*$ . This shifts the  $V(W, R; A)$  function up as households require higher wages to stay in the region as shown in Figure 5. Note that wages rise and rents fall as the regional equilibrium shifts along the  $\Pi(\cdot)$  function. But this provides an implicit market mechanism for valuing the effect of the rise in threat of terrorism in terms of variables, wages and rents, that are denominated in dollars. The implicit market mechanism converts an unobservable, terror threat, into an economically measurable implicit measure. If terror threats lower both  $A^*$  and  $\alpha^*$ , then  $V(\cdot)$  shifts up as shown and  $\Pi(\cdot)$  shifts down so that observable response is largely due to the fall in rents. This makes intuitive sense in that real estate in general and land in particular is the least mobile factor of production and hence it tends to bear the burden of any fall in local amenity.

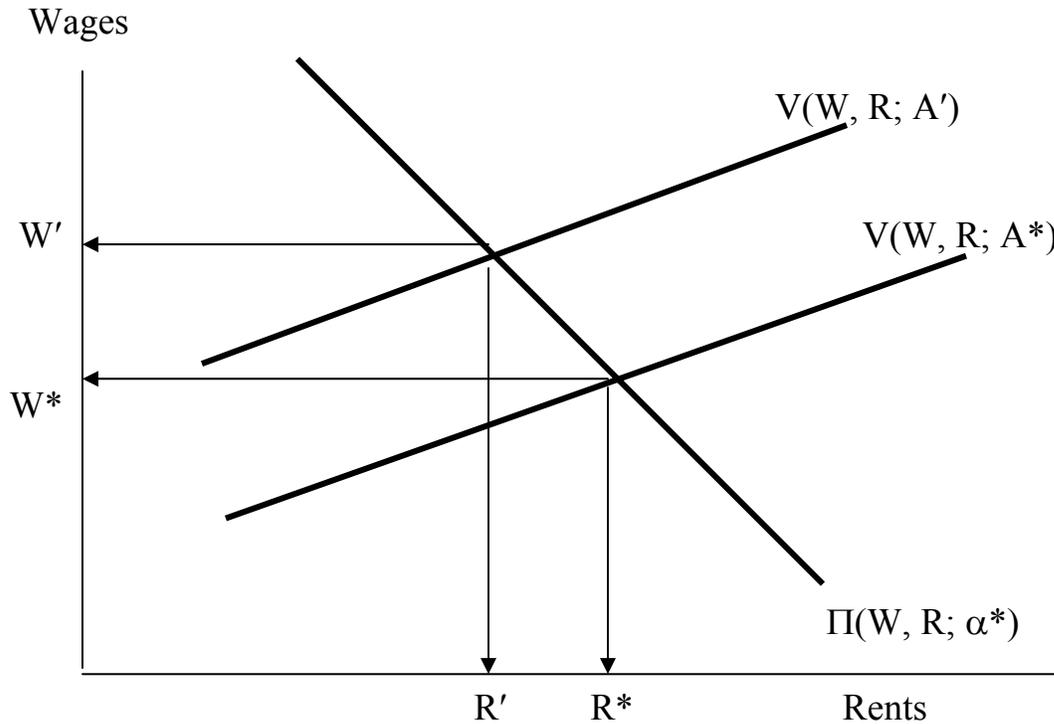
Figure 3.3

Rosen-Roback Model of Regional Development



**Figure 3.4**

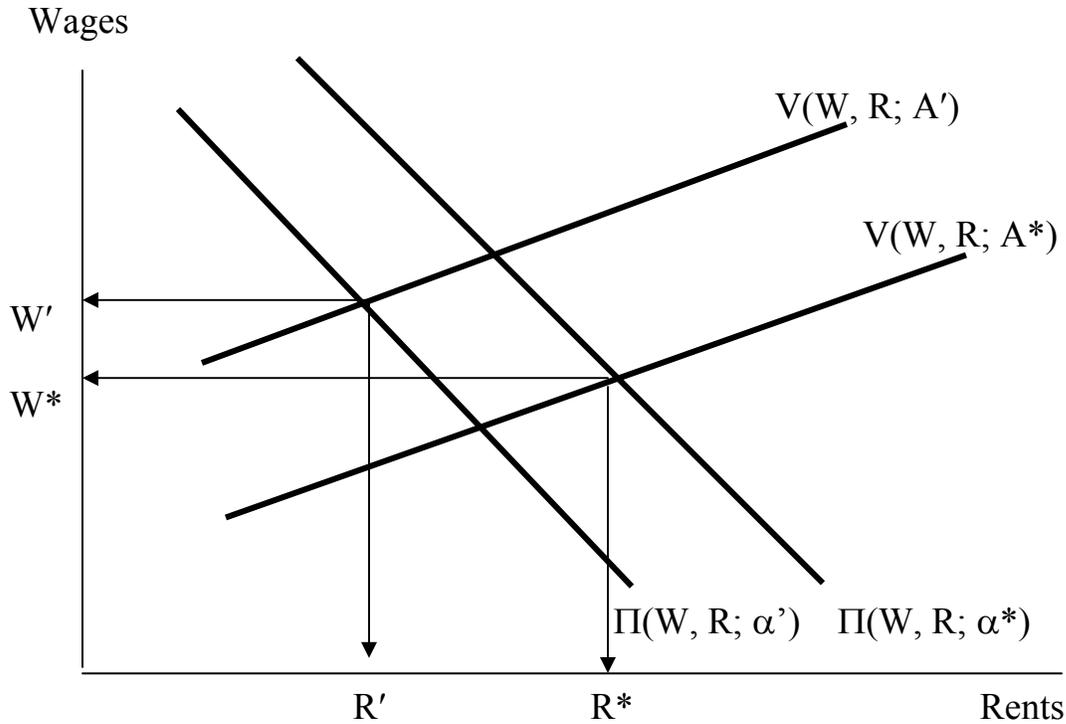
Effect of a Fall in Household Amenity in a Rosen-Roback Model



Similar arguments can be made for using the Rosen-Roback framework to produce an implicit markets measure of the cost of homeland security regulations that change an amenity. Any fall in amenity due to requirements that firms change production processes or the movement of workers is impeded will tend to lower both  $A^*$  and  $\alpha^*$  shifting  $V(\cdot)$  up and  $\Pi(\cdot)$  down as illustrated in Figure 6 below. These changes result in a large fall in rents, from  $R^*$  to  $R'$  and, in this case, a fall in wages from  $W^*$  to  $W'$ . In general the change in wages is ambiguous change in wages but the fall in rents is not. Once again, these changes provide an observable implicit economic measure of the cost of the regulation that can be applied if no explicit measure is available.

**Figure 3.5**

Effect of a Fall in both Household and Business Amenity



The arguments of the Rosen-Roback model have been applied to the issue of measuring effects of disaster events, and even the effects of terrorist attacks on New York City. Bram, et. al, use changes in housing prices and land rents to measure the economic effects of September 11 on New York City.<sup>4</sup>

### 3.5 Measures of Willingness to Pay: Contingent Valuation and Stated Preference

A wide range of public policies have consequences that are all but impossible to “value” based on market behavior. The *Contingent Valuation Method* (CVM) is a recent, though somewhat controversial, innovation in CBA that attempts to use a variety of survey techniques to elicit estimates of willingness-to-pay for “positive outcomes” of public policies, or willingness-to-accept for negative outcomes.

<sup>4</sup> See, Jason Bram, Andrew Haughwout, and James Orr, “Has September 11 Affected New York City’s Growth Potential,” in *Modeling Spatial and Economic Impacts of Natural Disasters*, Ed. By Stephanie Chang, and Yasuhide Okuyama, (Springer-Verlag: New York), 2004, pp. 53-73.

The basic premise of CVM is that if one wishes to know the value people place on something (e.g. a view, clean air, a safer working environment, a wider beach), one obtains estimates by administering (carefully designed) questionnaires or surveys.

A CVM study requires three basic items. (1) The item to be valued by CVM needs to be described in as much care and detail as possible so that people have a clear idea about what they are being asked to value. (2) The survey needs to specify a mechanism by which “payment” would be made hypothetically. This payment method should be as concrete and “realistic” as possible. (3) There needs to be a mechanism for taking individual responses to the survey and aggregating up to determine willingness-to-pay.

### 3.5.1 Ways of Eliciting Estimates of Willingness-to-Pay .

There are several different ways of eliciting responses about willingness-to-pay from respondents.

*Open-Ended Questions.* Respondents are asked to state their maximum willingness-to-pay for the good or policy outcome that is being valued. This approach was widely used in earliest CV studies. It went out of favor because people were concerned about getting “unrealistic answers” without giving respondents some sort of reference. But recently, people have become concerned about “starting point bias” that results when respondents *are* given a frame of reference. Thus, open-ended questions are coming back into use as a supplement to or a check on other CV methods, because open-ended questions are not subject to starting point bias.

*Closed-Ended Iterative Bidding Method.* Respondents are asked whether they would pay a specified amount for the good that has been described. If the respondent “agrees” to the amount, then the amount is increased incrementally. The process continues until the respondent expresses unwillingness to pay the stated amount. Conversely, if the respondent states an unwillingness to pay the initial amount, it is lowered incrementally until an amount is reached that elicits a positive response. This method was very commonly used until recently. But has become less popular because it is now recognized that the answers can be quite sensitive to the “starting point” that is chosen.

*Dichotomous Choice or Referendum Take-it-or Leave-It.* In this approach, the respondent is offered a simple choice. “Would you be willing to pay \$X in order to.....?” and are prompted to answer yes or no. The same question is then posed with different values for X to different survey respondents selected at random.

This procedure is one of the most widely used in CV studies for several reasons. One is that the take-it-or-leave-it nature of the choice closely approximates real choice that people have to make. One is presented with the price for a good and either decides to buy it or not. Another is that the choice that people are being asked to make is relatively simple.

*Payment Card With Relative Tax Prices.* After describing the good to be valued, present respondents with a card that shows respondents tax-prices for a range of other publicly-provided goods. For example, the card might show the specific dollar amount that someone in a given income bracket is estimated to pay per year for national parks.

*Payment Card with Range of Prices for the Good.* The contingent valuation instrument explains a particular, specified change in the good in question, and then provides a card with a range of dollar values. The respondent is then asked to select the maximum value that he or she is willing to pay for the change.

The payment card method of eliciting willingness to pay requires less complex information processing than open-ended or iterative bidding, but more than dichotomous choice. Some believe that by presenting a range, it helps avoid starting point or anchoring bias, but others are not quite so sure. Still experts generally agree that the anchoring problem is probably less severe for this method, than, for example, it is for the open-ended method).

### Payment Vehicles

The design of contingent valuation studies require specification of a *payment vehicle*. (Note that this is separate from the different methods for eliciting information about willingness-to-pay. For example, in the open-ended question, one would like to frame the open-ended question in terms of some kind of concrete payment mechanism.) The goal here is to create some “realism” in the questions by specifying a payment vehicle that people can “understand and relate to.” Examples of payment vehicles are tax bills, utility bills, product prices, and user charges.

### 3.5.2 Issues in the Use of Contingent Valuation Methods.

CVM is now quite widely used, but it is also controversial. Critics of the method point to a number of problems raised by using surveys in this way to elicit information about willingness-to-pay. Some of these concerns have to do with problems that one generally encounters in doing surveys of any type, while others pertain specifically to the use of contingent valuation.

One issue is that of sample bias. One is trying to use the contingent valuation survey to derive information about willingness-to-pay that can be applied to the “relevant population” of those who benefit. This requires, of course, that one have a “representative sample” of the “relevant” population. But it also means that one needs to be clear about who the relevant population is. One also needs to think about any possible bias introduced by nonresponse or interviewer bias.

### Conceptual Problems With Contingent Valuation Methods.

In the final analysis, most economists agree that contingent valuation methods ultimately provide information about “what people say they would do, or would be willing to pay” which is not the same as actual behavior revealed in markets in which people reveal their willingness to pay by making market choices. For this reason, questions raised about the validity of using this methodology. These include: How “realistic” can any survey setting be made, and do people understand what they are being asked? Do the questions frame the issue in a manner that avoids “skewing” the results? Can the questions be framed to minimize certain decision-making and judgment biases? Other issues, summarized below have also been raised.

*Noncommitment bias.* There seems to be a tendency for people to overstate their willingness to purchase a product that is described to them in surveys. This leads to concerns that people will overstate their willingness-to-pay on contingent valuation instruments. To some extent this can be dealt with how the instrument is designed. For example, having elicited an initial response, one might then ask a series of questions that make people more aware of the “budget constraint” that they face. In one case, people were first asked to state their willingness to pay to avoid a specific oil spill. Then, they were asked to value environmental protection compared with other social programs such as reducing crime, homelessness, etc. They were also asked questions about the valuation for different types of environmental protection(wilderness areas versus groundwater quality, rainforest protection, and other environmental goals. Then, some of these were chosen, and they were asked to state their willingness to pay for variants of these (e.g. willingness to pay for wilderness protection that took the form of reduced harm from human-caused problems, vs. wilderness protection in other forms). Then, after all this, they were again asked to state their willingness to pay to avoid the oil spill. The result was a reported WTP that was a hundred times smaller than that initially reported.

*Order effects.* There is evidence that the response to WTP questions can be quite sensitive to the order in which the questions are raised. The classic example is a study that asked people to value preserving seals and then the value of preserving whales. Others were asked to value preserving whales, and then asked the value of preserving seals. Seal values were considerably lower when the seal question was asked after the whale question.

*Embedding effects.* A basic axiom of economics is that “more is better.” And one would presumably be troubled if people’s reported WTP are only slightly higher for large changes in the amount of “good” than for small changes. But this happens often in contingent valuation surveys. This leads some critics to claim that this calls into question the notion that contingent valuations elicit even a rough approximation of willingness-to-pay. People may, instead, be

expressing broad “moral views” about “doing the right thing” rather than expressing willingness-to-pay in a sense appropriate for doing applied welfare economics.

*Starting point bias.* In many cases, the reported willingness-to-pay is sensitive to the starting point that is used. For example, an iterative-bid study of willingness-to-pay for cleaning up a fjord in Norway elicited different answers when the bid was started at 200 kroner and went up to 2000 kroner than when the bid started at 0 and went up to 2000 kroner – even though there were no bids between 0 and 200 kroner!

*Willingness to pay vs. Willingness to Accept.* In theory there should only be small differences between a respondents willingness-to-pay for receiving a good, or their willingness-to-accept the loss of a comparable good. But in practice, large differences are observed. These seems to reflect the fact that people seem to demand considerably more monetary compensation to give things they already have than they are willing to pay to acquire the same item. But, some evidence suggests that if people are allowed to “learn” this difference shrinks. The recommendation seems to be that one should always try to frame issues in terms of willingness to pay rather than willingness to accept.

### 3.5.3 Role of Contingent Valuation in Benefit Cost Analyses of Government Programs

The use of contingent valuation methods has received cautious endorsement from a blue-ribbon panel of experts assembled by the National Oceanographic and Atmospheric Administration. The Office of Management and Budget (2003) notes that the use of such methods have become increasingly common, but also notes because of the issues that have been raised about the reliability of estimates of willingness to pay that are obtained from contingent valuation studies, extra care is needed when using such estimates.<sup>1</sup>

### **3.6 Treatment of Time Issues of Discounting**

A potentially important issue in many cost-benefit studies is the valuation of benefits and costs that occur at different points in time. A common example is shown in Figure 3, which is a stylized illustration of a “typical” benefit-cost” profile found in the case of many public works projects which require that capital investments be made “up-front” in order to secure a flow of benefits that is experienced after the initial investment has been made. Examples of such projects would be highways, airports, and water projects. However, similar profiles can be found in other areas, such as public spending on improving environmental quality which often requires incurring costs today in order to provide benefits to future generations. In the case of homeland security, examples of measures with time profiles of benefits and costs similar that shown in Figure 4 would be investments undertaken to harden the physical infrastructure, which require incurring costs in the present to provide future benefits.

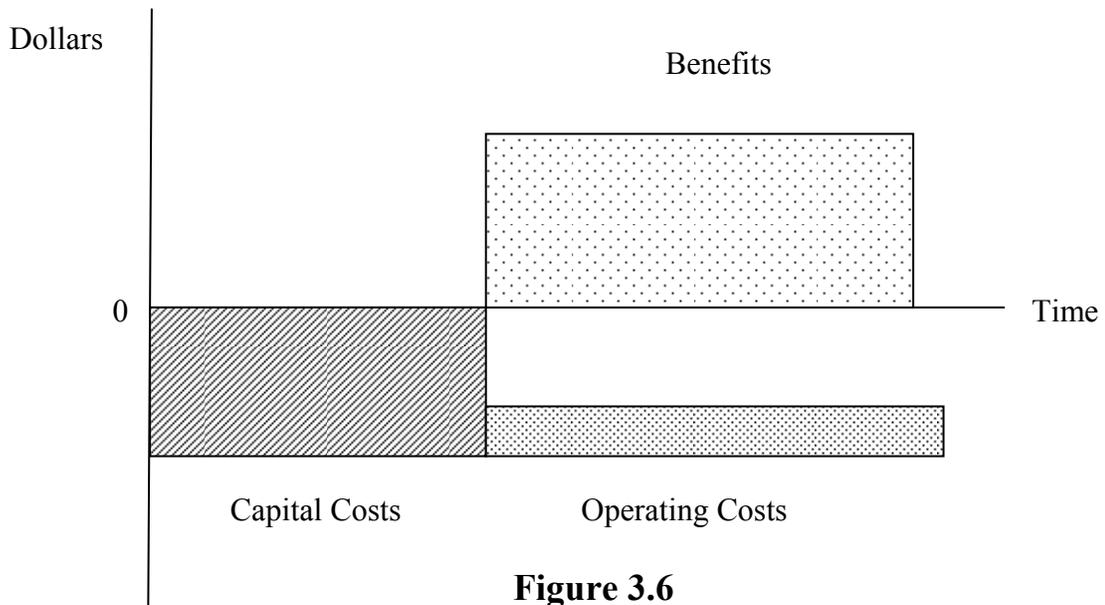
It is a basic principle in economics and finance that there is a “time value of money” meaning that a dollar spent or received sooner is worth more than dollars spent or received later. In cases such as that shown in Figure 4, it is therefore generally not appropriate to simply add up

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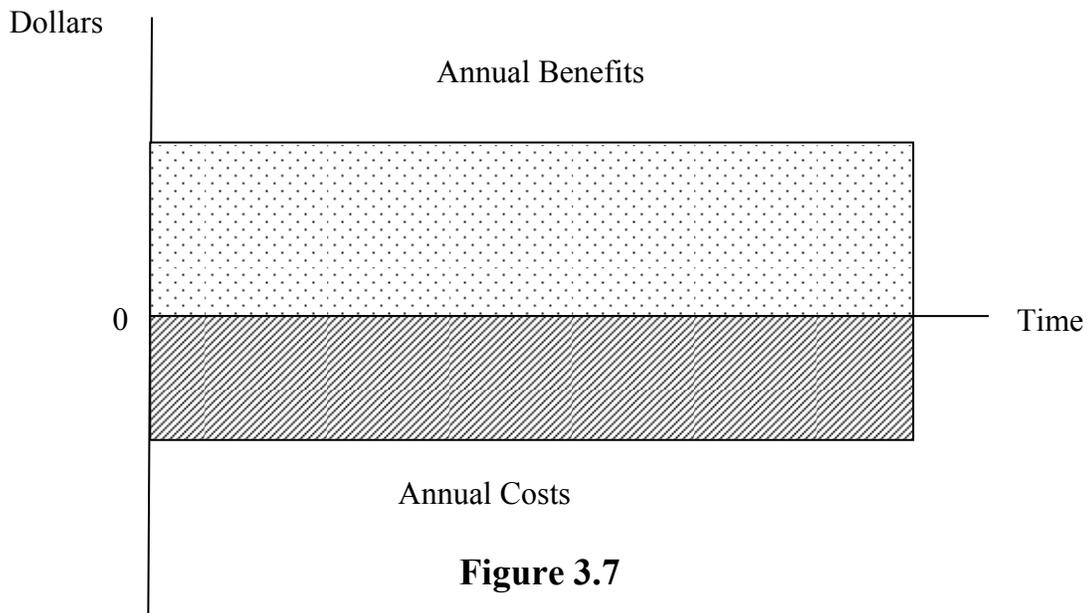
<sup>1</sup> For a discussion of the various debates surrounding the use of contingent valuation methodologies, see the symposium on the subject in *Journal of Economic Perspectives*, Autumn 1994.

the costs of the capital investment and compare this amount with the sum of future benefits without making adjustments to account for the fact that a dollar of cost or benefit experienced sooner is worth more than a dollar of cost or benefit experience later.

These adjustments take form of converting dollars of benefits and costs incurred at different points in time into what these amounts would be worth if received/incurred in the present. The analytic technique that is used for this purpose is *present value analysis*. In essence, this procedure involves applying a mathematical formula to add together benefits and costs that involves computing a weighted sum of benefits or costs, where the weights assigned to a dollar of benefit or cost depend on when that dollar benefit or cost is received or incurred. A dollar of benefit or cost experienced in the present has a weight of 1, while dollars of benefits or cost experiences in later periods have values that both are less than 1, and which decline the further in the future the benefit/cost occurs. The magnitude of these weights is determined by the “social discount rate” which is a type of interest rate that measures how much society discounts future benefits and costs. The higher the value of the social discount rate that is used, the more heavily the future is discounted. It can be shown that if the project that is being evaluated has a general time profile of benefits and costs like that shown in Figure 4 --- namely costs are incurred before benefits are received --- the higher (lower) the discount rate that is used to convert future dollars into their present value, the less (more) likely it is that a project with such a time profile will have positive net benefits.



**Figure 3.6**



Because it can affect the outcome of a benefit cost analysis, the choice of the discount rate that is used to discount benefits and costs can be important. Broadly speaking, the choice of discount rate should be guided by the concept of opportunity cost. If, for example, the resources for a public project or regulation come at a cost of less private investment, then the appropriate discount rate to use would be the before-tax return to private investment. If instead the resources come at the expense of less private consumption, then the appropriate discount should reflect the rate at which individuals are willing to trade-off less consumption today for more consumption tomorrow, which will generally be less than the before-tax return to private investment.

OMB Circular A-94 states that a discount rate 7 percent should be used as the base case in applying cost-benefit analysis to federal programs because in the judgment of OMB this rate approximates the average pre-tax return to private investment. OMB guidance (not included in A-94) does, however recognize the incidence of some programs and regulations may fall more on private consumption than on private investment, and in these cases recommends that a lower discount rate of 3% be used in addition to the OMB “default” rate of 7% to calculate present values. (OMB 2003). As a general matter it would seem that the incidence of many, if not most of the projects and regulations implemented in connection with homeland security where discounting of benefits and costs is required (e.g. hardening of critical infrastructure) are likely to fall more on private investment than on private consumption, suggesting that the 7% OMB default rate would be most relevant.

There are, however, also cases in which homeland security measures are more likely to have a time profile of benefits and costs such as that shown in Figure 3.7. The key difference between Figure 3.7 and Figure 3.6 is that in Figure 3.7, the ratio of benefits to costs can be reasonably assumed to be constant each year. An example might be the case of security

measures that involve more intense monitoring of air travelers, which impose costs immediate costs on an annual basis, and which can be assumed to provide a specific annual benefit in the form of reduction in the costs of air-travel-related terrorist acts. In such cases, it is sufficient to estimate the annual social benefits from greater homeland security, and compare these with estimates of the annual social costs of achieving more security, without converting either benefits or costs to their present values.

### **3.7 Treatment of secondary effects and joint outputs (dual benefit)**

Public programs often have multiple effects. For example, undertaking expenditures to harden the electric power grid against terrorist attacks will (a) impose costs on utilities in the form of investment required to add additional capacity to the system, (b) increase electricity rates paid by businesses and consumers, (c) raise the relative cost of producing electricity-intensive goods, and (d) provide protection not only against terrorist attack, but also against electric power disruptions caused by non-terrorist-related events. In such cases, the question arises as to which of these effects should be included in a benefit-cost analysis.

#### 3.7.1 Secondary Effects that are not Separate Costs or Benefits

The operative principle in cost-benefit is make sure that all benefits and costs are counted, while at the same time ensuring that no benefit or cost is counted more than once. The application of this basic principle to the above example would lead to the conclusion the effects listed under (a), (b), and (c) are not really different costs, but rather different ways in which the fundamental cost of expanding capacity – namely, the capital costs – are experienced or shared among different groups in society. This point may seem rather obvious in the case of (a) and (b) where presumably the higher electricity rates would be set to allow utilities to recover the capital cost of adding redundancy and capacity to the system. It is less obvious in the case of effects ((b) and (c) until one realizes that the demand of producers for electricity is a derived demand that reflects the value of the goods and services that are produced using electricity as an input. The result is that the change in consumer surplus experienced by business consumers of electricity, which would be the appropriate measure of the cost of higher electricity to businesses, implicitly also reflects the loss of economic well-being experienced by consumers of goods that use electricity as an input. Indeed, as shown in Appendix 3, the measured loss in consumer surplus experienced by business consumers of electricity in (b) is identical to the measured loss in consumer surplus experienced by consumers of goods that use electricity as an input in (c). The two consumer surplus measures are the same because they are measuring the same effect, though in different markets. The main conclusion is that either (a) or (b) or (c) would be appropriate measures of the social cost of creating redundancy, but that to add these measures together as if they were separate costs would (in this case) amount to triple counting.

#### 3.7.2 Secondary Effects that Are Dual Benefits (or Costs)

The set of effects listed under (d) represent a different case. In this instance both of these effects of the project need to be counted because they represent a change in the availability of two different goods --- security from power disruption due to storms and security from power disruption due to terrorist attack --- rather than different manifestation of the same effect as in

cases (a) – (c). Positive joint or dual effects can either be treated as a subtraction from cost, while negative joint or dual effects can either be treated as a subtraction from benefits, or an addition to cost. So long as one uses the difference between benefits and costs as the summary measure.

### **3.8 Showing Distributional Effects in Benefit-Cost Analysis**

Although benefit-cost analysis is intended to show how a project or program affects the production and/or consumption potential of the economy, without regard to how these impacts are distributed among different stakeholders, it is nonetheless possible to provide considerable insight into the distributional as well as the social efficiency aspects of a project or program by how benefits or costs of programs are presented. Indeed the OIRA in OMB encourages those conducting CBAs to “provide a separate analysis of the distributional effects...so that decision makers can properly consider such effects” in evaluating the program. (OMB, 2003, p. 5517). Thus, in the example above, although one would not add together the separate “primary” and “secondary” costs of hardening the electric power grid listed described in the preceding section, it would be both appropriate and useful to enumerate these effects for decision makers.

### **3.9 Benefit & Cost Transfer**

The data requirements for undertaking benefit cost-analyses can often be substantial, and the time-line for conducting such studies more often than not may preclude undertaking much, if any, original research to value costs or benefits of interest. But, although obtaining the quantitative data needed to undertake a CBA can be challenging, it should not be seen as an insurmountable obstacle.

When it is not feasible to provide “fresh” estimates of either the costs or the benefits of a policy or program, it is often still possible to obtain plausible estimates of these magnitudes by drawing on the results of previous research. This process is known as benefit or cost transfer.

For example, as noted above, there is no direct market that places a value on people’s willingness to pay to avoid having to wait in lines. However, a large body of empirical research has established implicit values of time, either based on labor market data, or on choices that individuals make among different modes of transportation based on time. Thus, if an analyst were tasked to estimate the time costs of homeland security measures that increased waiting time at airports, she would proceed in two steps. First, she would estimate the likely magnitude of policy-induced change in the amount of time spent waiting at airports, and then monetize this magnitude by using the range of existing values of time that have been summarized above.

Another example of this approach may be found in the benefit-cost analysis of the City of San Francisco’s response to a raised threat alert level which appears in Appendix 1 of this report. In that case, data were available on the added expenses incurred by the City and County of San Francisco in the process of responding to raising the threat level from yellow to orange. However, estimates were not available of the potential dual benefit from crime reduction resulting from heightened police security in San Francisco, nor were estimates available of the expected benefits from reducing the probability of a terrorist attack.

Plausible estimates of these magnitudes, however, were obtained, or “plugged-in” (to use Boardman et. al.’s phrase) from other sources. In the case of the dual benefit of crime reduction, use was made of an empirical study that estimated the reduction in crime attributable to an increased police presence prompted by raised threat levels in Washington, D.C. and estimates of the expected benefits of lowering the threat of attack in San Francisco were based on the estimated economic cost to New York City of the 9/11 attacks.

In each of these cases, an obvious difficulty with simply “borrowing” estimates from elsewhere is that the estimates of unit costs or benefits may not be comparable due to differences in the affected populations and differences in study methodologies. In the case of the estimates of the dual crime reduction benefit and the expected benefit from reduced threat of attack, the issue would be whether and how to transfer estimates of crime reduction from Washington, D.C. to San Francisco, and estimates of the estimate economic cost of the 9/11 attacks in New York to San Francisco. This difficulty is recognized by OIRA in commenting on the use of benefit-transfer, noting that there “are potential problems and significant uncertainties that are inherent in any benefits analysis based on...benefit transfer techniques. The extent of these problems and the degree of uncertainty depends on the divergence between the policy situation being studied and the basic scenario providing the benefits transfer estimate.” (OIRA, p. 5502).

### **3.10 Using cost estimates as inputs into CBA**

How might estimates of the cost of anti-terrorism measures inform decision-making about homeland security policies? One approach would be to compare the estimated costs of such measures with the potential benefits. Because the main benefit of anti terrorism measures is a reduction in the risk of the bearing the costs of terrorist acts, the general benefit measure would be defined as:

$$(1) B_i = \Delta P_i \cdot CT_i$$

where  $B_i$  is the expected primary benefit,  $\Delta P_i$  is the change in the probability of a terrorist attack that would result if homeland security measure  $i$  is adopted, and  $CT_i$  is the cost that terrorist attack of type  $i$  (that would be affected by the adoption of ant-terrorist measure  $i$ ), would impose if it were successful.

Although it is challenging to estimate the cost of successful terrorist attacks, obtaining such estimates appears to be feasible. What is much more difficult, if not impossible to estimate is the change (reduction) in the probability of an attack that would occur as a result of implementing homeland security policy  $i$ .

One approach for dealing with this issue has been suggested by Richard Posner, who proposes that “inverse cost-benefit analysis” be used to make inferences about what the change in the probability of a terrorist attack would have to be in order to justify spending scarce resources. This procedure solves for the value of the change in the probability of terrorist attack

( $\Delta P_i$ ) that equates the estimate costs of a proposed homeland security measure,  $C_i$  with the expected benefits.

$$(2) C_i = B_i \rightarrow Cost_i = \Delta P_i \cdot CT_i \rightarrow \Delta P_i = \frac{Cost_i}{CT_i}$$

For example, if \$1 billion is spent on a homeland security measure to avert an attack that would impose costs of \$100 billion should it occur, the \$1 billion investment would be justified if the reduction in the probability of attack is  $\Delta P_i = \$1 \text{ billion}/\$100 \text{ billion}$ , or .01 (one in one hundred) (Posner, 2004, pp. 176 – 177). Judgment of whether the expenditure of \$1 billion was socially cost effective would then turn on whether it was reasonable to expect a reduction in the probability of terrorist attack of one in one hundred.

This approach is rather crude because it effectively uses benefit cost analysis to produce an estimate of what the change in probability would have to be in order for a homeland security measure to be socially cost effective. This is not the same thing as actually estimating what the change in the probability of a terrorist attack is likely to be. However, in the absence of independent estimates of  $\Delta P_i$ , this approach offers a simple quantitative framework that can then be combined with subjective judgments by experts. The estimated “break-even” change in probability could also be used a means of comparing the potential social cost effectiveness of different policies.

### 3.11 Using sensitivity analysis

Because there is often uncertainty about the magnitude of costs or benefits, even when they are directly obtained from market data or original research, and perhaps *a fortiori* when based on “plug-ins” from other studies, there is likely to be uncertainty about the true magnitudes of either costs or benefits.

The recommended procedure for dealing with such uncertainty is to undertake a sensitivity analysis in which key parameters, such as price elasticities used to estimate changes in consumer or producers surplus, and/or estimates of costs and of benefits are systematically varied to ascertain the robustness of the benefit-cost analysis.

There are several steps in common in conducting any type of sensitivity analysis. First, the analysis is done using as inputs “baseline values” of the parameters (e.g. elasticities) and/or costs and benefits (e.g. budgetary cost estimates) that the analyst believes to be the most reasonable. The analyst then specifies a range of possible values around the baseline value. This range may be symmetric – e.g. a range centered around the baseline value with an upper bound that is 50% higher than baseline and a lower bound that is 50% lower-- but need not be if the analyst believes that the uncertainty is likely to be “greater” on the positive or negative – e.g. a range that is 50% above and 100% below baseline.

Once the plausible range is specified, the actual sensitivity analysis can take on several forms. The simplest version, termed “partial sensitivity analysis” by Boardman et. al., involves

varying the values of each “key” parameter or benefit or cost category within the range specified, while holding the values of other parameters and benefit/cost estimates constant at their baseline values. This approach is most appropriate when there is reason to believe that the uncertainty in the analysis is due to one or a few “key variables, and can be used to find “break-even values” of such variables at which the estimated benefits just equal the costs. Such information can be helpful in decision-making because it then focuses the question on how likely it is that the break-even value of the parameter or benefit or cost is likely to be observed in reality.

A somewhat more complex approach that involves interactions among uncertainty about several different variables in the analysis is to use the lower and upper bound of values for each variable to specify “most favorable” and “least favorable” scenarios as illustrated below in Table ZZ, and net program/project benefits would then also be computed for these scenarios in addition to the baseline. If estimated net benefits were found to be positive not only in the baseline case, but also in the least favorable “high cost-low benefit” case the implication would be that the project or program was likely to “pass” the benefit cost test despite uncertainty about underlying estimates of benefit or cost. Conversely, a case in which estimated net benefits were negative even in the most favorable “low cost-high benefit” scenario would yield the opposite conclusion. Intermediate cases, such as for example, when the project/program passed the benefit-cost test in the baseline and most favorable scenarios, but failed the test under the “least favorable” scenario, would then require additional assessment about the relative plausibility of the baseline vs. the least favorable scenarios.

	<b>Benefits</b>			
	<b>Benefit Category 1</b>		<b>Benefit Category 2</b>	
<b>Costs</b>	<i>Lower Bound</i>	<i>Upper Bound</i>	<i>Lower Bound</i>	<i>Upper Bound</i>
<b>Cost Category 1</b>				
<i>Upper Bound</i>	Least Favorable		Least Favorable	
<i>Lower Bound</i>		Most Favorable		Most Favorable
<b>Cost Category 2</b>				
<i>Lower Bound</i>		Most Favorable		Most Favorable
<i>Upper Bound</i>	Least Favorable		Least Favorable	

As the table indicates, however, even for a relatively small number of variables, the number of possible combinations of variable values that could, in principle, be observed, can become quite large. One way of addressing this issue is to undertake what is commonly described as Monte Carlo simulation analysis of the results. In this case each range of values specified by the analyst is assumed to be drawn from a probability distribution of possible values for each of the variables. Using spreadsheet software that is readily available, the analyst then creates many different scenarios that involve “random draws” of variable values from each probability distribution, and the net benefits of the project/program are then calculated for each of these scenarios. A distribution of estimates of net benefits is then created to describe the “risk” that the project or program being analyzed is likely to have net benefits that are negative. As Boardman et. al. note, this approach can be a useful and a powerful way of illustrating the degree of uncertainty about both the sign and the magnitude of the net benefits.

## 4: Models and Measures: (Regional) Economic Impact Analysis

As noted in Section 2, the costs that are imposed by homeland security measures are apt to trigger behavioral responses by governments, businesses and individual, that in turn affect economic variables such as jobs, incomes, profits, and tax revenues. These economic impacts should not be thought of as additional costs (or benefits) of a program, but rather as ways in which these costs are manifested in the economy. Nonetheless, such impacts are relevant for understanding how adoptions of homeland security measures can affect various stakeholders.

The analytical framework that is useful both for identifying and quantifying such effects is that of regional economic analysis. Given that threats vary geographically, it is inevitable that homeland security efforts will vary with location and costs will be similarly differentiated by location. Indeed, Frey (2004) has suggested that geographic dispersal is an attractive strategy for minimizing the potential damage associated with terrorist efforts.<sup>1</sup> However, such dispersal may not be costless, particularly as vulnerable facilities are moved away from population centers.

Regional models are often employed to measure “impacts” – i.e. changes in the spatial pattern of economic activity that represents shifts rather than costs. For social and political reasons, interest in impacts is often substantial. Indeed, there is often more interest in impacts than in costs.

Because there are many varieties of regional models, this exposition will begin with a simple classification system. For example, military base closings are expected to result in modest cost savings. More defense services will be produced with the same expenditure. However, the closings result in significant shifts in the location of production. These shifts are not costs because production remains the same but its location changes. Such impacts are often given substantial attention, particularly by the political system and owners of immobile real estate assets. However, impacts should not be confused with costs. Changing the location of production from areas where costs are high to areas lower costs may have regional impacts but the cost effects should be measured in terms of the fall in production costs, which are likely small compared to the amount of production actually shifted.

Conversely, homeland security policies may shift economic activity from areas where costs are lower to places with higher cost production. The amount of production shifted may result in large impacts but the cost of the shift should be measured based on the differences in production cost. These differences are likely very small compared to the shifts indicated by regional impact analysis. The next section of this report presents a relatively straightforward diagrammatic analysis of the concepts at the heart of regional models. In doing so, the emphasis is on presenting the assumptions that differentiate these models. There is no single model of a regional economy that is appropriate for all circumstances, because without making strong assumptions, the model must rely on assumptions that are so strong that available data are completely inadequate to calibrate the model.

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<sup>1</sup> See, Bruno S. Frey, *Dealing with Terrorism – Stick or Carrot?*, (Northampton, Massachusetts: Edward Elgar, Inc.) 2004.

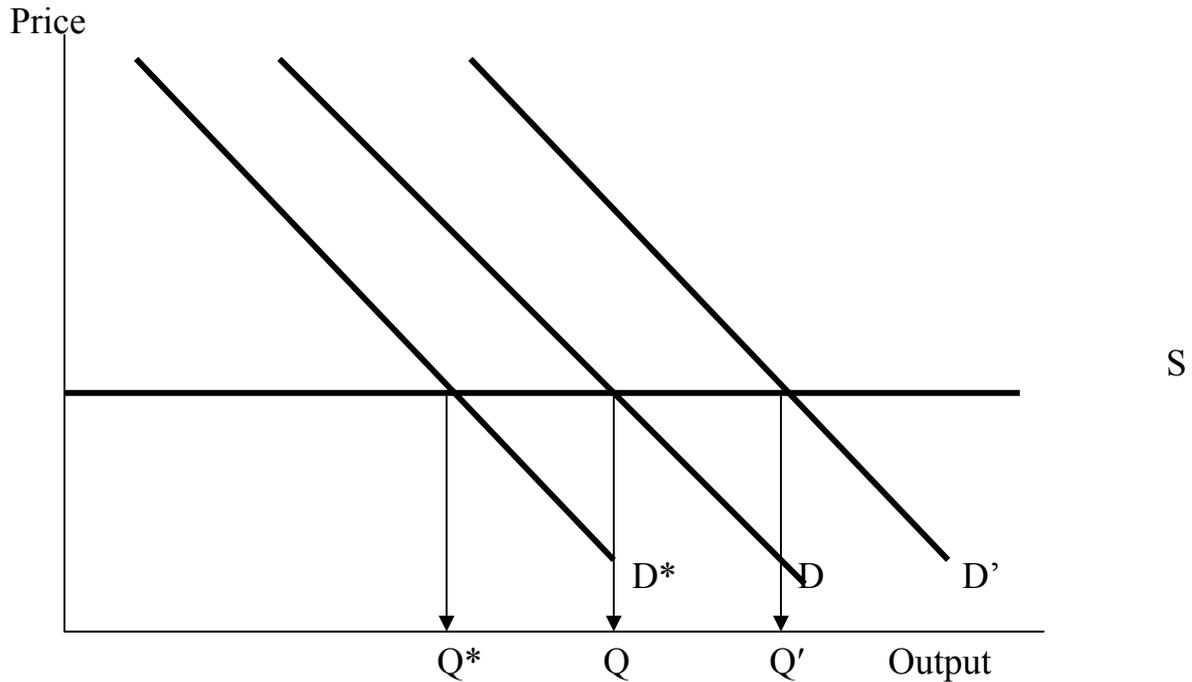
After the simple diagrammatic presentation of alternative regional models, the discussion continues with an illustration of the potential use of these models based a simplified, highly stylized case example. The closure of Regan National Airport to civilian aviation and accompanying shift of these flights to a small regional airport is analyzed in terms of its costs and impacts on Washington, D.C. and on a hypothetical largely rural county containing a regional airport to which civil aviation is diverted.

#### **4.1 Graphical Presentation of Alternative Regional Development Models**

Each type of regional development model makes specific assumptions about the conditions of production and supply from the region. It is tempting to conclude that one should use the model whose approach is least restrictive under the assumption that it encompasses the “simpler” models. While this is intellectually correct, the problem of model selection is complicated because more elaborate regional development models require far more information about the characteristics of regional production and supply. Given the limited information on these conditions and the lack of data appropriate for calibrating the elaborate models, major “compromises in calibration” are necessary in order to implement elaborate models. These compromises in calibration are effectively assumptions in themselves that produce errors in model performance. Furthermore errors in more elaborate models are very difficult to characterize and constitute a “black box” problem. Simpler models have less demanding data requirements and errors related to the straightforward assumptions behind these models are easier to identify. In regional development modeling, more elaboration and complexity is not always better!

The most basic approach to regional economic development is the *demand driven* model, which takes a number of forms. Specifically, economic base, input output, and (most) regional econometric models are demand driven in that shifts in aggregate demand for regional product translate directly into changes in regional output. This implies that the regional supply curve is horizontal (perfectly elastic), i.e. that regional production can expand or contract without change the cost of production. This suggests that the supply of inputs, including labor, capital, and materials, for regional production is perfectly elastic so that the prices of these inputs do not rise as the region grows or fall as it declines. Obviously these assumptions are more reasonable to the extent that the changes in the regional economy are not large. The standard diagram representing a demand driven model is presented in Figure 4.1 below.

**Figure 4.1**  
Demand Driven Model of Regional Development



In Figure 4.1 the horizontal supply curve is cut by three different demand curves.  $D$  represents an initial level of demand for regional product,  $D'$  indicates a higher level of demand and  $D^*$  a lower level of demand. Note that the horizontal supply curve guarantees that any shift in demand is translated immediately into a change in regional product,  $Q$ , represented on the abscissa. In this sense, the response of the regional economy is completely “demand driven” giving rise to the name for this class of models. The total shift in demand for regional product consists of a shift due to exogenous “export” demand that is determined outside the region and endogenous local consumption demand that is induced by the initial rise in production for export. The “export base multiplier” model gets its name from the fact that shifts in exogenous export demand are multiplied by complementary changes in local consumption demand to get a total shift in the aggregate demand for regional product shown in the diagram.

Input-output models are also demand driven in that changes in exogenous export demand are multiplied up into a total demand response that can be represented by the shift in aggregate demand in Figure 1. However, in input-output models there is disaggregation into various sectors of the regional economy giving rise to industry-specific multipliers so that the demand shift produced by a change in exogenous demand for manufacturing production will not be the same as that produced by an equivalent shift in demand for services production. However, intellectually the structure of input-output and economic base models is identical and well represented by Figure 1. It is also possible to construct simple regional econometric models that are demand driven in that the regional demand labor, capital, and materials does not change the cost of production.

The next logical choice for this regional development modeling typology is the *supply side* model. In such a model, demand for regional product is perfectly elastic and the supply curve is upward sloping. This is most reasonable when the region produces only commodities, i.e. goods that are sold at a standardized price in world markets. Then shifts in the supply curve produce corresponding changes in regional product as supply slides along the horizontal demand curve. While supply side econometric models have been created, this type of regional development model is of limited importance for two reasons. First, the assumption of perfectly elastic demand is unrealistic even if the region produces a product that is essentially a commodity. Second, estimation of regional supply functions is very difficult because of identification problems and data limitations.

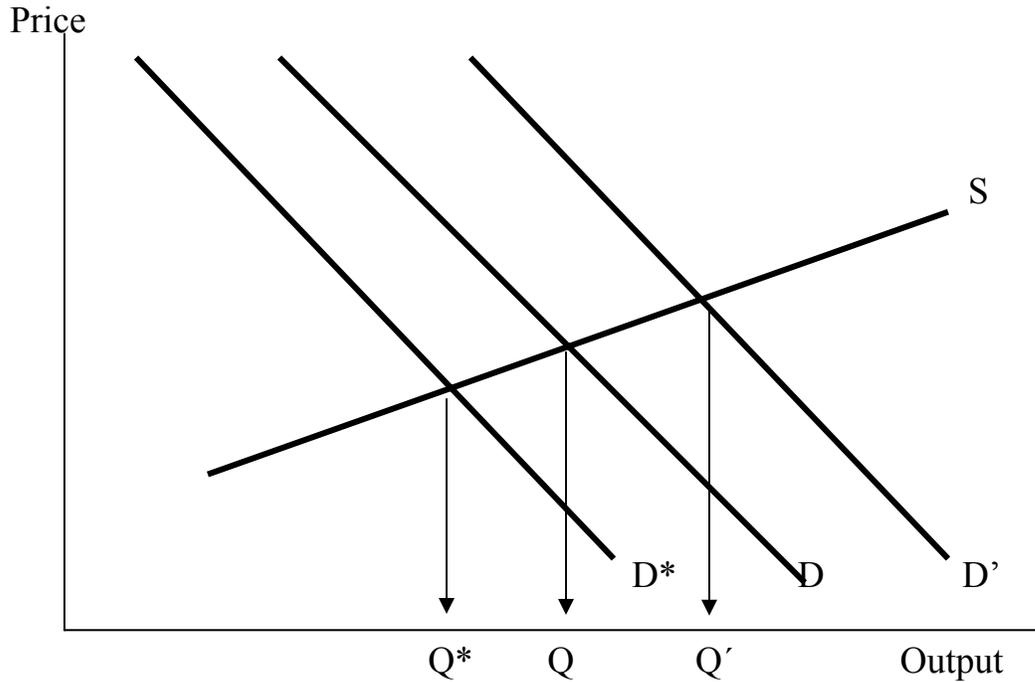
The next important category of regional development model is the *hybrid demand driven* model. These models take two forms. First, it is possible to build input-output models in which the supply of regional product is not perfectly elastic, i.e. to build *hybrid input-output* models.<sup>2</sup> Second, most regional econometric models do not assume that supply of regional product is perfectly elastic. Indeed, hybrid input-output models are usually a combination of ordinary input-output models and supply side constraints based on econometric models of regional supply equations.

The hybrid model is illustrated in Figure 4.2 where the aggregate supply curve has a positive slope. Observing the same shifts in demand for regional product as in the previous case of demand driven models, we find that shifts in regional output are uniformly smaller for the hybrid model than they were for the demand driven model because price shifts in the same direction as output. The fall in price when demand falls, attenuates the effect of the demand shift on regional product compared to Figure 6 where supply is perfectly elastic. Thus the responsiveness of the regional economy to demand shocks is smaller for the hybrid model than for the demand driven model.

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<sup>2</sup> For a discussion of the most widely used hybrid model, see Geroge Treyz, Dan Rickman, and Gang Shao, The REMI Economic-Demographic Forecasting and Simulation Model, in *Regional Dynamics*, Elgar Reference Collection, Modern Classics in Regional Science, Vol 4, (1996) pp. 451-483; and George I. Treyz, *Regional Economic Modeling*, (Kluwer: Boston), 1993.

**Figure 4.2**  
Hybrid Model of Regional Development



Another feature of the hybrid model is that the cost of production changes as demand shifts along the supply curve. In hybrid input-output models this means that an increase in demand for one sector within a region raises costs of production for other sectors that causes them to lower production. This type of *crowding out or sectoral shifting* is characteristic of the hybrid input-output model and illustrates the opportunity cost of expanding production in one sector in terms of lost output elsewhere. These changes in production cost may well be an important component of the costs of government policies that shift the spatial pattern of demand.

A policy that increases the cost of production, perhaps due to extra security requirements regarding storage or transportation of hazardous materials, has effects that can be modeled as an upward shift in the regional supply function, resulting in a fall in output in the sector(s) affected by the security policy. However, the hybrid input-output model shows that these increased costs and falling output in one sector provide opportunities for other sectors to expand and attenuate the overall effect of the policy on regional output.

The hybrid input-output model has been adapted to the special purpose of predicting the impacts of natural disasters.<sup>3</sup> There are two major difficulties associated with modeling recovery from disasters. First, observation has shown that relative prices change less than expected, even if production of some outputs is substantially affected. Instead, alternative sources of supply are found and there is a complex pattern of input substitution. One approach to modeling these effects is to use a hybrid model combining an input-output model with a linear programming model to handle the substitution effects.<sup>4</sup> A second complication arises because transfer payments, either insurance or government transfers, tends to maintain local consumption levels even in the presence of falling earnings and profits. This has prompted hybrid models where consumer expenditure is exogenous.<sup>5</sup>

An extreme case of the type of model illustrated in Figure 7 is the regional *computable general equilibrium (CGE)* model. CGE models develop estimates of the regional supply function based on industry cost functions and then solve analytically for the equilibrium of supply and demand. CGE models with several sectors can be developed. Unfortunately the data and estimation requirements needed to implement these models are extreme and there have been few serious attempts to implement regional CGE models for areas in the U.S

The final type of regional development model is that developed as part of what has been termed the *new economic geography (NEG)* approach. Although operational versions of these models are not commercially available, they provide an important intellectual check that should be made before accepting the results of alternative models that have been empirically implemented. NEG models emphasize the importance of increasing returns to scale and product differentiation. These models imply that, at least over some ranges of output, the aggregate supply of regional product may well be negatively sloped as shown in Figure 8.

Comparing the effects of the same pattern of demand shifts across Figures 6, 7, and 8, note that NEG models have the property that the shift in regional output is larger than the demand shift because price and output change in opposite directions along the negatively sloped supply curve! This implies that government policies changing the pattern of output may shift costs of production but the direction of change, compared to the hybrid model, is reversed. Actions that lower the amount of production in a region, actually raise the cost of production in other sectors of NEG models. Data constraints have thus far prevented the implementation of NEG models capable of producing estimates for regional impact and cost analysis.<sup>6</sup>

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<sup>3</sup> See, for example Adam Rose, "Economic Principles, Issues, and Research Priorities in Hazard Loss Estimation," in *Modeling Spatial and Economic Impacts of Natural Disasters*, Ed. By Stephanie Chang, and Yasuhide Okuyama, (Springer-Verlag: New York), 2004, pp. 13-36..

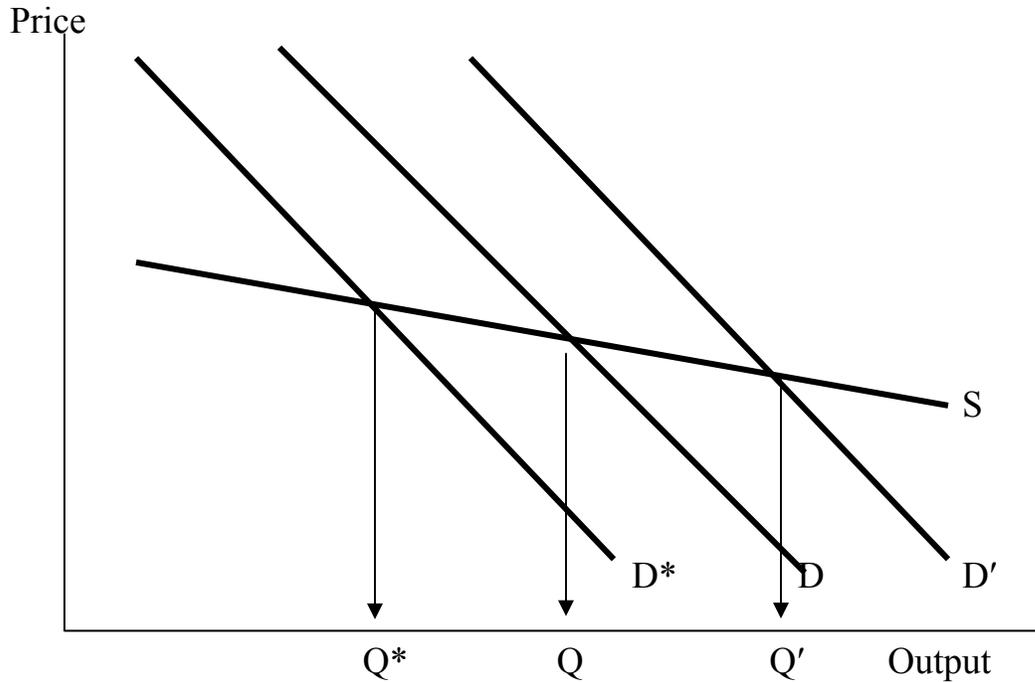
<sup>4</sup> See, for example, Adam Rose, Juan Benavides, Stephanie Chang, Philip Szczesniak, and Dongsoo Lim, "The Regional Economic Impact of an Earthquake," *Journal of Regional Science*, Vol, 37, No. 3, (November 1997) pp. 437-458.

<sup>5</sup> See discussion in Harold C. Cochrane, "Indirect Losses from Natural Disasters: Measurement and Myth," in *Modeling Spatial and Economic Impacts of Natural Disasters*, Ed. By Stephanie Chang, and Yasuhide Okuyama, (Springer-Verlag: New York), 2004, pp. 13-36.

<sup>6</sup> For an illustration of a regional simulation model using NEG principles, see Wei Fan, Frederick Treyz, and George Treyz, "An Evolutionary New Economic Geography Model," *Journal of Regional Science*, (November 2000), V. 40, No. 4, (671-695).

**Figure 4.3**

New Economic Geography (NEG) Model of Regional Development



Given the differences in the slope of the regional supply curve among demand driven, hybrid input-output and CGE, and NEG models of regional development, it might appear that a simple empirical test could determine which approach is most appropriate. The difficulty is that there are good reasons to believe each curve holds in some regions and that the slope of the regional supply curve depends on characteristics of each region being studied. For the regional researcher this is intriguing but for anyone seeking to apply regional development models to answer policy questions it is a major inconvenience.

**4.2 Implementation and Use of Demand Driven Regional Models**

This section illustrates the application of the demand driven regional development models reviewed above to problems of estimating the costs and impacts of homeland security initiatives. Both cost and impact estimation are discussed, in part, because they are often confused in the literature. Basically, any change in the level, location, or composition of production and consumption can be viewed as an impact but few of these changes involve social costs. For example, moving the location of production without increasing its cost is an impact that imposes no cost on society. Regional development models are generally used to measure or predict impacts as opposed to costs.

The particular case chosen to illustrate the use of various models is the closure of Regan National Airport to private aviation for homeland security purposes. In this stylized example, we assume that the aviation travel is diverted to landing at a remote suburban airport, or

alternatively travelers use commercial aviation, other modes of travel, or simply travel less to the District of Columbia (D.C.). The straightforward way to measure the cost of this landing restriction would be to evaluate the extra cost, particularly in terms of travel time, of landing at the alternative location and driving to downtown D.C. as opposed to the quicker access from Regan National Airport and multiplying this by the number of passengers affected.<sup>7</sup> A regional development model is not necessary to measure these regulatory costs.

Measuring impacts of the landing restrictions does require regional models. The first choice is generally a demand driven model, either an input-output or economic base model. Three alternative versions of a demand driven regional input-output model might be implemented and used. These models have the distinct advantage that commercial versions are readily available for areas as small as individual counties.

It is customary to begin a discussion of input-output modeling by examining the regional input-output accounts that provide the intellectual support for this modeling approach. In contrast to income and product accounts so common in national accounting, input-output accounts disaggregate production by product types or industrial sectors. The accounting identity states that, for each sector, total output is equal to total sales and that total sales are equal to total purchases, including wages, profits, rents, and taxes. Thus the firm is a hollow box receiving revenue from sales and dispensing the revenue in return for material inputs, labor, capital, and real estate inputs.

Given that the landing restrictions example presented here is going to involve two regions, a large city and a small county economy, two sets of input-output accounts are presented in Tables 1B and 1L below (B for big and L for large regional economy). Entries should be interpreted as annual dollar flows in thousands.

The input-output accounts are divided into three sections reflecting the three types of input-output model available. These are the *type I or open*, *type II or closed*, and *SAM or social accounting matrix* versions of an input-output model. The models are increasingly general or have the property that the SAM encompasses the closed model which encompasses the open model.

The most limited, or open model is based on input-output accounts that include only local interindustry sales of intermediate product and treats all other sales as exogenous, i.e. as if they were determined outside the region. This particular example has four local sectors that can sell local intermediate product to one another and these sales are contained within the type I rectangle. Thus in Table 1S the transportation row of the accounts reveals that the local transportation sector sells \$300 to itself (i.e. transportation uses transportation inputs as intermediate product), sells \$500 to retail, \$100 to petroleum, and \$100 to business services locally. All other sales of transportation is considered exogenous in an open or type I model. The transportation column of the type I accounts indicates that transportation purchases local intermediate product in the amount of \$300 from itself, and \$100 from retail, \$2,000 from

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<sup>7</sup> For those switching to commercial airline travel or using an alternative mode, presumably these are lower cost alternative than landing in the suburban airport. Thus our proposed cost estimate is an upper bound on the cost of the landing restrictions on private aviation.

**Table 1S: Input-Output Accounts, Small County (\$000s)**

		Buyers				Consumption		Exports	Total Sales
		Trans- portation	Retail	Petrol- eum	Business Services	House- holds	Local Gov't		
Sellers	Trans	\$300	\$500	\$100	\$100	\$200	\$0	\$8,800	\$10,000
	Retail	\$100	\$500	\$50	\$200	\$12,000	\$1,000	\$6,150	\$20,000
	Petrol	\$2,000	\$100	\$100	\$50	\$2,150	\$100	\$500	\$5,000
	Bus Ser	\$100	\$200	\$50	\$150	\$1,000	\$200	\$300	\$2,000
Households		\$1,000	\$4,000	\$550	\$450	\$0	\$7000	\$30,000	\$43,000
Loc. Gov't		\$1,000	\$1,000	\$450	\$100	\$2,150	\$0	\$4,000	\$8,700
Imports		\$5,500	\$13,700	\$3,700	\$950	\$25,400	\$400	NA	\$49,750
Tot. Purch		\$10,000	\$20,000	\$5,000	\$2,000	\$43,000	\$8,700	\$49,750	\$138,450

**Table 1L: Input-Output Accounts, Large City (\$000s)**

		Buyers				Consumption		Exports	Total Sales
		Trans- portation	Retail	Petrol- eum	Business Services	House- holds	Local Gov't		
Sellers	Trans	\$30,000	\$150,000	\$50,000	\$70,000	\$50,000	\$1,000	\$649,000	\$1,000,000
	Retail	\$30,000	\$75,000	\$10,000	\$175,000	\$2,000,000	\$165,000	\$545,000	\$3,000,000
	Petrol	\$250,000	\$20,000	\$15,000	\$35,000	\$350,000	\$20,000	\$60,000	\$750,000
	Bus Ser	\$30,000	\$90,000	\$15,000	\$75,000	\$400,000	\$70,000	\$320,000	\$1,000,000
Households		\$400,000	\$1,200,000	\$300,000	\$555,000	\$0	\$775,000	\$1,170,000	\$4,400,000
Loc. Gov't		\$100,000	\$150,000	\$67,500	\$50,000	\$220,000	\$0	\$500,000	\$1,087,500
Imports		\$160,000	\$1,315,000	\$292,500	\$40,000	\$1,380,000	\$56,500	NA	\$3,244,000
Tot. Purch		\$1,000,000	\$3,000,000	\$750,000	\$1,000,000	\$4,400,000	\$1,087,500	\$3,244,000	\$14,481,500

petroleum, and \$100 from business services locally. The other purchases, including wages of local households, are all considered exogenous in a type I model.

The type II or closed accounts include the household row giving local value added and column where local consumption is entered. For example, the household row of Table 1S indicates that local households earn \$1,000 in local value added (wages, rents, and proprietors' income) from the local transportation sector and \$4,000 from local retailers while the household column shows that local households purchase \$12,000 from local retail but only \$200 from local transportation. The closed accounts include both local interindustry sales of intermediate product and local income and consumption among the economic phenomena considered within the accounts.

A SAM adds other activity into the input-output framework as if were a producing sector. This is illustrated in the Tables 1S and 1L by adding local government. The local government row includes payments. But these are not voluntary purchases of intermediate product. They are primarily indirect business taxes, property taxes, and local income taxes. Although these are not market payments, they are isomorphic to purchases of intermediate product and hence can be accommodated in a row of the accounts. Similarly, the local government column includes entries that reflect the purchases of intermediate product from local firms and value added from local households in order to produce local government services. For example, the \$7,000 payment to households is wages and salaries paid to employees of local government. In essence the construction of the SAM is a clever way to trick the input-output framework to include payments outside the private market economy. Even in the SAM, there are significant entries in the imports row of the accounts indicating that firms in these regional economies are dependent on the rest of the economy for a significant proportion of their intermediate product and value added. Note that total purchases in each column of the SAM are equal to total sales in each row and this preserves the fundamental basis of input-output accounts, the assumption that the firm or organization is a hollow box with revenues equal to purchases. The accounting identity is also useful in reconciling data and dealing with missing or erroneous observations.

Tables 2S and 2L are direct requirements tables computed from the input-output accounts in Tables 1S and 1L by dividing each entry in the accounts by the total purchases recorded for that column. The resulting *technical coefficients* are then assumed to reflect the constant relation between output of the particular sector represented by that column and necessary inputs of intermediate product, local value added, or any other rows that could be inserted in a SAM. Consider, the transportation column of Table 2S and note that each element of Table 1S has been divided by total purchases of \$10,000. This results in a technical coefficient of 0.2 in the petroleum row indicating that it takes 20 cents of petroleum to per dollar of transportation output. By similar method it takes 10 cents of local value added by households and there appears to be 10 cents in indirect business taxes collected by local government per dollar of transportation output.

Unfortunately the great detail on possible regional economic impacts and costs obtained from the demand driven model requires very strong assumptions regarding the structure of the local economy. It is not possible to observe the interindustry purchases of local intermediate

product that enter the input-output accounts. In view of data limitations, various methods have been used to estimate the direct requirements matrix in Tables 2S and 2L.

One approach to direct requirements is to take technical coefficients from the national input-output accounts under the assumption that production patterns are identical across the country. However, the direct requirements are not based on production needs alone. They are also based on regional supply conditions. A particular region may produce furniture without any of the major materials that are used to make that furniture, including lumber, fabric, and hardware being produced locally. Because regional industries are highly specialized, local intermediate product is often unsuitable as an input for other local industries. This second element of regional specialization means that the direct requirements coefficients used in demand driven regional models are rough estimates of those found in Tables 2S and 2L. Each producer of commercial regional input-output tables has its own approach to producing and validating these direct requirements but they are all estimates. Unfortunately these errors in estimating the degree of regional interdependence are crucial in generating indirect effects in the models and hence the errors in estimating direct requirements produce errors in the regional multipliers.

This problem of measuring regional self sufficiency is even more acute when local consumption must be divided between locally produced consumption and imports. In the case of regional models, imports are any production occurring outside the region. Separating local consumption spending into a component produced locally and imports is extremely difficult and yet crucial to determining the size of induced effects. Indeed, NEG models claim that the fraction of local consumption produced locally changes dramatically with the overall level of regional production. All this means that the final estimates of impacts by industry are definitely measured with error and furthermore it is generally not possible to put confidence intervals on these estimates.

Under the assumption that these direct requirements are constant when output changes, i.e. that there is a proportional relation between inputs and outputs reflected in the technical coefficients, it is possible to solve for the relation between exogenous final demand and output of the regional economy. In an open model, exogenous final demand includes consumption, local government, and exports. In a closed model it includes local government and exports and in a SAM only exports are exogenous. Given that this is a system of linear equations, the solution of the input-output model produces a constant and proportional relation between changes in exogenous final demand and output of each sector. This relation is called the *output multiplier* and it is illustrated in Tables 3S and 3L for the three types of models.

**Table 2S: Technical Coefficients, Small County**

		Buyers				Consumption		
		Trans- portation	Retail	Petrol- eum	Business Services	House- holds	Local Gov't	
<b>Sellers</b>	<b>Trans</b>	0.030	0.025	0.020	0.050	Type I	0.005	0.000
	<b>Retail</b>	0.010	0.025	0.010	0.100		0.279	0.115
	<b>Petrol</b>	0.200	0.005	0.020	0.025		0.050	0.011
	<b>Bus Ser</b>	0.010	0.010	0.010	0.075		0.023	0.023
	<b>Households</b>	0.100	0.200	0.110	0.225	Type II	0.000	0.805
<b>Loc. Gov't</b>	0.100	0.050	0.090	0.050	0.050		0.000	

SAM

**Table 2L: Technical Coefficients, Large City**

		Buyers				Consumption		
		Trans- portation	Retail	Petrol- eum	Business Services	House- holds	Local Gov't	
<b>Sellers</b>	<b>Trans</b>	0.030	0.050	0.067	0.070	Type I	0.011	0.001
	<b>Retail</b>	0.030	0.025	0.013	0.175		0.455	0.152
	<b>Petrol</b>	0.250	0.007	0.020	0.035		0.080	0.018
	<b>Bus Ser</b>	0.030	0.030	0.020	0.075		0.091	0.064
	<b>Households</b>	0.400	0.400	0.400	0.555	Type II	0.000	0.713
<b>Loc. Gov't</b>	0.100	0.050	0.090	0.050	0.050		0.000	

SAM

**Table 3S: Various Input-Output Multipliers, Small County**

**Type I Multipliers**

		<b>Exogenous Demand Change</b>			
		<b>Trans- portation</b>	<b>Retail</b>	<b>Petrol- eum</b>	<b>Business Services</b>
<b>Output Change</b>	<b>Trans</b>	1.036	0.027	0.022	0.060
	<b>Retail</b>	0.014	1.027	0.012	0.112
	<b>Petrol</b>	0.212	0.011	1.025	0.040
	<b>Bus Ser</b>	0.014	0.012	0.011	1.083

**Type II Multipliers**

		<b>Exogenous Demand Change</b>				
		<b>Trans- portation</b>	<b>Retail</b>	<b>Petrol- eum</b>	<b>Business Services</b>	<b>House- holds</b>
<b>Output Change</b>	<b>Trans</b>	1.039	0.031	0.024	0.064	0.016
	<b>Retail</b>	0.056	1.093	0.049	0.199	0.312
	<b>Petrol</b>	0.220	0.024	1.033	0.057	0.061
	<b>Bus Ser</b>	0.018	0.018	0.015	1.092	0.031
	<b>Households</b>	0.143	0.228	0.129	0.298	1.078

**SAM Multipliers**

		<b>Exogenous Demand Change</b>					
		<b>Trans- portation</b>	<b>Retail</b>	<b>Petrol- eum</b>	<b>Business Services</b>	<b>House- holds</b>	<b>Local Gov't</b>
<b>Output Change</b>	<b>Trans</b>	1.041	0.032	0.026	0.066	0.018	0.020
	<b>Retail</b>	0.111	1.123	0.093	0.236	0.345	0.413
	<b>Petrol</b>	0.229	0.029	1.040	0.064	0.066	0.070
	<b>Bus Ser</b>	0.025	0.022	0.021	1.097	0.036	0.057
	<b>Households</b>	0.274	0.299	0.232	0.387	1.154	0.974
	<b>Loc. Gov't</b>	0.145	0.078	0.113	0.098	0.084	1.080

**Table 3L: Various Input-Output Multipliers, Large City**

**Type I Multipliers**

		<b>Exogenous Demand Change</b>			
		<b>Trans- portation</b>	<b>Retail</b>	<b>Petrol- eum</b>	<b>Business Services</b>
<b>Output Change</b>	<b>Trans</b>	1.055	0.057	0.074	0.094
	<b>Retail</b>	0.044	1.034	0.021	0.200
	<b>Petrol</b>	0.271	0.023	1.040	0.064
	<b>Bus Ser</b>	0.041	0.036	0.026	1.092

**Type II Multipliers**

		<b>Exogenous Demand Change</b>				
		<b>Trans- portation</b>	<b>Retail</b>	<b>Petrol- eum</b>	<b>Business Services</b>	<b>House- holds</b>
<b>Output Change</b>	<b>Trans</b>	1.099	0.094	0.111	0.152	0.078
	<b>Retail</b>	0.457	1.372	0.361	0.743	0.725
	<b>Petrol</b>	0.357	0.093	1.111	0.177	0.151
	<b>Bus Ser</b>	0.141	0.117	0.107	1.223	0.175
	<b>Households</b>	0.844	0.689	0.693	1.107	1.478

**SAM Multipliers**

		<b>Exogenous Demand Change</b>					
		<b>Trans- portation</b>	<b>Retail</b>	<b>Petrol- eum</b>	<b>Business Services</b>	<b>House- holds</b>	<b>Local Gov't</b>
<b>Output Change</b>	<b>Trans</b>	1.119	0.106	0.127	0.169	0.091	0.095
	<b>Retail</b>	0.650	1.486	0.513	0.909	0.851	0.901
	<b>Petrol</b>	0.395	0.116	1.141	0.210	0.176	0.178
	<b>Bus Ser</b>	0.196	0.150	0.151	1.270	0.211	0.258
	<b>Households</b>	1.151	0.870	0.936	1.373	1.680	1.436
	<b>Loc. Gov't</b>	0.247	0.146	0.195	0.213	0.162	1.155

Examination of Tables 3S and 3L produces three obvious insights regarding the application of demand driven models to the issue of regional costs and impacts of government policies. First, multiplier effects are smallest for the open model and largest for the SAM. This is a consequence of the fact that effects exogenous to and hence excluded from the open model are included in the closed model and the SAM. The open model multipliers give the effect of a change in exogenous transportation demand due to the landing restrictions that arise either due to the direct effect on transportation itself, or the indirect (interindustry) effect of a change in transportation output on sales of local intermediate inputs. The closed and SAM models include the direct and indirect effects and add the induced effect of the change in income and

consumption that happens when any change in local output causes a change in local value added and hence in local consumption. Put another way, the open model shows the effects of a change in output demand assuming local income and consumption is unchanged and the closed model and SAM allow local income and consumption to change so that they reflect a general equilibrium of production and consumption changes.

The second apparent insight is that multipliers are larger in Table 3L than in 3S. This is particularly true of the difference in multipliers of the closed model and SAM. The reason for this difference is that larger regions are more independent or self-sufficient and hence they internalize more of the effects of a shift in exogenous final demand than smaller regions where much of the effects of shocks to the local economy leak out to producers in other regions. This difference in size of regional multiplier effects is relevant for impact analysis if the object is to focus on what is happening within a region. However, it is largely unimportant for analysis of impacts to the larger national economy and certainly for cost analysis because the differences in multipliers largely reflect differences in the extent to which effects within a region stay there or spread to other regions.

Third, is the observation that these demand driven models take a single event, changes in exogenous final demand for a particular industry such as transportation in this case, and produce a host of impacts on the regional economy. Each multiplier in Tables 3L and 3S indicates a change in output, value added, or local government revenue per dollar change in exogenous final demand for a particular sector. In the case of the SAM, a \$10,000 shock to demand for transportation can be projected to have effects on output of transportation, retail, petroleum, business services, household value added, and local government within each region.

### **4.3 Application of Regional Models to Cost and Impact Estimation**

As noted in the introductory section, most changes in regions reflect shifts in production that, while they may have significant impacts on the location of economic activity, should not be confused with regional costs. In the particular example of closing Reagan National Airport to private airplanes, the previous sections have demonstrated substantial regional impacts as a small suburban county economy expanded and a large urban county contracted. The percentage impacts were larger on the small economy and the absolute impacts were smaller for the small economy. Changes regional in transportation output, value added, and employment were multiplied through indirect effects on regional intermediate product and induced effects on regional consumption and even local government revenues and expenditures. It was even possible to estimate impacts on individual sectors of the economy.

The actual amounts of these effects, due to a shift from private airplanes landing at Regan National Airport to the regional airport, are displayed in Tables 4S and 4L. Total impacts obtained from the SAM are disaggregated by sector into direct, indirect, and induced components.

Hybrid input-output models can also be used to measure shifts in aggregate demand following the same procedures, and with the same empirical challenges, as ordinary input-output models. However, the hybrid models have a positively sloped supply equation that interacts

with the input-output model to attenuate the effects of shifts in aggregate demand on regional output. The most important component of regional supply is the cost and availability of labor and hybrid models generally have an explicit econometric model of the labor market in which regional population, labor supply, unemployment, and wages are jointly determined by the level of economic activity in the area.

For regions that actually have positively sloped regional supply functions, i.e. regions where housing, commuting, and living costs change significantly with population change, hybrid models have a clear advantage in that they attenuate output responses that are overstated by demand driven models. Another advantage of hybrid models is that it is possible to use the supply side econometric model to measure the effects of policies that change costs of production. Put another way, the hybrid model can trace the regional impacts of shifts in supply conditions in a manner that is difficult for demand driven models. If the policy being evaluated here were a rise in the cost of using Reagan National Airport by private aircraft rather than a landing ban, then hybrid models could potentially use this cost change to shift the supply curve of airport travel services and the effects of that shift could be analyzed. With a demand driven model, the effects of a change in cost of landing on demand would have to be analyzed outside the model and then imposed on it in order to apply the appropriate transportation sector as illustrated in the previous section.

The sample demand driven input-output model from the previous section has been adapted to illustrate hybrid models by adding a regional labor supply equation that relates wages to total employment. This wage increase has the property of raising regional income and hence regional consumption. However, the regional retail industry is sensitive to cost increases because there are many alternative shopping opportunities in both the large and small areas under study. Thus the fraction of consumption that is produced within the region is negatively related to regional wages and cost of production. Therefore the composition of regional product changes, with the proportion of retail production falling as output, employment, and wages increase. This should be viewed as a simple, illustrative demonstration of the way in which a demand driven model can be converted into a hybrid model.

**Table 4S: Initial Regional Impact from \$10,000 Positive Exogenous Shock to the Transportation Sector, Small County (\$000s)**

	<u>Pre-Shock</u>	<u>Impact from Shock</u>			<u>Post-Shock</u>
	<b>Total Sales</b>	<b>Direct</b>	<b>Indire</b>	<b>Induc ed</b>	<b>Total Sales</b>
<b>Transportation</b>	\$10,000	\$10,300	\$64	\$48	\$20,412
<b>Retail</b>	\$20,000	\$100	\$42	\$971	\$21,113
<b>Petroleum</b>	\$5,000	\$2,000	\$119	\$175	\$7,294
<b>Business Services</b>	\$2,000	\$100	\$36	\$118	\$2,254
<b>Total Output</b>	<b>\$37,000</b>	<b>\$12,500</b>	<b>\$261</b>	<b>\$1,311</b>	<b>\$51,073</b>
<b>Households (Val Add)</b>	\$43,000	\$1,000	\$0	\$1,742	\$45,742
<b>Local Government</b>	\$8,700	\$1,000	\$0	\$453	\$10,153

**Table 4L: Initial Regional Impact from \$10,000 Negative Exogenous Shock to the Transportation Sector, Large City (\$000s)**

	<u>Pre-Shock</u>	<u>Impact from Shock</u>			<u>Post-Shock</u>
	<b>Total Sales</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total Sales</b>
<b>Transportation</b>	\$1,000,000	-\$10,300	-\$248	-\$647	\$988,805
<b>Retail</b>	\$3,000,000	-\$300	-\$136	-\$6,067	\$2,993,497
<b>Petrol</b>	\$750,000	-\$2,500	-\$209	-\$1,242	\$746,049
<b>Bus. Services</b>	\$1,000,000	-\$300	-\$115	-\$1,548	\$998,037
<b>Total Output</b>	<b>\$5,750,000</b>	<b>-\$13,400</b>	<b>-\$707</b>	<b>-\$9,504</b>	<b>\$5,726,389</b>
<b>Households (Val Add)</b>	\$4,400,000	-\$4,000	\$0	-\$7,512	\$4,388,488
<b>Local Gov't</b>	\$1,087,500	-\$1,000	\$0	-\$1,474	\$1,085,026

Tables 4S and 4L show that the fall in output and value added (local household income) in the large city is larger than the rise in output and value added in the small city. This is a consequence of the increase in multipliers with city size found in Tables 3S and 3L. However, this change is the result of shifting output patterns and should not be attributed as a cost of the flight limitations. More of the output effects of the shift in demand “leaks out” of the small city compared to the large city so the difference in output and value added impacts is due to the difference in the amount of the effects captured within the boundaries of a small versus a large city economy. It is very easy to confuse differential impacts with costs.

Tables 5S and 5L illustrate the changes in estimated outcomes from the private airplane diversion when supply side conditions are added to create a hybrid input-output model. Note that there are more results and that they are different as demand driven effects are attenuated by cost considerations. Effects on sectors where demand is sensitive to cost are different than those where demand is inelastic.

**Table 5S: Exogenous Shock Comparison, Small County (\$000s)**

	<b>Pre Exog. Shock</b>	<b>Demand Side Only</b>	<b>Demand Side Hybrid</b>
Households Earnings	\$43,000	\$45,742	\$45,273
Local Value Added	\$13,000	\$15,742	\$15,273
Wage Rate	\$34.29	\$34.29	\$35.99
Local Employment	379	459	424
HH Spending on Local Retail	\$12,000	\$12,765	\$10,380
Total Local Output	\$37,000	\$51,073	\$48,687

**Table 5L: Exogenous Shock Comparison, Large City (\$000s)**

	<b>Pre Exog. Shock</b>	<b>Demand Side Only</b>	<b>Demand Side Hybrid</b>
Households Earnings	\$4,400,000	\$4,388,488	\$4,393,156
Local Value Added	\$3,230,000	\$3,218,488	\$3,223,156
Wage Rate	\$44.85	\$44.85	\$44.82
Local Employment	72,023	71,766	71,916
HH Spending on Local Retail	\$2,000,000	\$1,994,767	\$2,003,822
Total Local Output	\$5,750,000	\$5,726,389	\$5,735,443

The hybrid model divides changes in local value added into changes in employment and wages, both of which change in the same direction. Thus a positive demand shock, is associated with increasing wages and employment. This contrasts with demand driven models in which wages are fixed and the entire increase in value added results in a change in employment.

Note that the hybrid input-output model does not have a fixed set of output and value added multipliers. The technique for using this model involves the simultaneous solution of the demand driven input-output model and the labor market equilibrium equations. In this case, an iterative solution technique was used. As a consequence, some of the simple understanding of the reasons for a particular impact evident from demand driven models is lost in the simultaneous solution process.

The landing rights example was chosen to illustrate that substantial displacement in the location of economic activity may produce large economic impacts but that these effects are not a measure of social costs of the regulation of airplane landing rights. General interest in measurement of regional impacts may be substantial but these should not be confused with social costs of regulation. The fall in output in the city is an impact as is the rise in output in the small county. The fact that these two are not exactly offsetting has nothing to do with the social costs of the regulation.

Similarly, the restriction of landing rights has shifted output from a large city where wages are high to a small city where wages are low. Again this is an impact measure but it has

no immediate implications for cost measurement. Presumably the lower wages in the small town allow production of landing services at lower cost. However, these services must have lower social value because, in the absence of regulation, they would be produced at the higher cost large city location.

Overall, the danger in applying regional impact models to measure cost changes due to homeland security initiatives is that these models produce a laundry list of changes or impacts on the regions affected but most of these changes have no particular relation to the measurement of cost of the policies.

## 5: Other Models

Although benefit cost analysis and regional economic impact analysis are likely to be the most frequently used forms of economic analysis as applied to homeland security issues, there are two additional analytical frameworks that may prove useful for addressing certain questions of interest to policy makers. One is computable general equilibrium modeling which can provide considerable insight about the effects of policies that have “large-scale” effects in several different markets. The other is game theory which provides a formal way of modeling strategic behavior of agents, including terrorists and those seeking to protect themselves from terrorist attack.

### 5.1 Computable General equilibrium models

In many cases, the effects of homeland security measures, though significant in specific markets, are likely to “small” in relation to the larger economy. The case of installing anti-missile defense systems on commercial aircraft would be an example of such a measure. Although installing such systems would increase the cost of air travel, it does not seem likely that it would increase the cost of air travel by a large enough amount to cause large numbers of individuals and businesses to switch from air travel to other modes of transit, or release large amounts of capital and labor from employment in the air transport to other sectors in the economy. In such cases, the economic impact of the particular homeland security measure can be analyzed by focusing on only one, or most a few markets.

The same cannot be said, however, for a number of different terrorist threats, whose effects would not only be experienced in the market of primary impact, but which would ripple throughout the economy. Consider for example the impact of a terrorist act that had the effect of severely limiting the ability of U.S. producers to produce and to ship gasoline. Because gasoline is an important intermediate input into a wide variety of economic activities, the effects would be experienced in many different markets. Roughly speaking, those sectors of the economy that were “gasoline-intensive” in their production processes would experience relatively heavier burdens than those sectors of the economy that were not, and these relative effects would translate into reallocations of capital and labor over time, as productive inputs in the form of capital and labor moved from the more heavily-burdened sectors of the economy to the relatively less-heavily-burdened sectors. In the process, relative incomes of those employed in the various sectors would also change.

Computable general equilibrium models, which are used to examine the effects of “large scale” changes in the economy caused by policy changes such as tax and trade policy, changes in relative prices of key inputs such as energy, and the effects of large scale natural hazards, provide an analytical framework for analyzing large scale economic changes that might be caused by terrorist events.<sup>1</sup> Such models could also be used to evaluate the effects of homeland security measures that had similar large-scale effects, although it would appear that such models

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<sup>1</sup> For a useful survey of the use of basic computable general equilibrium models to analyze the effects of tax and trade policy, see Shoven and Whalley (1992). Kokoski and Smith (1987) use computable general equilibrium modeling to examine the economic effects of climate change. Most recently Rose (forthcoming) has shown how existing computable general models can be used to analyze the impact of terrorist attacks.

would be less useful in this sphere because actions taken in response to large-scale terrorist events are less likely to have the same economy-wide effects as the terrorist events that such measures are meant to counter.

## **5.2 Game theory**

Game theory offers another set of tools that, while not directly relevant to estimating the costs of different homeland security policies, can nonetheless be quite helpful in thinking both about the design of anti-terrorist policies, and how these policies are likely to affect the behavior of terrorists and others. This section summarizes some recent research that attempts to apply game theory to these questions.

### 5.2.1 The Interaction Between Private and Public Antiterrorist Measures

Manuel Trajtenberg analyzes the quasi-private, public good nature of anti-terrorist security a discrete choice multinomial logit framework. In his model, the terrorists must first decide whether or not to strike. Then conditional on their decision to strike, terrorists select the target that maximizes their random utility function. The conditional probability that a given target is selected increases with the magnitude of the potential loss and decreases with the target's level of self-protection and the effectiveness of that self-protection. The probability that the terrorists will strike at all is decreasing in the amount of public protection directed at fighting terrorism at its source and increasing in the maximum expected benefit of a strike.

Each target selects its level of self-protection so as to maximize its expected benefits taking as given the probability that the terrorists will strike somewhere and the self-protection decisions of the other targets. The government selects the level of public protection so as to maximize the expected benefits to the targets net of total security costs. Because the government acts first, it takes into account how the targets will adjust private protection in response to the level of public protection. The marginal productivity of both private and public protection is assumed to be constant.

#### Outcome and Policy Implications.

Trajtenberg (2003) uses the model to show that self-protection is a quasi-private good that benefits not only those who invest in self-protection, but others as well. The amount that targets spend on self-protection is an increasing function of the overall probability of a terrorist strike anywhere, the effectiveness of private protection and the magnitude of the target's potential loss. Private protection generates positive externalities by decreasing the "inclusive value" of the set of targets, thereby, decreasing the probability of an attack anywhere. Private protection also generates negative externalities by transferring risk to other targets in the event that terrorists decide to attack. Trajtenberg proves that the latter effect dominates which has the important policy implication that an increase in self-protection by one target increases the overall risk to other targets.

Trajtenberg also shows that a dollar spent fighting terrorism at its source is much more effective in reducing the probability of any terrorist attack than a dollar spent on self-protection.

However, despite the greater productivity of fighting terrorism at its source, targets are unlikely to voluntarily pay for this type of security because fighting terrorism at its source is a true public good that must be provided by the government. Trajtenberg proves that the optimal amount of public security reduces the much less efficient private security spending to zero. Furthermore, public spending on R&D that improves the productivity of public security is much more effective at reducing the probability of any terrorist attack than public spending to encourage R&D that increases the productivity of private security.

Trajtenberg notes that his model is a benchmark, and there may be cases for which some amount of private security is optimal. This may be the case if there are diminishing returns to public security. Furthermore, some targets such as airplanes may be used to inflict great damage elsewhere. Target specific security for these types of targets retains certain public good characteristics.

### 5.2.2 Interdependent Security Among Targets

Kunreuther Heal, and Orzag, (2002) develop a game between airlines that shows that when firms' security is interdependent, underinvestment in security is a possible Nash outcome. In the case of airlines, this interdependency exists because even if an airline screens the luggage of its passengers, it is still vulnerable to explosives in luggage it accepts from airlines that don't screen. Under certain circumstances there are multiple Nash equilibria.

In the Kunreuther-Heal model,  $N$  identical airlines must each decide whether or not to screen luggage for explosives. If the airline doesn't screen, there is a probability of  $p$  that the airline will suffer a loss due to explosives in a bag from one of its customers. If an airline screens that probability is reduced to zero. However, even airlines that screen may still suffer a loss due to the transfer of luggage from an airline that doesn't screen. The probability of receiving a bomb from an airline that doesn't screen is  $q/(N-1)$ .

### Outcome and Policy Implications

Kunreuther and Heal show that it is never a Nash equilibrium for some airlines to invest in security while others do not. It is always the case that all airlines screen bags or none do. The cost range for which the suboptimal outcome of no screening is possible is increasing in  $q$  and decreasing in  $N$ . This is because the negative security externality imposed on an airline that screens by airlines that do not screen is increasing in  $q$  and decreasing in  $N$ . Essentially increases in  $q$  or decreases in  $N$ , reduce the benefits of an airline screening its bags because the costs of screening remain the same but the benefits of screening decrease.

Kunreuther and Heal examine various policy measures for tipping the outcome to the Pareto optimal outcome in which all airlines screen bags. Insurance could be useful because premium reduction for security measures would be an incentive for airlines to invest in security. However, the usefulness of no-fault insurance is limited because the insurer of an airline that screens must still pay for the damage caused by a bomb in luggage accepted from another airline. Only a monopolistic insurer like the government would fully internalize the security externality. Theoretically, imposing liability on airlines who accept a bomb and transfer it to another airline

could internalize the externality. However, it may be difficult to determine where the bomb came from. Furthermore, it may be difficult to prove negligence on the part of the airline that didn't screen. Either a tax on airlines that don't screen or a subsidy for airlines that do, if set properly, could result in a Pareto efficient outcome. Regulations or coordinating mechanisms among airlines such as airline associations could also be helpful in achieving the optimal outcome.

### 5.2.3. Differences Between Natural Hazards and Terrorist Threats

Lakdawalla and Zanjani (2002) analyze some important differences between natural hazards and terrorist threats. Unlike natural hazards, terrorist organizations adapt to the protective measures of potential victims. When an individual target protects itself, terrorists shift resources toward other targets and the risk to other targets increases. According to Lakdawalla and Zanjani, this feature of the terrorist threat creates a negative externality in the market for self-protection that results in inefficient overprovision of private security. Lakdawalla and Zanjani argue that government subsidies for terrorism insurance may be an effective policy instrument for correcting this market failure. They also examine the effects of public protection on the market for self-protection and the market for insurance. Their analysis is based on a game theoretic model of the behavior of terrorists, their targets, and the government.

After observing the self-protection decisions of a set of targets, the terrorist organization allocates its resources across the set of targets to maximize the organization's expected benefits from terrorism. Fixed costs of attacking a target are assumed to be low, so that the terrorist organization allocates resources across all targets instead of directing all of its resources against a single target.<sup>2</sup> The organization's total resources are fixed<sup>3</sup> and the self-protection efforts of the individual targets are taken as a given by the terrorist organization.

Each target decides how much to spend on insurance and self-protection so as to maximize its expected utility, while taking account of how the terrorist organization will allocate resources in response. An additive utility term for a public good or bad related to self-protection is included in the utility function. Each target considers the effects of its self-protection decisions on its insurance premiums and its personal utility derived from the public good.

If the government intervenes, it sets insurance subsidies and public protection levels so as to maximize the total expected utility of all targets taking into account how the targets will respond to its policies. All targets are taxed equally to cover the cost of the subsidies and public security measures. It is assumed that the targets do not consider the effect of their self-protection and insurance purchasing decisions on their tax bill.

### Outcomes and Policy Implications

Lakdawalla and Zanjani first analyze the symmetric Nash equilibrium with identical agents and no government intervention. Terrorists allocate resources so that the marginal productivity of terrorist resources is equalized across targets. Because self-protection measures

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<sup>2</sup> Without this assumption the game has no stable Nash equilibrium.

<sup>3</sup> The model allows for effects of self-protection on terrorist resources. However, the analysis in the paper is focused on the case of fixed terrorist resources.

decrease the marginal productivity of terrorist resources, an increase in self-protection by one target causes terrorists to shift resources toward other targets. Individual targets consider both the direct effects of self-protection and the re-allocation of terrorist resources toward other targets as benefits of increased security. Lakdawalla and Zanjani demonstrate that in the socially optimal outcome the targets would base their self-protection decisions solely on the direct benefits of private security. Therefore, the risk externality leads to over investment in private security.

Lakdawalla and Zanjani next analyze the effects of insurance subsidies and public protection on the symmetric Nash equilibrium. In the presence of moral hazard<sup>4</sup>, the government can use insurance subsidies to get targets to substitute insurance coverage for self-protection. Lakdawala and Zanjani show that without public protection, as long as there is moral hazard, some insurance subsidization is always required to achieve the optimal outcome. With public protection, insurance subsidization is optimal as long as targets would otherwise engage in some level of self-protection.

Insurance subsidies and public protection may be substitutes or compliments from the point of view of the government, depending on the technological relationship between private and public protection and the efficiency of public protection. If public protection increases the effectiveness of private protection, insurance subsidization and public protection would be complimentary policies. Insurance subsidies reduce the amount of self-protection that would take place because of the increasing effectiveness of self-protection. If public protection is a substitute for private protection, insurance subsidies and public protection are substitutable policy instruments because both reduce the amount of private protection. Finally, insurance subsidies and public protection may be complimentary policies if public protection decreases the cost of insurance to the government.

#### 5.2.4 Modeling Terrorism Risk

Major (2002) explores the potential usefulness of game theory in quantifying terrorism risk for the purposes of setting insurance rates. He develops a zero sum game between a terrorist and defender, each with a fixed amount of resources. By assigning a specific functional form to the probability of loss function, Major illustrates how such a model might be used to calculate a probability distribution of losses. Unlike some of the economists, Major explicitly recognizes that using game theoretic models is, “an exercise in futility at best (and self-delusion at worst) without adequate input from terrorism experts.” He also discusses some of the issues involved in operationalizing these models.

Major models a zero sum game, i.e., the defender’s loss is the attacker’s gain. There is one defender who allocates a fixed amount of resources to protect a set of targets of varying value. The attacker must also decide how to allocate a fixed amount of resources among the targets. The probability of a successful attack against any given target is a function of the value of the target, the amount of resources protecting it, and the amount of resources deployed to

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<sup>4</sup> There are two sets of circumstances based on the form of the insurance subsidy and insurance pricing that give rise to moral hazard. Both sets of circumstances rely on CARA utility functions and the existence of a stable Nash equilibrium.

attack it. The attacker's objective is to maximize the expected loss, while the defender's objective is to minimize the expected loss.

In equilibrium, the defender adopts the minmax strategy. Protective resources are deployed so as to minimize the maximum expected loss at any one target. This implies that the expected loss is equalized across the more valuable targets. Targets whose value is less than the maximum expected loss at any one target are not protected at all. If the attacker assumes the defender is rational, the attacker will deploy its resources at a single target randomly selected from the targets valuable enough to be protected.

In his numerical example, Major uses search theory to derive the probability function for an attack against a particular target going undetected and a dose response model to derive the probability function of success in event of an attack. The probability of a successful attack against a particular target is the product of these two probabilities. After assigning parameter values to these functions, Major calculates the probability distribution of losses for a set of targets.

### Outcome and Policy Implications

Major identifies a number of questions that are raised by application of the model. Among these are: (1) How does one model the frequency of terrorist attacks? (2) How realistic are the key assumptions of the model? For example, is it realistic to assume that defense allocation decisions across targets are made by a centralized authority? (3) Does it make sense to assume that all defenses are target specific? (4) How does one measure the value of targets? Do terrorists and defenders place the same value on targets? How accurate are the databases of targets? (5) How does one determine the amount of resources available to terrorists or the total amount of societal resources devoted to defenses? (6) What is the attacker's strategy if defenses are not allocated optimally and the attacker must expend resources seeking out the most attractive attack opportunities? (Major cites sources for full-blown simulation models for these scenarios.) (7) How does one determine the parameters of the model? (8) How does one incorporate dynamics into the model?

## **6. Application: Going to Orange Alert in San Francisco<sup>1</sup>**

In the days and weeks after September 11, 2001 terrorist attacks in New York City, Washington, D.C., and Pennsylvania, public officials began to develop strategies to prevent the next terrorist attack. It quickly became clear that the government needed the ability to put the nation on alert, and so officials created the Homeland Security Advisory System. As new intelligence becomes available, policy makers must decide to raise or lower the threat level. Former Secretary of Homeland Security, Tom Ridge recently talked with reporters describing the intense debates among presidential advisors with regard to raising the threat level. “Raising the terror alert level generally costs state and local emergency responders millions of dollars in overtime salaries, causes widespread travel delays and takes a hit on the public’s psyche” (Jordan, 2005, May 10). As there are no requirements for cities and states to fulfill when the federal government raises the alert, governors, mayors and city councils must decide whether or not to take action. Since local officials are not always privy to information regarding the credibility of the threat, cost-benefit analysis should be utilized as an economic tool to aid policy makers in their decisions to take action after the alert is raised.

### **6.1 History and Purpose of The Homeland Security Advisory System**

Directly after September 11, the government issued a series of circuitous warnings recommending a state of higher vigilance. Critics admonished the government for confusing local authorities and alarming the public (Sostek, 2003). In response, on March 11, 2002 President George W. Bush issued Homeland Security Presidential Directive 3 (HSPD-3), which established the Homeland Security Advisory System (HSAS). According to HSPD-3, the purpose of the advisory system is “to provide a comprehensive and effective means to disseminate information regarding the risk of terrorist acts to Federal, State, and local authorities and to the American people” (U.S. President, 2002, p. 394). The system can either be used to alert the entire nation, or when the intelligence permits, it can be used on a smaller scale to warn of threats against specific states, cities, or types of critical infrastructure or industry.

Modeled after the Department of Defense’s Threatcon system, the HSAS has five levels each of which describes a different threat condition and provides a list of recommend protective measures that should be implemented when the alert level is raised (see Table 1). With the exception of military facilities, all federal agencies are required to comply with the directives in HSPD-3 and the subsequent variations in the alert level, and to disband any preexisting threat advisory systems utilized by the agency. Although state and local governments, as well as, private industry are not required to comply with the HSAS, the Department of Homeland Security (DHS) recommends that they do so.

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<sup>1</sup> This principal author of this chapter is Charlotte Kirschner.

**Table 6.1: Homeland Security Advisory System Threat Levels**

Threat Level	Risk of Terrorist Attack	Protective Measures
Green Low	Low	<ul style="list-style-type: none"><li>* Refine preplanned protective measures</li><li>* Ensure personnel trained on HSAS and preplanned protective measures</li><li>* Institutionalize a process for assuring all facilities are assessed for vulnerabilities and measures are taken to mitigate these vulnerabilities</li></ul>
Blue Guarded	General	<ul style="list-style-type: none"><li>* Check emergency response communications</li><li>* Review and update emergency response procedures</li><li>* Provide information to public that would strengthen its ability to react to an attack</li></ul>
Yellow Elevated	Significant	<ul style="list-style-type: none"><li>* Increase surveillance of critical locations</li><li>* Coordinate emergency plans with other federal, state and local facilities</li><li>* Assess the threat and refine protective measures as necessary</li><li>* <u>Implement contingency and emergency response plans</u></li></ul>
Orange High	High	<ul style="list-style-type: none"><li>* Coordinate security efforts with federal, state and local law enforcement agencies</li><li>* Take additional protective measures at public events or possibly consider changing venues or canceling</li><li>* Prepare to execute contingency procedures, such as moving to an alternate site or dispersing workforce</li><li>* Restrict facility access to essential personnel only</li></ul>
Red Severe	Severe	<ul style="list-style-type: none"><li>* Increase or redirect personnel to address critical emergency needs</li><li>* Assign emergency response personnel and mobilize specially trained teams</li><li>* Monitor, redirect, or constrain transportation systems</li><li>* Close public and government facilities</li></ul>

Source: Reese, S. (2005). "Homeland Security Advisory System: Possible issues for congressional oversight." Congressional Research Service. Retrieved April 13, 2005, from <http://www.fas.org/sgp/crs/RL32023.pdf>

## 6.2 Putting the Nation on Alert: The Decision Process

On a daily basis, DHS receives intelligence information from the Federal Bureau of Investigation (FBI), the National Security Agency (NSA), the Central Intelligence Agency (CIA), the Department of Defense (DOD), the Drug Enforcement Agency (DEA), and the National Counterterrorism Center (NCTC), among other agencies. When determining the threat level, officials consider the available intelligence information concentrating on the answers to the following questions: to what degree is the threat information credible; to what degree is the threat information corroborated; to what degree is the threat specific and imminent; and, how grave are the potential consequences of the threat (Reese, 2005).

HSPD-3 originally designated the responsibilities of administering the HSAS to the Attorney General, including assigning the threat conditions, which was to be done in conjunction with the Homeland Security Council<sup>1</sup>. The Attorney General also became responsible for establishing a system for conveying the relevant threat information to federal, state, and local government officials, law enforcement agencies, and the private sector in an expeditious manner. These responsibilities changed within the next year. The November passing of the Homeland Security Act of 2002, P.L. 107-296, established DHS, and transferred the task for administering the HSAS to the DHS Under Secretary for Information Analysis and Infrastructure Protection. In February 2003, the Bush administration released Homeland Security Directive 5 (HSPD-5), which transferred authority for assigning the threat level and conveying that information to others, from the Attorney General to the Secretary of Homeland Security. Except in exigent circumstances, HSPD-5 still requires the Secretary to consult with the Homeland Security Council when determining the threat level. If members of the Homeland Security Council cannot agree on whether to change the threat level, the decision is brought to the President (Government Accountability Office, 2004).

When the HSAS was first initiated, the national threat level was determined to be at yellow or elevated alert. Since its inception, the level has never been lower than yellow, but it has been raised to orange or high alert seven times. Table 2 provides a list of dates and reasons the HSAS was raised from yellow to orange. The first five times the alert was raised to orange, were general alerts for the entire nation, and were also relatively short in duration. The last time the alert level was raised to orange, the nation stayed at yellow, while financial sectors in New York City, areas of northern New Jersey and Washington, D.C. went to orange. This alert lasted more than four times longer than the average length of the other alerts. On May 11, 2005 the alert level was raised to red for the first time. For eight minutes, the Secret Service and the Capitol Police put the White House and the Capitol on red alert as a small plane flew within three miles of the buildings. Once the plane was secured, the threat level returned to yellow (Jordan, 2005, May 12). The system was activated again on July 7, 2005 for a period of 36 days. The Department of Homeland Security raised the alert level for mass transit systems including regional and inter-city passenger rail, subways and metropolitan bus systems in fear of a

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<sup>1</sup> Members of the Homeland Security Council include: Secretary of Homeland Security; Secretary of the Treasury, Secretary of Defense, Attorney General, Secretary of Health and Human Services, Secretary of Transportation, Director of the Office of Management and Budget, Director of the FBI, Director of the Federal Emergency Management Agency, Chief of Staff to the President, and Chief of Staff to the Vice President (Reese, 2005).

duplicate attack in the United States. The alert level was lowered once long-term security measures were in place in mass transit systems across the nation.

<b>Table 6.2: HSAS Threat Level Changes</b>		
Dates	Days At Orange	Reasons for Change
09/11/2002 - 09/24/2002	13	Terrorist threat information based on debriefings of a senior al Qaeda operative
02/07/2003 - 02/27/2003	20	Intelligence reports suggest al Qaeda attacks on apartment buildings, hotels & other soft targets
03/17/2003 - 04/11/2003	25	Intelligence reports indicate al Qaeda would probably attempt to launch attacks against U.S. interests to defend Muslims & Iraqi people
05/20/2003 - 05/30/2003	10	After bombings in Saudi Arabia & Morocco, U.S. intelligence believes al Qaeda beginning operational phase worldwide, including attacks on the United States
12/21/2003 - 01/09/2004	19	Increased terrorist communications indicating attacks
08/01/2004 - 11/10/2004	98	Intelligence indicates al Qaeda planning attacks financial institutions in NY, DC, and NJ, since before 9/11
07/07/2005 - 08/12/2005	36	After bombings in London, the Department of Homeland Security raises the alert for mass transit systems including regional and inter-city passenger rail, subways and metropolitan bus systems in fear of a duplicate attack

Source: Reese, S. (2005). "Homeland Security Advisory System: Possible issues for congressional oversight." Congressional Research Service. Retrieved April 13, 2005, from <http://www.fas.org/sgp/crs/RL32023.pdf>

### **6.3 Reactions to Raising the Terror Alert**

Although HSPD-3 described a list of protective measures that federal agencies should take when the alert is raised, there is no such requirement for state and local governments, and as a result, specific procedures are left up to individual jurisdictions. Under the assumption that there is a valid reason for the increasing the alert level when it is done, most states and local jurisdictions follow suit and react, raising their alert levels as well. Generally cities attempt to increase security at strategic targets while limiting the burden placed on the public. Some typical measures that cities and states take include the following: activating surveillance cameras; increasing port security patrols; placing first responders on alert; increasing patrols by mass transit law enforcement officers; and increasing surveillance of sensitive locations, such as courthouses, bridges, and shopping centers (Reese, 2005). Yet all of these measures impose costs on state and local governments. For the most part, government officials are willing to bear the cost. City managers in Tulsa, Oklahoma believe in reacting first and asking questions later

when the national alert is raised. Dennis Beyer, chair of the technical advisory group for Tulsa's homeland security task force said "[a]s a local government, we cannot afford not to prepare for the low-probability, high-consequence events, there are too many lives at stake" (Sostek, 2003). However, other cities choose not to participate in the orange alerts unless they are provided with specific threat information. For four of the five national alerts, city officials in Charlotte, North Carolina opted to remain at what they describe as "dark yellow," believing that a temporary security increase would not provide a genuine improvement in security. Rather, they focused on increasing general preparedness by creating programs to increase communications among first responders (Sostek, 2003).

City and state officials struggle with determining what the real risk to their populations is when the national threat level is raised, and they are not given specific information about the threat. As most government officials see themselves as guardians of their citizens, they are often willing to go to any expense to take all precautions, believing that their citizens will be comforted by the fact that the government is doing something to protect them. Although the cities of Tulsa or Charlotte are less likely targets than New York City or Los Angeles, an attack could happen anywhere. Jamie Metzl, a senior fellow and coordinator of homeland security programs at the Council on Foreign Relations, notes that no city is truly safe from terrorism; each city has a water supply and some government buildings to protect (Sostek, 2003). Deterrence is the other reason cities and states justify their compliance with the orange alerts. Conveying the image of preparedness and security may result in preventing an attack as terrorists opt for a perceived easier target. Therefore, smaller cities tend to go to the expense of raising the alert level, even if it is not a cost effective decision (Sostek, 2003).

### 6.3.1 San Francisco At Risk

According to a RAND Corporation model, San Francisco is among the top six American cities that would be a likely target of the next terrorist attack. Created in conjunction with Risk Management Solutions, a San Francisco based company that specializes in advising insurance companies on the risks of natural disasters, the model attempts to calculate the potential value of property damage in a city, correlated to the potential scale of damage for natural disasters and the likelihood of high damage events occurring in that city. If the model is accurate, San Francisco is the third most likely target, only topped by New York and Chicago, with Washington, D.C., Seattle and Los Angeles completing the list. They note that the model ranks economic damage more than iconic value of landmarks, which explains why Washington, D.C. ranks fourth in the nation. After the top six cities it becomes virtually impossible to differentiate the relative risk of an attack between cities because the risk is not significantly different from any other city (UCLA International Institute, 2003).

## **6.4 Cost Benefit Analysis: An Appropriate Tool**

As many city and state managers struggle with the decision to follow the pronouncement indicated by the national HSAS, they are implicitly weighing the benefits of preventing a potential attack compared to the costs of doing so. With a fixed amount of resources, these managers are essentially attempting to make an efficient allocation of resources, which makes

this policy decision ideal for cost-benefit analysis. In *Risk and Reason*, Cass Sunstein suggests that cost-benefit is

a simple pragmatic tool, designed to promote a better appreciation of the consequences of regulation. A government that uses cost-benefit analysis is certainly entitled to consider who is helped and who is hurt . . . Properly understood, cost-benefit analysis is no theology. It is instead an effort to assist both government and citizens, in hope of ensuring that risk regulation will actually promote its purposes (2002, p. *xiv*).

As a tool to aid decision makers, cost-benefit analysis answers the question, “How does the policy being analyzed affect economic welfare?” This is certainly not the only method that should be used when making policy decisions, but it is a useful tool for getting at the efficient use of scarce resources. Other methods need to be used in conjunction with cost-benefit analysis to evaluate other social values such as equity, justice, or respect; however, these values are less of a concern for with the policy decision at hand.

#### 6.4.1 Standing in the Analysis

In order to determine the impacts of the City of San Francisco’s decision to enact a response to the increase in the National Homeland Security Advisory System to orange, a decision was made to include Oakland, California in the analysis as the cities are closely linked in many ways. Not only are the two cities connected by the San Francisco-Oakland Bay Bridge, potentially a softer target than the iconic Golden Gate Bridge, but many of the cities’ citizens work or travel to the other city. For ease of analysis, an assumption was made that if San Francisco opts activate a response, that Oakland will do so as well.

In any cost-benefit analysis, it is important to determine who has standing. That is, to answer the question, costs and benefits for whom? This study gives standing to the city governments and taxpayers of the cities of San Francisco and Oakland, as well as to those who live and work in, or travel to these cities. Although this is a population that is difficult to capture in terms of numbers, the purpose of this definition of standing is to include anyone who may become a victim of a terrorist attack to San Francisco or Oakland. It is assumed that the taxpayers of San Francisco and Oakland would be willing to pay to prevent a terrorist attack on all people, not just to prevent an attack on tax paying citizens.

#### 6.4.2 Identification and Measurement of Costs and Benefits

As with many projects, there are costs and benefits to raising the terror alert level from yellow to orange; however, not all of the impacts are measurable. Assuming the national HSAS level has been raised to orange, the costs and benefits of raising the terror alert level from yellow/elevated to orange/high for the city of San Francisco will be compared to the counterfactual policy of leaving the alert level at yellow. Table 3 provides a summary of the impacts of raising the alert level and notes if the costs and benefits will be measured for this project, or not.

**Table 6.3: Measured Costs and Benefits**

	Costs	Benefits
Measured	Increased City Security Presence Police Presence Increased Screening of People and Vehicles Increased Wait Times At Airports Increased Wait Times on Highways	Costs Avoided by Preventing Attack Lives Saved Injuries Prevented Property Destruction Avoided Emergencies Response Costs Saved Tax Revenues Lost Emotional Stress Avoided Reduction in Crime
Not Measured	Increased Security for Private Industry Decreased Tourism Crisis Fatigue Effects on Financial Markets	Capturing Terrorists

6.4.3 Measured Costs

*Increased City Security Presence* - When the national HSAS is raised from yellow to orange, city governments who decide to raise their own alert levels, typically do so by enacting protective measures. Police increase security patrols, which generally requires overtime. Some cities initiate a twelve-hour workday, rather than eight-hour shifts, to ensure adequate coverage. During the May 20 through May 30, 2003 orange alert period, the San Francisco Police Department reportedly double-checked critical locations during each shift and closely monitored public events with crowds (King, Ensor & Frieden, 2003, May 20). Another report noted that portions of the Golden Gate Bridge and the bike trails around it were closed as a result of an alert level change (Ensor, King, MacVicar, Starr & Frieden, 2003, May 22). For security purposes, government officials, of all levels, do not discuss the specific measures they take when the alert level is raised. So, it is difficult to determine exactly what measures are taken and which costs are associated with which measures.

In March 2003, the U.S. Conference of Mayors released survey results from nearly 150 cities describing the costs related to the high threat alert. They extrapolated from their survey responses to determine that nationally cities are spending nearly \$70 million per week in additional homeland security costs due to the War in Iraq and heightened threat alert level. San Francisco reported spending \$2.6 million per week. The U.S. Conference of Mayors notes that these costs come on top of existing homeland security spending that cities were already spending to maintain general security measures. Respondents were asked to report only direct costs of raising the alert and not to report indirect costs such as the effects from reassigning a police officer from anti-gang work to guarding a public building. The reported costs also do not include the costs of equipment and training that city first responders need to ensure they are prepared to react in a time of crisis (U.S. Conference of Mayors, 2003).

The survey results may be overestimated for this purpose because it includes extra security measures because of the impending war in Iraq. However, it is also possible that the

figures are underestimated because they excluded indirect costs that would be borne by society. Therefore, this analysis will consider San Francisco’s estimate of \$2.6 million per week as an accurate estimate of the costs of raising the threat alert level to orange.

The U.S. Conference of Mayors report did not include information on Oakland’s costs during an orange alert, so it was necessary to estimate this figure. One of the major expenses of providing increased security to any city is increasing the police presence in the area. Therefore, to determine the costs of raising the alert in Oakland, the San Francisco cost figure was scaled down proportionally based on ratio of the two cities police departments. According to the Bureau of Justice Statistics for 1999, Oakland had roughly one-third the number of full-time sworn officers as San Francisco (2003). It was determined that Oakland’s cost of raising the alert level to orange for a period of one week was approximately \$760,000.

Of the seven times the HSAS was raised to orange, the median number of days the threat lasted was 20 days (see Table 2 for the number of days each orange alert lasted). Table 4 shows the calculations necessary to transform these reported weekly costs to a cost for the average orange alert for the two cities, the result of which is \$9.6 million per occasion of raising the alert (in 2003 dollars).

**Table 4: Transformation of Cost Figures**

San Francisco's Reported Cost per Week	a	\$2,600,000
Oakland's Estimated Cost per Week	b	\$760,000
San Francisco Bay Area's Approximate Cost per Week	c= a+b	\$3,360,000
San Francisco Bay Area's Approximate Cost per Day	d = c/7	\$480,000
Median Number of Days at Orange	e	20
San Francisco Bay Area's Cost for Average Terror Alert	f = d*e	\$9,600,000

*Increased Wait Times* – When the national terror alert is raised from yellow to orange, security checkpoints pop up all over the place, from airports to entering some businesses to crossing the Golden Gate Bridge. During one orange alert, California Highway Patrol (CHP) officers set up a checkpoint to stop trucks about to cross the Golden Gate Bridge and the Bay Bridge. Truck drivers pulled off to the side of the road and were asked a series of questions by CHP officers, as they visually inspected the outside of the truck, sometimes aided by an explosive sniffing dog (Kee, Burress, Koopman, Cabanatuan, & Gledhill, 2003, February 8). Checkpoints such as these on San Francisco’s already crowded bridges can slow traffic and cause delays.

According to an article in the San Francisco Chronicle, during the March 17, 2003 to April 11, 2003 orange alert, CHP officers set up security checkpoints in various locations in the San Francisco area; however, only one of which was located in San Francisco County. Only trucks were required to stop at the checkpoint. Two CHP officers reported approximately 900 trucks going through their checkpoint during a twelve-hour shift (Fimrite and Goodyear, 2003, March 20). Assuming that the checkpoints were operated 24-hours a day, as many as 1800 trucks could be delayed. For illustration purposes, it was assumed that the average wait time to go

through the checkpoint was one hour.<sup>2</sup> Using the U.S. Department of Transportation's (2003) recommended hourly value of travel time savings for truck drivers it can be determined that the additional cost of the security checkpoints during the average orange alert is approximately \$696,251 (see Table 5).

**Table 6.5: Calculations to Determine Costs of Waiting Time at Highway Checkpoints**

Number of Trucks per Day Through Checkpoint	a	1800
Average Wait Time in Hours	b	1.0000
Average Hourly Rate of Travel Time Saved for Trucks (2000 Dollars)	c	\$18.10
Additional Cost per Truck per Hour	$d = b*c$	\$18
Cost of Additional Travel Time per Day	$e = a*d$	\$32,580
Median Number of Days at Orange	f	20
San Francisco's Cost for Average Terror Alert (2000 Dollars)	$g = e*f$	\$651,600
San Francisco's Cost for Average Terror Alert (2000 Dollars)	$f = g*1.068525$	\$696,251

Along with delays at highway security checkpoints, additional security checkpoints also cause individuals to spend more time at airports. When the HSAS was raised to orange in December 2003, airport officials advised the public to plan an additional half an hour to an hour at the airport because of additional security procedures. Passengers were told to expect delays both at security checkpoints and because of random vehicle searches outside terminals (Security boosted in orange alert, 2003). Although not all passengers will actually experience an additional half an hour delay at the airport because of the increased security measures; however, passengers arriving a half an hour earlier for their flights still spend that time waiting at the airport.

According to the Airports Council International (2005), San Francisco International Airport (SFO) handled over 32 million passengers in 2004. To determine the number of passengers departing from SFO, those most likely to be affected by additional security procedures, this figure was divided by two. This may be an overestimate of the number of passengers affected by security because the total passenger figure also includes passengers with a layover at SFO; however this possible overestimate will be controlled for in the sensitivity analysis. Data was not available to differentiate business travelers from individuals traveling for pleasure, so the U.S. Department of Transportation (2003) average hourly value of travel time savings for all air travel purposes was used to calculate the additional social costs. Table 6 details the calculations used to arrive at the additional \$13.5 million of costs for the average orange alert.

<sup>2</sup> At the time of this draft, the average wait time in hours at highway checkpoints had yet to be determined. In order to include this variable in the Net Present Value calculation and the Sensitivity Analysis a period of one-hour was used. Further research will be conducted to provide an actual estimate.

**Table 6.6: Calculations to Determine Costs of Waiting Time at Airports**

Total Passengers at SFO in 2004	a	32247746
Passengers Departing SFO per Day	$b = (a/2)/365$	44174.99452
Increased Wait Time per Person (in Hours)	c	0.5
Increased Wait Time per Day (in Hours)	$d = b*c$	22,087
Average Hourly Rate of Travel Time Saved (2000 Dollars)	e	\$28.60
Cost of Additional Travel Time per Day	$f = d*e$	\$631,702
Median Number of Days at Orange	g	20
San Francisco's Cost for Average Terror Alert (2000 Dollars)	$h = f*g$	\$12,634,048
San Francisco's Cost for Average Terror Alert (2003 Dollars)	$i = h*1.068525$	\$13,499,797

Although all airports fall under the jurisdiction of the Transportation Security Administration and are therefore required to initiate additional security procedures when the national HSAS is raised, it is assumed that San Francisco would only raise its alert level in conjunction with the federal government. This assumption allows the waiting time of those departing from SFO to be considered. However, it should be noted that the cost of the additional security is not included, as the federal government does not have standing in this analysis.

#### 6.4.4 Costs Not Measured

*Increased Security for Private Industry* – Not all security in a city comes from the local government agencies. Private industry also has a responsibility for protection. According to DHS, private companies own 85 percent of America’s critical infrastructure (Department of Homeland Security, 2005). Critical infrastructure sectors include transportation, energy, water, public health, chemical, shipping, and finance along with several others. Although not every city has a chemical plant, every city does have water and electricity infrastructure to protect. The National Strategy for the Protection of Critical Infrastructures and Key Assets indicates that private industry is America’s first line of defense in protecting their own facilities. As continuity of services can affect public perceptions, and therefore, shareholder values, private companies provide a baseline level of security during normal operations (White House, 2003). Private industries, like cities and states have the option of increasing security when the HSAS is raised to orange. C. Jeffery Triplett, vice president of Risk-Management Services, estimated that for one-three building office complex, with approximately 2,000 people, “it cost in additional operating costs -- additional contract labor, extra hours of coverage – about \$10,000 per week” (Harris, 2003). However, this figure would vary greatly based on the type of facility, the type of infrastructure, the other security precautions previously implemented and the decisions of the owners of the company. Therefore, attempting to measure these costs is outside the scope of this analysis.

*Decreased Tourism* – Raising the terror alert tends to cause a decrease in tourism. Even though officials have tried to persuade the public to carry on with their normal lives, residual fear of airplanes or concern over being in public places cause individuals to cancel trips and possibly avoid scheduling them. This affects American travelers in terms of lost opportunities, but it also affects American companies relying on both foreign and domestic tourism. For example, in March 2003, Disney’s financial advisors at Merrill Lynch reduced the companies second quarter

operating income by \$90 million, this signaled a 29% decline in income from the same time during the previous year. The Merrill Lynch analysts cited the prospects of war in Iraq and the orange alerts as the reason for the lost income. Michael Eisner, Disney Chairman noted “When the orange alert hit we saw an immediate reaction.” Eisner also suggested that the upgrade in terror alert levels hurt the parks in Florida more than the parks in California, because the parks in Florida are more dependent on tourist arriving by air travel (Schneider, 2003, March 12). Data on the impact of tourism to the San Francisco area were not located, and therefore, this impact will not be monetized.

*Crisis Fatigue* – As the HSAS bounced from yellow to orange and back again, some began to be concerned with crisis fatigue or the public and first responders reaching a state of ambiguity about the rise of the threat level. Linda Feldman of the Christian Science Monitor writes:

Fifteen months after the color-coded alert scheme was introduced, experts on terrorism and those on the front lines of protecting public safety are grateful that there have been no attacks on American soil since Sept. 11, 2001. But this stretch of suspenseful calm, punctuated by government warnings of possible attack that don’t occur, risks what analysts call a “crying wolf syndrome,” in which the public and even first responders lower their guard (Feldmann, 2003).

It is not known what type of costs would be associated with this phenomenon, but at a minimum it could make the HSAS less effective. Plagued by tight budgets, frustrated by insufficient information coming from the federal government, there is some evidence that cities are suffering from crisis fatigue and opting not take as many precautions when the alert level is raised to orange (Feldmann, 2003). The vagueness in the responses of city officials and the public to crisis fatigue results in this cost not being quantified.

*Effects on Financial Markets* - There is some evidence that the rise and fall of the HSAS has an impact on the financial markets. According to a report in Barron’s, the S&P 500 fell nearly 10 percent in the two weeks after the alert level was raised in September of 2002. After the alert was lowered back to yellow, the S&P bounced back up four percent (Blumenthal, 2003). As this effect was noticed during the first increase in the alert level, it is unclear if the trend will continue; therefore, it is not calculated in the analysis.<sup>3</sup>

#### 6.4.5 Measured Benefits

*Costs Avoided by Preventing a Terrorist Attack* – Even when the intelligence is good enough to warn a specific city, it is unlikely that the type of attack will be known. Although the last attack was with “conventional” high explosives, the next attack could be similar or it could be biological, chemical or nuclear. For the purpose of this project, an assumption was made that the next attack will be an attack of similar magnitude to the September 11<sup>th</sup> attacks in New York City, scaled down proportionally to occur in San Francisco or Oakland.

The Government Accountability Office reviewed eight studies from seven different organizations on the economic impact of September 11<sup>th</sup> on New York City. They determined that the study done by the New York City Partnership and Chamber of Commerce provided the

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<sup>3</sup> If time permits, this variable will be monetized and included in the analysis.

most comprehensive estimate of the economic impacts. In making this determination, GAO compared each study’s methods and assumptions to that of standard economic analysis; specifically examining the extent to which each study: accounted for major categories of losses; included only the cost required to rebuild or restore property to pre-attack levels; avoided double counting losses; and included a baseline to control for the economic slowdown underway before the attack (Government Accountability Office, 2002). The New York City Partnership (2001) estimated the economic impact of the attack was likely to reach a total of \$83 billion. The direct and indirect costs included in this estimate are shown in Table 7.

**Table 6.7: Direct and Indirect Costs Measured in Estimate of 9/11 Impact**

Direct Costs	Indirect Costs
Human lives	Lost Employee Income and Business Profits
Property loss	* Days bussiness closed or services cut back because office infrastructure damage or destroyed
* Buildings	
* Technology and Fixtures	
* Subway Stations	* Other firms that depend on those that are closed or cut back
* Phone and Power Utilites	
Response to the Emergency	Reduced Tax Revenues
* Emergency Management (including loss of equipment)	Delays to Travelers and Commuters
* Debris Removal	
* Building Stabilization	
Health Effects, Injuries, and Emotional Distress	
Temporary Living Assistance	

Source: New York City Partnership and Chamber of Commerce. (2001). Working together to accelerate New York’s recovery: Economic impact analysis of the September 11th attack on New York City. Retrieved May 12, 2005, from <http://www.nycp.org/reports/ImpactS>

The New York City Partnership and Chamber of Commerce reviewed their initial analysis in the months after the attacks as some costs became more evident. They determined that two factors might have contributed to an overestimate of the total costs. First, clean up of ground zero was occurring at faster rates and lower costs than anticipated. Second, the loss of life was overestimated at the time of the original report; they estimated 5,000 deaths, which was incorrect by over two thousand lives. However, the Partnership valued human life based on lost productivity, rather than the value of a statistical, which produces a lower estimate of the cost of life.<sup>4</sup> Therefore, the \$83 billion figure was used in this analysis because GAO considered it the

<sup>4</sup> The New York City Partnership study valued life at \$2 million (\$2 million \* 5000 lives = \$10 billion). In a recent study Viscusi and Aldy determined that “the value of a statistical life for prime-aged workers has a median value of about \$7 million in the United States” (2003, p. 68). Using this figure the estimated cost of lives lost during the attack in New York City should be closer to (\$7 million \* approx. 2,750 lives lost = \$19.5 billion). Therefore, the net impact of these estimations could be an underestimate.

most comprehensive estimate, even with these overestimates. Also, the New York Partnership value lies within the range of estimates from the other studies (Government Accountability Office, 2002).

It was necessary to scale the impacts of an attack the size of September 11<sup>th</sup> in New York City to an attack that might occur in San Francisco or Oakland. To do this, U.S. Census bureau data were used. To find a per capita cost of the New York City attacks, the economic impact was divided by the 2001 population of New York City. A total of the population for New York’s five boroughs was used since the entire area was affected by the attacks. This per capita cost of September 11<sup>th</sup> was then multiplied by the combined 2004 population of San Francisco and Oakland to obtain the estimated value of benefits from preventing a similar attack in San Francisco or Oakland. Table 8 shows these calculations.

**Table 6.8: Calculations of Estimated Benefits of Preventing a Terrorist Attack in San Francisco or Oakland**

Estimated Cost of 9/11 (2001 Dollars)	a	\$83,000,000,000
2001 Population of NYC	b	8,067,993
Per Capita Cost of 9/11	$c = a / b$	\$10,288
2004 Combined Population of San Francisco and Oakland	d	1,142,206
Estimated Benefits of Preventing a Future Attack in San Francisco or Oakland (2001 Dollars)	$e = c*d$	\$11,750,518,128
Estimated Benefits of Preventing a Future Attack in San Francisco or Oakland (2003 Dollars)	$f = e*1.03896$	\$12,208,330,064

*Reduction in Crime* – The changes in terror alert puts more police officers on the street to make a visible security presence. Not only will this deter potential terrorists, it also deters crime. Klick and Tabarrok (2005) found a 15 percent reduction in street crimes, mostly auto-theft and burglary, during high-alert days in Washington, D.C.; however, Washington, D.C. has a few unique characteristics that suggest this may be an overestimate when trying to generalize to other populations. For example the majority of the crime reduction found in this study occurred in the police district that includes the National Mall. Although Klick and Tabarrok controlled for the effects of tourism, the National Mall is an area in which police presence increases more than in other areas of the city during orange alerts, in part because of the federal law enforcement presence in addition to city police. There is also a closed circuit television system on the Mall that is activated when the city is at orange alert. Theoretically, it is possible to conceive of a situation in which there would be no significant reduction of crime. For example, if a city decided to save the costs of police overtime, they might choose to relocate police officers already on duty to protect specific areas, rather than extending shifts and increasing the police presence across the city. If this situation occurred, there would be a transfer in crime location instead of a reduction of crime. For these reasons, a mean of 7.5 percent crime reduction will be used to estimate this impact. The sensitivity analysis will evaluate a range of burglary and motor vehicle theft rate reductions from zero to 15 percent.

According to the Uniform Crime Report, 22,854 burglaries and motor vehicle thefts occurred in the Cities of San Francisco and Oakland during 2003 (Federal Bureau of Investigation, 2004). This translates to an average of 63 burglaries or motor vehicle thefts per day. Again using the median terror alert of 20 days, a 7.5 percent reduction in these street crimes during the average orange alert would result in 92 crimes prevented. Boardman, et al. (2001), suggest the shadow price of burglary of \$16,200 per burglary (in 1999 dollars). After accounting for inflation, preventing 92 burglaries or motor vehicle thefts will result in \$1,638,412 in benefits for the cities. Table 9 displays the necessary calculations to obtain this estimate.

**Table 6.9: Calculations for Estimated Benefits from Crime Reduction**

City of San Francisco		
Number of Burglaries	a	5,784
Number of Motor Vehicle Thefts	b	6,991
Total Burglaries and Auto Thefts	c = a+b	12,775
City of Oakland		
Number of Burglaries	d	4,568
Number of Motor Vehicle Thefts	e	5,511
Total Burglaries and Auto Thefts	f = d+e	10,079
Total Burglaries and Auto Thefts	g = c+f	22,854
Average Number of Burglaries and Auto Thefts per Day	h = g/365	63
Median Number of Days per Orange Alert	i	19.5
Estimated Number of Burglaries and Auto Thefts during Orange Alert	j = h*i	1221
Estimated Number of Burglaries and Auto Thefts Prevented	k = j*.075	92
Cost Per Burglary (1999 dollars)	l	\$16,200
Estimated Benefits from Crime Reduction (1999 Dollars)	m = k*l	\$1,483,475
Estimated Benefits from Crime Reduction (2003 Dollars)	n = m*1.104442	\$1,638,412

#### 6.4.6 Benefits Not Measured

*Capturing Terrorists* – Raising the alert level can prevent a terrorist attack in two possible ways. First, the terrorists planning the event could postpone the attack or decide to forgo the specific plan. Second, and a greater long-term benefit, is the potential that raising the alert level will lead to the capture of terrorists involved in the plot. Capturing terrorists could not only prevent immediate attack, but interrogation of those individuals could lead to the arrest of other terrorists that are involved in planning future attacks. This effect could be exponential; each captured terrorist may lead to the capture of additional members of the terrorist network. However, there are several unknown factors that prevent this benefit from being measured. First, the probability of preventing an attack by raising the alert level is unknown. Second, even if an attack was planned, and raising the alert level prevented that attack, it is possible that no

terrorists would be captured. Finally, if at least one terrorist was captured, it is still not known how many other terrorists would be arrested as a result. Therefore, this potential benefit will not be measured simply because of the number of uncertain variables involved.

### 6.5 Determining Net Present Value

As both the benefits and costs of increasing the HSAS from yellow to orange occur over a relatively short period of time, it is not necessary to discount the impacts to adjust for the time value or money. However, it does require an expected value analysis because the actuality of preventing a terrorist attack is not certain. The set of contingencies possible when considering raising the HSAS alert level is displayed in Table 10, along with an indication of when measured costs and benefits would be realized. To determine the Net Present Value (NPV), it is necessary to determine the probability of a terrorist attack. Once this is estimated, an expected value analysis can be used to calculate the NPV.

**Table 6.10: Possible Contingencies - When Benefits and Costs are Realized**

		Does terrorist attack occur?		
		No		Yes
		Was an Actual Attack Preempted?		
		No	Yes	
Is terror alert level raised?	No	Status quo – no additional costs and no additional benefits	No costs of raising the alert level, benefits are realized but attributable to other policies	No costs of raising threat level, and benefits are not realized
	Yes	Cost of raising alert level incurred but only benefits realized are from reduction in crime	Costs of raising alert level incurred and benefits are realized	Cost of raising the threat level compounded by benefits that are not realized

#### 6.5.1 Determining Probability of a Terrorist Attack: Inverse Cost Benefit Analysis

Whereas the probability of a natural occurring catastrophe, such as a hurricane or tsunami, can be estimated using scientific knowledge and experience with historical events, the actual probability of a terrorist attack cannot be estimated. Richard Posner explains “[i]t is not only that terrorists are secretive as to plans and capabilities, but also that they – or at least the ones that have vague and encompassing aims – have such a wide range of potential means and targets to choose among, and if suicidal, cannot be deterred” (2004, p. 174). The human element of terrorist activity makes deterrence extremely difficult. While hurricanes may change course from the anticipated path because of changing ocean currents, it is next to impossible for a hurricane to change its course based human countermeasures. Terrorists on the other hand are driven more by human phenomenon rather than physical phenomenon; they react to human

counter measures and adapt appropriately. This ability of the terrorists to adapt makes determining the probability of their actions difficult.

Some have suggested turning to information markets to gather information about the likely risks of particular terrorist attacks; however, terrorists could manipulate the market resulting in inaccurate predictions or the potential of terrorists themselves to profit by making the predictions accurate. Likewise, others have tried inferring the risk of terrorism from insurance markets, but it seems that the insurance industry is as puzzled on how to estimate this risk as others. After September 11<sup>th</sup>, insurance companies terminated coverage for losses from terrorism.<sup>5</sup> Although the Terrorism Risk Insurance Act of 2002 requires insurance companies to offer coverage of business property and casualty losses due to terrorism, the federal government subsidizes this insurance heavily. This makes it difficult to determine the industry's implicit estimate of the probability of an attack occurring (Posner, 2004, pp. 172 - 176).

Posner suggests “inverse cost-benefit analysis” as an alternative to determining the probability of catastrophic events. This procedure determines the probability of a terrorist attack (P) by dividing what the government is spending to prevent a particular type of attack (C) by the anticipated social losses of the terrorist attack actually occurring (L). This results in an implied or subjective probability of the terrorist attack. So, if P and L can be estimated, C can be calculated using the formula for expected cost ( $C = PL$ ). For example, if \$1 billion is spent to avert an attack that if it occurs will create \$100 billion in losses the probability of such an attack occurring is  $P = C/L = \$1 \text{ billion}/\$100 \text{ billion} = .01$  (Posner, 2004, pp. 176 – 177).

This method is far from perfect. Most importantly this is a subjective probability, rather than an objective one. Using government budgets to determine probabilities relies on the subjective opinions of policy makers. Behavioral psychology has shown that when faced with fear and imperfect knowledge, people will determine probabilities based on several reactions to fear. First, individuals use the availability heuristic to determine the probability of an event based on whether a readily available example of that event comes to mind. Second, people tend to show a greater fear of risks that they perceive as unfamiliar or hard to control. Finally, people are prone to probability neglect, in which case they focus on the bad event itself and become unmindful of the fact that it's occurrence is unlikely. These aspects of the human psyche suggest that in the wake of the September 11<sup>th</sup> attacks, people are prone to overestimating the likelihood of another attack, and are likely to divert resources towards preventing an attack even if the magnitude of risk does not warrant the actions (Sunstein, 2003). Therefore, using government budgets to estimate the probability of an attack could result in an overestimation. The other issue with using this method of arriving at the subjective probability is that it assumes that one dollar spent of prevention equals one dollar of reduced risk. However, without information on the marginal costs and marginal benefits of terrorism prevention, using total costs and total anticipated losses is the best proxy measure available. Although the “inverse cost-benefit analysis” method is far from perfect, it provides a more realistic method for estimating the probability of an attack than the other options available.

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<sup>5</sup> Prior to the September 11<sup>th</sup> terrorist attacks, insurance companies charge very small premiums for terrorism insurance, therefore data from before the attack would not be useful in determining the risk insurance companies assign to terrorism.

## 6.5.2 Implementing the Inverse Cost-Benefit Analysis Method

In the specific case of San Francisco, since the cost of a successful terrorist attack is \$12.2 billion, and the total estimated monetary costs of going to an elevated alert level is \$23.1 million, the reduction in the probability of attack that would just equate benefits with cost is .0019. Given the estimates of the other parameters in the calculation -- e.g. the estimated total cost of a terrorist attack, and the estimated cost of reducing the likelihood of such an attack during an elevated alert period --, the implication of this estimate is that in the case of San Francisco, going to an orange alert level would be a socially efficient use of scarce resources, and people's time, if the action lowered the likelihood of a successful attack by at least .0019. Interestingly, this estimate is of the same order of magnitude as the implied probability that would make current expenditures devoted to reducing the probability of a 9/11-type attack in New York city just equal to expected benefits.<sup>6</sup>

## **6.6 Sensitivity Analysis**

As this entire analysis is based on estimates of values and unknown amounts of risk it is useful to run a sensitivity analysis of the variables in which there is the greatest amount of uncertainty. A Monte Carlo Sensitivity Analysis was completed with the assistance of Crystal Ball, a software program specially designed for completing this type of analysis. The Monte Carlo approach provides an answer to the question: what distribution of net benefits results from multiple draws of the probability distribution assigned to key variables (Boardman et al., 2001).

### 6.6.1 Assumptions of the Sensitivity Analysis

The Monte Carlo analysis requires the identification of the variables that are uncertain; in this analysis, those variables are the net costs of waiting time on highways, the net costs of waiting time at airports, the net benefits of preventing a terrorist attack, the probability of a terrorist attack, and the net benefits from the reduction in crime. Although there is undoubtedly some uncertainty in the value of costs to San Francisco and Oakland to provide an increased security presence, no information on the range of that value or indications about the shape of the distribution were available. Therefore, this figure was not varied in the sensitivity analysis. Table 13 summarizes the variable assumptions in the analysis.

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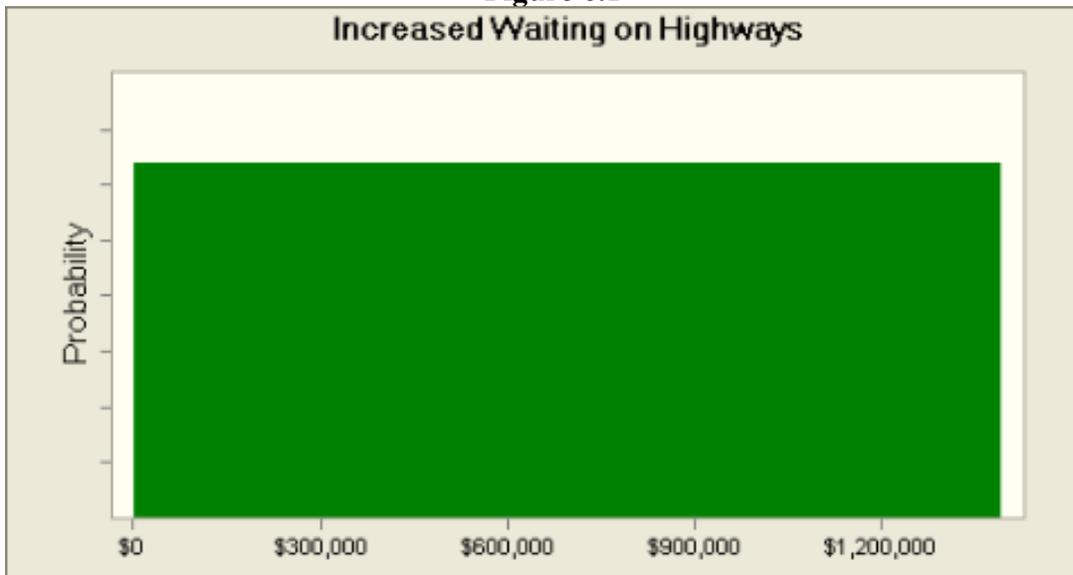
<sup>6</sup> Specifically, it has been estimated that a repeat of the Sept. 11<sup>th</sup> attack in New York City would cost \$86.2 billion, and estimated government expenditures needed to avert a repeat disaster have been estimated to be \$137.6 million. The reduction in the probability of attack that equates cost with benefit in this case is .0016.

**Table 6.11: Assumptions in Sensitivity Analysis**

	Base Case	Minimums	Maximums	Distributions
Waiting Time on Highways	\$9,283	\$0	\$1,392,502	Uniform
Waiting Time at Airports	\$13,499,797	\$0	\$22,406,377	Triangular
Preventing a Terrorist Attack	\$12,208,330,064	\$7,942,768,958	\$15,444,272,973	Triangular
Probability of Terrorist Attack	0.00190	0	0.0038	Triangular
Reduction in Crime	\$1,638,412	\$0	\$3,276,824	Uniform

*Value of Waiting Time on Highways* - For the purpose of the sensitivity analysis, the distribution of this variable is assumed to be uniform. A uniform probability distribution is a simple distribution that only requires a minimum and maximum value and assumes that all values in between the two values are just as likely to occur. As it is possible to have zero waiting time at any security checkpoint, the minimum value was easy to determine. For illustration purposes, the upper bound of the distribution is assumed to be two hours.<sup>7</sup> Without specific information regarding the likelihood of a specific wait time, the uniform distribution seems to be the best fit. Figure 6.1 displays this distribution.

**Figure 6.1**



<sup>7</sup> This assumption will be updated when additional data are available.

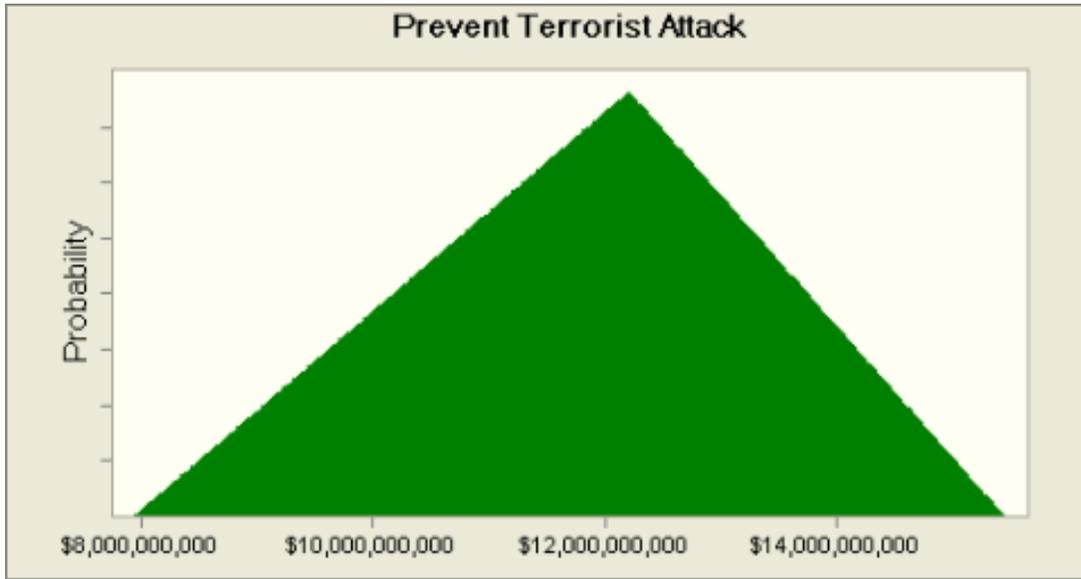
*Value of Waiting Time at Airports* – The distribution of this variable is assumed to be triangular. A triangular probability distribution is also a fairly simple distribution, but it also takes into account the most likely value of the distribution. Although most citizens will heed directives to arrive at the airport a half an hour before they would have when the HSAS is at yellow, some citizens will ignore this and will not have any waiting time. However, it is also possible that people will end up waiting longer than a half an hour. When lines at security checkpoints get long, it is not uncommon for airport personnel to begin removing people from line whose flights are about to depart. Given that most airlines terminate boarding there aircraft ten minutes before flight time, it is assumed that the maximum amount of time an individual could be waiting at the airport because of an orange alert is forty minutes. The distribution for this variable, which is slightly positively skewed is shown in Figure 2.

**Figure 6.2**



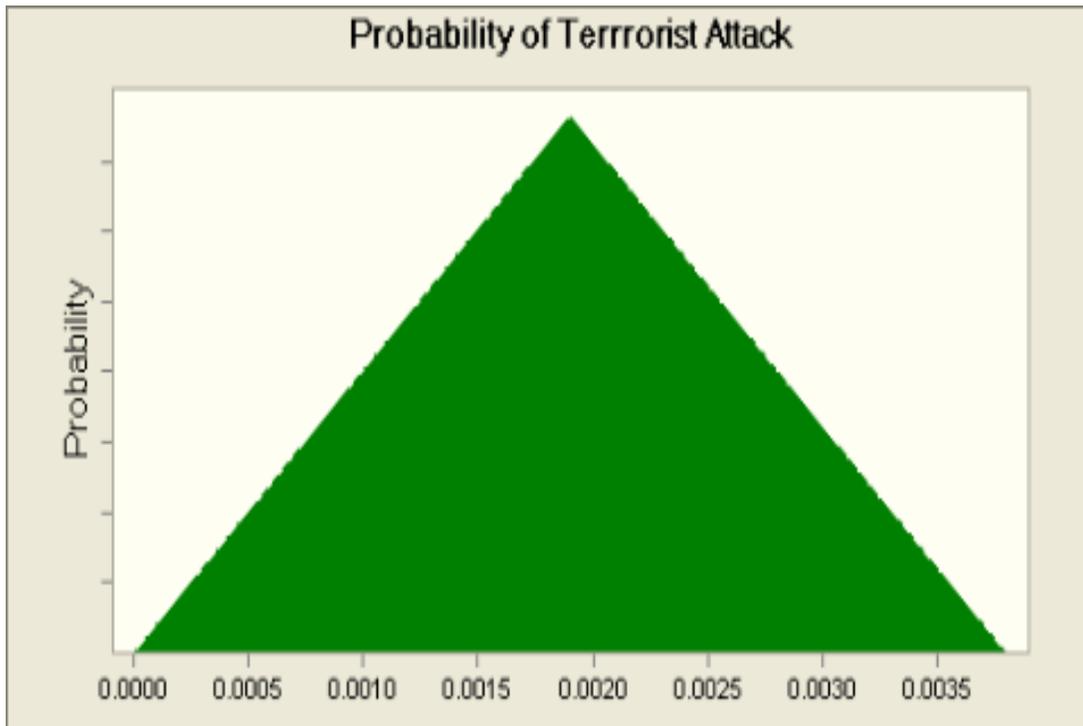
*Value of Preventing a Terrorist Attack* – For the purpose of the sensitivity analysis, the distribution of this variable was assumed to be triangular, with a minimum value of \$7.9 billion and a maximum value of \$15.4 billion centered around the baseline value used in the analysis of \$12.2 billion. The triangular distribution was used because a mean value was known. The GAO review of reports analyzing the impact of September 11<sup>th</sup> on New York City included impacts as low as \$54 billion and as high as \$105 billion. The same per capita scaling applied to the base case was applied to these minimum and maximum values to establish the range of possible benefits from preventing an attack in San Francisco. The triangular distribution was chosen because it provides a continuous distribution and is an approximation of a random variable with an unknown distribution. These assumptions lead to a distribution that is slightly positively skewed. Figure 6.3 displays the distribution with these assumptions.

Figure 6.3



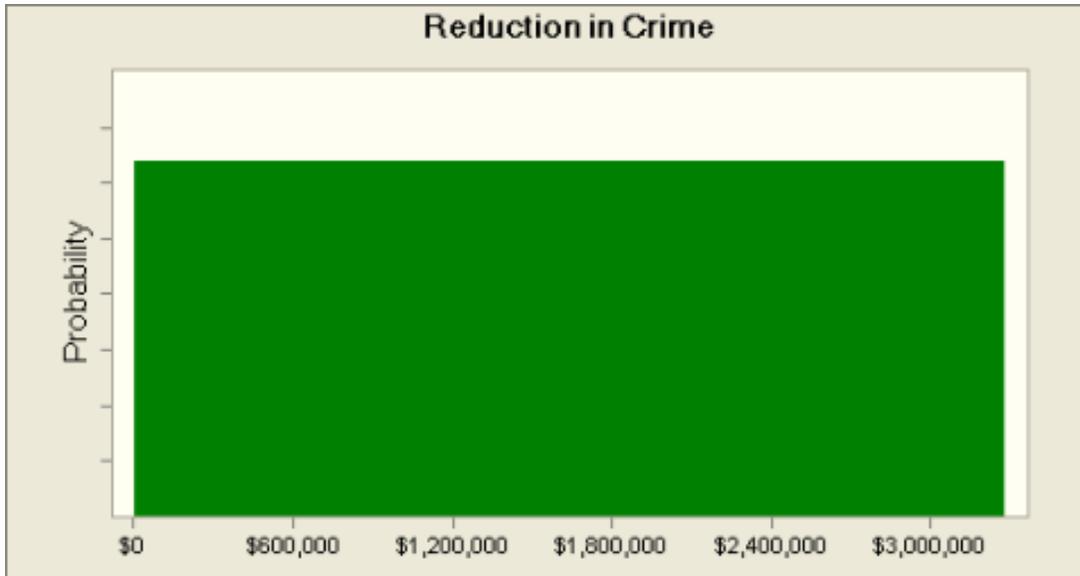
*Probability of a Terrorist Attack* – A triangular distribution was assumed in this case as well, centered around the estimate of the “break-even probability of .0019. The minimum value was set at 0.0000 (no effect on the probability of terrorist attack) and the maximum value at 0.0038 (twice the estimated break-even probability).

Figure 6.4



*Reduction in Crime* – This variable was assumed to have a uniform distribution because there is no theoretical reason to believe that any one value has a higher probability of being correct than any other value. As noted above, there is limited information on the actual reduction of crime during orange alerts. The fifteen percent reduction established in the one available study is assumed to be an upper bound of this impact. It is also assumed that it is possible to have no reduction in crime. Figure 6.5 shows this distribution.

**Figure 6.5**

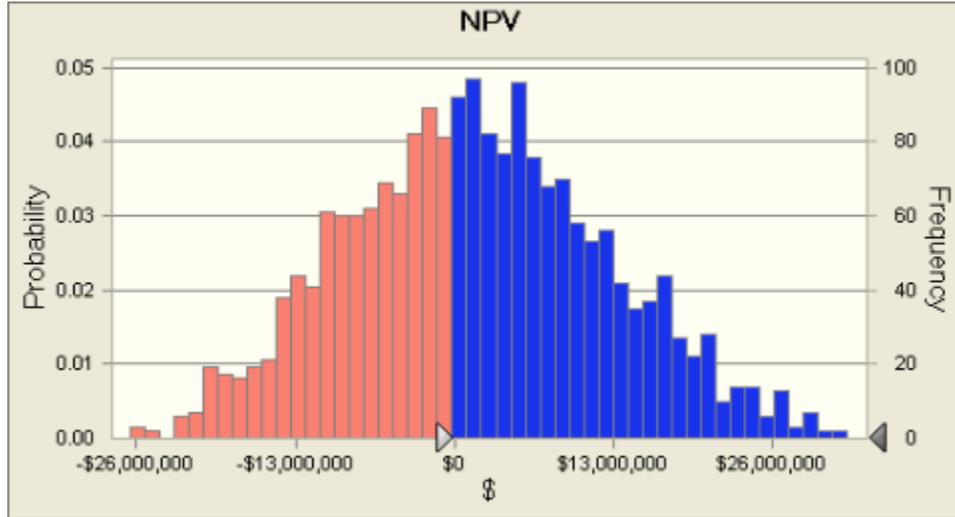


### 6.6.2 Results of Sensitivity Analysis

Two thousand cases were run and Figure 6 displays a histogram of the realized benefits. The analysis of 2000 cases was done to achieve at least a 95% confidence level in the results. The analysis showed with 56% certainty that the net benefits of going to alert level orange in San Francisco would be positive. The mean net benefit was \$1.9 million with a range from a net loss of -\$26 million to a net gain of just under \$40 million. Table 12 provides other pertinent descriptive statistics.

Figure 6.7 shows that 75.4 percent of the variance in the net present value was due to uncertainty about the probability of a terrorist attack occurring. Uncertainty about the value of the primary benefit from preventing a terrorist attack and the dual benefit of reduced crime accounted for 7.7% and .4% of the variance in the net benefits, respectively. Uncertainty about the costs of waiting time at airports accounted for 16.3 percent of the variance in expected net benefits.

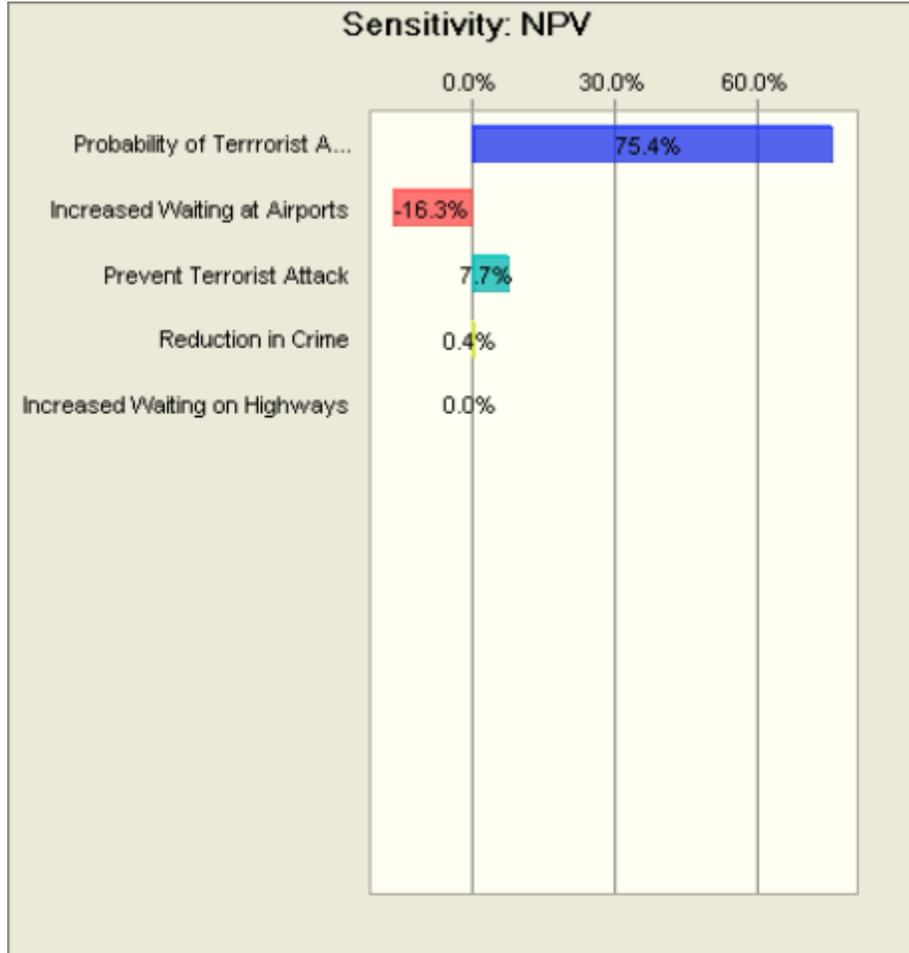
**Figure 6.6**



**Table 6.12: Descriptive Statistics**

Statistics:	Forecast values
Trials	2,000
Mean	\$1,916,548
Median	\$1,556,534
Mode	---
Standard Deviation	\$10,799,446
Variance	\$116,628,023,683,666
Skewness	0.20
Kurtosis	2.81
Coeff. of Variability	5.63
Minimum	-\$26,544,617
Maximum	\$39,941,356
Range Width	\$66,485,973
Mean Std. Error	\$241,483

Figure 6.7



## 6.7 Conclusion

A city's decision to increase their Homeland Security Advisory System, from yellow to orange, to correspond to a similar change in the national alert status implies a direct weighing of costs and benefits. For the city, costs include the price of increasing a security presence in areas of critical locations, typically accomplished by extending police officer shifts from eight hours to twelve hours resulting in major overtime costs. The San Francisco and Oakland city governments' costs for increasing the alert level were determined to be approximately \$9.6 million for the average alert time period of 20 days. The combined cost of increased waiting time at airports and on highways was estimated as \$14.2 million. Other social costs that were not measured include private industry costs for securing their facilities, and any possible decrease in tourism.

The primary benefit from a city's decision is the possibility of preventing a terrorist attack. Based on scaled down simulation of the economic impacts of September 11<sup>th</sup> on New York City, the potential benefits to San Francisco and Oakland from preventing this type of an

attack would be approximately \$12.2 billion. However, the likelihood of a terrorist attack is not certain, therefore an inverse cost benefit analysis was used to determine expected benefits would just equal expected cost of the elevated alert level was successful at lower the probability of a successful terrorist attack by just under two-tenths of one percent (.0019). The analysis also estimated that the cities would also benefit an additional \$1.6 million from a reduction in crime as a result of the increased police presence. The potential benefits of capturing additional terrorists were not measured in this analysis.

A Monte Carlo sensitivity analysis was run on this base case and found that the NPV would result with positive net benefits 56 percent of the time. On balance, given the uncertainties involved in obtaining these estimates, a reasonable inference from the analysis is that, especially if it is deemed wise to err on the side of caution, spending the resources associated with going to an elevated alert level in San Francisco represented a reasonably socially efficient use of scarce resources.

## **7. Application: Decreasing Vulnerability of the Transportation Systems: The Case of the Electric Transmission Network**

One category of policy initiatives under the homeland security effort involves government actions that would investments that decrease vulnerability of fundamental systems, particularly transportation systems. Because of their physical exposure and their critical role in the operation of a modern economy, transportation systems have been and likely will continue to be a favorite target of terrorists. While hardening and protecting these systems against potential attackers is one important option for homeland security planners, an alternative is to increase redundancy and resiliency in transportation networks so that components can be lost or disabled without causing substantial harm. This section discusses the measurement of costs of these efforts in the context of electric power transmission. It should, however, be noted that the general economic principles underlying the analysis are completely general and can be applied in other transportation contexts.

The analysis proceeds in several steps. The next section discusses the general issue of cost analysis for projects increase the capacity of a transportation system, which effectively reduces vulnerability by raising redundancy and resiliency. The general principles developed in this analysis are then applied to analyzing the economic costs of benefits and costs of “hardening the electricity transmission infrastructure” as a homeland security measure.

### **7.1 General Issues in Benefit/Cost Analysis of Expanding the Capacity of Transportation Systems**

Analyzing the benefits and costs of expanding the capacity of a transportation system, such as one that transmits (transports) electricity requires that one address the issue of how to attribute costs of improvements in the capacity of a system to multiple beneficiaries of that system. The analysis of this problem applies equally to roads, railroads, ports, pipelines, electrical grids, etc.

The central issue that cost attribution must address is that capacity expansion in a transportation network accomplishes a number of purposes. Attributing the cost of the expansion to these various purposes is difficult even when the expansion is based on an optimal configuration of the network. It becomes more difficult when the capacity is being added to system that it not configured optimally prior to the expansion. These issues are first discussed and then some recommendations for a resolution appropriate for capacity improvements designed to enhance reliability and resiliency of networks are presented.<sup>1</sup>

The problem of cost attribution is clarified by considering the purpose of cost attribution. One purpose is to determine if a proposed project or policy to expand capacity is socially efficient. When there are multiple beneficiaries, it is important to consider all benefits, just as all costs must be considered in proper benefit/cost analysis.

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<sup>1</sup> Much of this discussion follows arguments in Kojo Ofori-Atta, Elliot Roseman, Bansari Saha, Scott Stuart, Marc Lipschultz and Jonathan Smidt, (2004).

A second purpose is that to the extent that beneficiaries are to be charged for the cost of added capacity, user charges should be based on the benefit principle. This is necessary to ration use of a facility or resources and it is also useful to identify funding to cover the inframarginal costs of a project. In the case of electricity transmission or other transportation issues, each of these two issues is important. Additions to the transmission grid or enhancements to a transportation system can be funded from rates charged for transmission or presumably could be subsidized if they were determined to be based on homeland security needs. Accordingly, cost attribution for enhancements to the transmission grid could be funded fully by rate payers, fully by homeland security, or any intermediate combination.

Consider the problem of cost attribution in the case of a simple stylized expansion in electric transmission capacity.<sup>2</sup> Assume that there an electric transmission network connects a number of generators with several distribution networks and that the capacity of the network can be expanded at some known construction cost that is a function of the capacity provided, so that cost =  $C(Q)$ , where  $Q$  is the additional capacity constructed. Expansion of a transmission network connecting many generators with many distributors creates two direct but independent types of benefits.

First there is a “reserve capacity” benefit in that an expanded network is more reliable in case of service interruption and hence the amount of reserve generation capacity needed in the system for given level of reliability falls. The benefit from this “reserve capacity” cost saving effect is an increasing function of the additional capacity and can be represented by the total benefit function  $B_K(Q)$ . Capacity increases in electricity transmission networks may improve reliability so that marginal benefits of some users are only experienced under some states of the world, i.e. when capacity utilization is high or there is unusual congestion. In such cases marginal benefit is based on the expectation that these periods of congestion cost are reduced when capacity is added. Thus the marginal benefit to reserve capacity might be valued based on the expectation that the reserve capacity is actually needed to avoid service interruption.

Second there is a “generation cost” benefit because an enhanced transmission network is better able to connect the more efficient (lower cost) generators with major users. The resulting saving in generation cost increases at a decreasing rate with the expansion of the transmission network and gives rise to a total benefit function  $B_L(Q)$ , where  $L$  refers to the lower generation cost achievable with enhanced transmission capacity. The next section will show that both of these sources of cost savings are recognized in the literature as sources of benefit from transmission expansion and are used in the valuation of transmission projects.

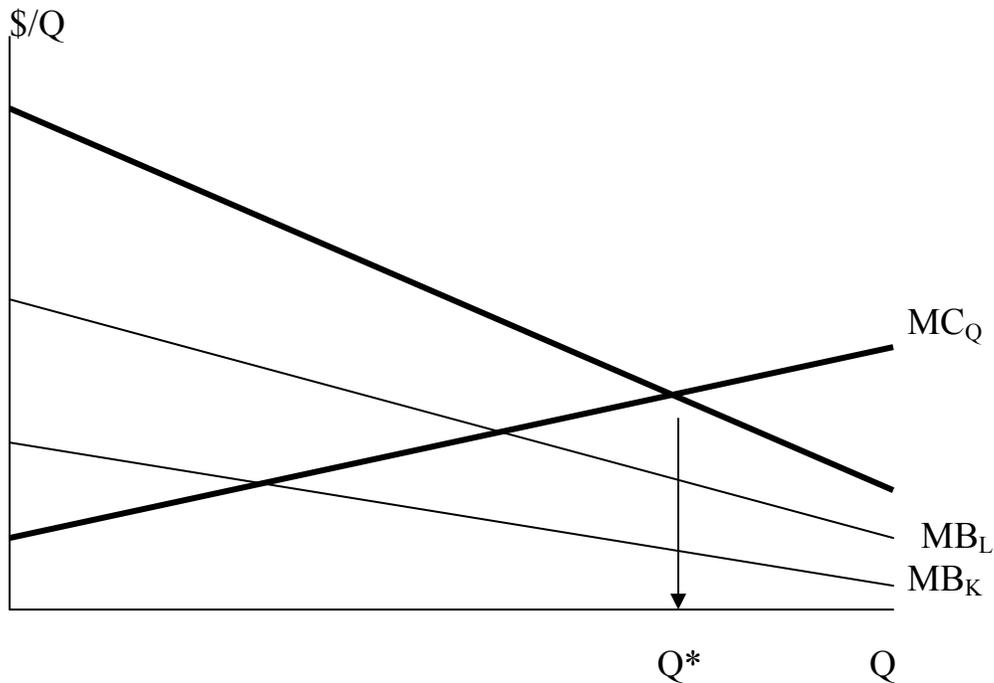
Optimal expansion of the network, noted as  $Q^*$ , is determined where marginal cost of adding an additional unit of capacity,  $MC_Q$ , is equal to marginal benefit of that capacity. In the example just described, this marginal benefit would be the sum of the marginal benefit from having additional reserve capacity plus the marginal benefit from having lower generation cost. or  $MB_K + MB_L$ . If capacity were expanded in this manner, the amount spent on adding capacity would be socially cost efficient in the sense discussed in Chapters 1 and 2 of this report.

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<sup>2</sup> Note that this example could be adapted to expansion of transportation capacity in any network but it adapted to the electric transmission case for purposes of this chapter.

Analytically, the solution that describes the benefit/cost criterion of maximizing net benefit, i.e. is illustrated in Figure 1 below where expansion of capacity is carried on up to the point where the sum of the marginal benefits of expanded capacity from both classes of beneficiaries ( $MB_K + MB_L$ ) just equals the marginal cost

Figure 7.1  
Maximizing Net Benefit With Multiple Benefits

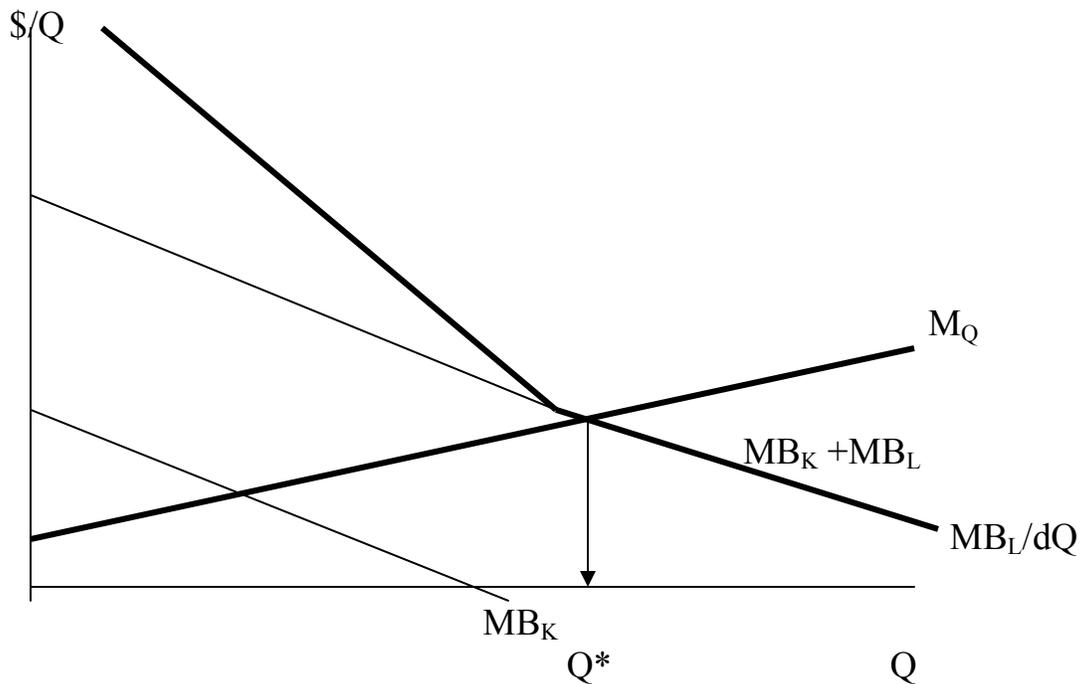


Even in this situation, which is analytically relatively simple, attributing the total cost of expanding capacity by  $Q^*$  units to beneficiaries K and L, is not trivial. If, as in the case shown above, the marginal benefit to both K and L is greater than zero, then cost can generally be attributed based on the ratio of marginal benefits or the ratio of average benefits. Use of marginal benefits – assuming they can be measured -- has an important virtue that is the user charge that would cause each of the users to support adding the socially efficient amount of extra capacity.

It is, however, possible that the optimal increase in capacity,  $Q^*$ , may be so large that it goes beyond the point where the marginal benefit of having additional capacity falls to zero for one of the users. This case is illustrated in Figure 2, where the marginal “reserve capacity benefit” is 0 at point  $Q^*$ . In this instance, application of the marginal benefit principle would result in all cost being attributed only to those beneficiaries who derive a marginal benefit from capacity expansion, which in this case would be those who value the reduction in generation cost.

Figure 7.2

Maximizing Net Benefit With Multiple Benefits:  
Marginal Benefit of one User Driven to Zero



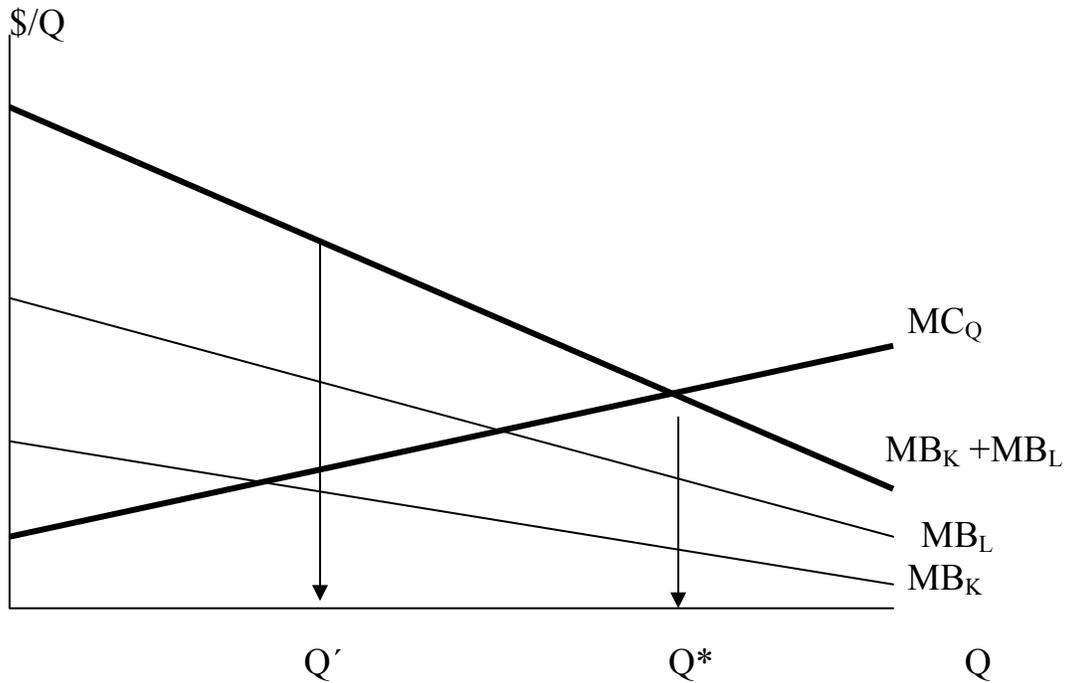
Note that, under these circumstances, use of marginal benefit as the basis for cost attribution would result in all cost being attributed to L. While this may seem counterintuitive, it is certainly true at the margin that charging back a portion of cost to user K would not be efficient because it would lower willingness to expand capacity for reserve capacity purposes when the marginal cost of that extra capacity is zero. Another way of describing this result is to say that the portion of cost attributable to purpose K should be based on the difference between total marginal cost and marginal benefit to purpose L. This difference, of course, is less than or equal to zero resulting in no attribution of cost to purpose K.

If owners or operators of transmission networks face incentives to add capacity over time that is based on marginal benefits to users, particularly when those incentives are in the form of user fees, there is reason to believe, *a priori*, that network capacity will approach  $Q^*$  and the analysis presented above should apply. In the United States, however, there is general agreement that electric transmission facilities are not provided based on such market or quasi-market incentive mechanisms so that proposed investments in transmission capacity provide for levels of  $Q$  that are generally believed to be less than optimal. This situation is illustrated in Figure 7.3 where the actual capacity --  $Q$  is shown as being at  $Q' < Q^*$ . It is widely believed that this situation of less than optimal investment in capacity holds for most electricity

transmission networks in the U.S. because cost-based pricing and incentives are the exception rather than the rule.

Figure 7.3

Cost Analysis With Multiple Benefits:  
Project Capacity Less than Optimal



The important implication of the case shown above is that given current financial incentives for electricity providers to limit redundancy in electricity transmission networks, the expectation is that, investments that expand current capacity are likely to represent situations in which the starting point is suboptimal investment  $Q'$ .

At  $Q'$  in Figure 7.3,  $[MB_K + MB_L] > MC_{Q'}$ . In this case, attribution of project cost to purposes K and L based on their marginal or average benefit may appear completely arbitrary. However, at least one of criteria for cost attribution, which is based on rationing access to the scarce facility, suggests that users be charged based on marginal benefit. If this pricing scheme were to be implemented, it might result in large surpluses of revenue over cost because the marginal benefit of the extra capacity (which would be the basis for the user charge) exceeds the marginal cost, but the alternative would be for use to be rationed by queues or other non-price mechanisms.

A key point to be noted is that in the above case, it would already be socially efficient to expand existing capacity even if there were no homeland security reason for doing so. Thus, even if all of the additional cost of hardening the electrical transmission infrastructure were to be attributed to homeland security, which the analysis above suggests is *not* appropriate, the benefits of such investment would be likely to exceed the cost.

## 7.2 Reasons for Suboptimal Investments in Capacity

The primary reason for this expectation is that it is very difficult under current market and institutional arrangements to provide appropriate price incentives for transmission investment even in the absence of consideration of issues of network reliability and resilience.<sup>3</sup> The pricing problem arises because demand for a particular link in the transmission network varies continuously over time and depends on decisions of generating plants and distribution networks whose costs and demands change substantially over time. Given that the pricing process producing revenues for transmission companies during “quiet” periods is both complex and very dynamic, it is very difficult to even compute the revenue consequences for these companies if additional capacity is installed that improves reliability and resilience.

As noted above, the generation cost benefit arises because the transmission network connects diverse generators of electric power with local distribution systems. There are substantial differences in cost of power production among generators, based on size, age, and type of fuel. Demand conditions vary continuously across distribution systems. Thus ignoring issues of reliability and resiliency, transmission networks do not merely connect producers and consumers, they facilitate efficient production and consumption of electric power. Therefore, a potential expansion of the transmission network – whether prompted by concerns about reliance and resiliency, or by other considerations -- can produce benefits by minimizing the delivered energy by enabling high cost production to replace low cost production. This substitution of high for low cost energy is accomplished by allowing low cost generators to run at capacity while holding high cost generators in reserve, or shutting them down entirely. Such substitution is particularly valuable in areas that have highly variable demand and when the relative costs of different generators vary substantially. Note that generating costs can vary because of technological differences but also because of differences in the cost of energy. Hydro-electric power costs vary with water flow, natural gas prices are volatile, and some renewable energy costs, particularly wind power, vary substantially.

The incentive problem faced by investments that improve transmission capabilities is that it is difficult for transmission companies to capture in terms of revenue a significant portion of the cost savings that they make possible. Therefore, it is reasonable to expect that investment in transmission capacity may not be sufficient to minimize the cost of generating electricity for end users at any time and that some measure of additional capacity would generate benefits in terms of reduced cost of production.

In addition to lowering the cost of producing power, the transmission network also lowers the cost of producing reliability and resiliency for reasons independent of homeland security. The risk of outages can be diversified away across power pools created by transmission

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<sup>3</sup> See, for example, Paul L. Joskow (1997).

networks. Furthermore, just as the cost of fully-used generation capacity varies substantially, the cost of reserve capacity also varies. Transmission networks allow the substitution of low cost reserve capacity for high cost reserve capacity and hence lower the cost of maintaining a given level of reliability and resiliency.

A very important economic point arises here. Transmission network expansion lowers the cost of producing reliability and resiliency for distributors who pool outage risk across a large network and gain access to low cost producers of emergency power. However it is very difficult for transmission networks to capture a revenue stream to compensate for the cost of these expansions. First, there is a “*time inconsistency problem*” because the expansion, once installed, cannot charge premium rates during power interruptions because the politics of disaster recovery does not permit such premium charges in recovery periods. Second, there is an “*agency problem*” because the distribution networks with which the transmission companies contract, only experience a fraction of the losses from power interruption. Most of these losses accrue to end users who cannot contract directly with transmission networks. The combination of the time inconsistency and agency problems in providing electric transmission networks with proper incentives to install capacity to deal with failure and interruption leaves the strong economic presumption that these investments will not be made given the current regulatory environment.

### **7.3 Application to Benefit/Cost Analysis of Electric Transmission Network Improvements**

Consistent with the scenario shown in Figure 7.3, a recent analysis indicates that the benefits of proposed enhancements to the electric transmission network, in the form of cost savings for electricity actually generated and capacity held in reserve, are large compared to the costs. Furthermore the analysis indicates that net benefits associated with further expansion of the transmission network, beyond those currently contemplated or judged likely to be completed, would also generate positive net benefits.

Consider first the relation between planned transmission network investment and net benefits due to savings in generation cost due to replacement of high with low cost power sources. Ofori-Atta, et. al.<sup>4</sup> simulated the U.S. power production costs under different levels of transmission investment. They first estimated the cost of additional transmission capacity investment, the  $C(Q)$  function, and the benefit in terms of reduced power generation cost, i.e. the benefit function  $B_L(Q)$ , from investment in transmission expansion. Then they measured the net benefit from transmission investment,  $[B_L(Q) - C(Q)]$ , as the difference of savings in generating cost less the cost of transmission expansion. The calculations were performed over the 2003-2030 using a proprietary simulation model that claims to simulate transmission loads between generators and distributors for the entire U.S.

The analysis indicated that the present value of generation cost savings of \$12.6 billion in 2003 dollars by itself already exceeded the present value of the costs of \$8.2 billion that would

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<sup>4</sup> Kojo Ofori-Atta, et. al., *op. cit.*

be needed to add the additional capacity that would better connect low-cost providers to the rest of transmission network.<sup>5</sup>

The analysis goes on to note that there would be additional economic benefits from the simulated \$8.2 billion increase in capacity. Another source of benefit from electric transmission investment is from improved reliability and resiliency of the network which was represented by the  $B_K(Q)$  function in the previous discussion. As noted above, both problems of time inconsistency and agency in the incentives facing transmission providers lead to the a priori conclusion that there will be serious underinvestment in transmission networks to enhance reliability and lower the cost of whatever level of reliability is currently provided. There are two types of benefits in terms of cost savings that are generated by transmission network enhancements. First are the benefits from reserve sharing among distribution companies due to risk pooling and use of lower cost reserve power sources. Second are the benefits due to reduced frequency and severity of lost load – i.e. benefits in the form of a reduction in the value of lost load. These will be discussed in turn.

Again relying on the illustrative national net present value benefits over the 2003-2030 period from Ofori-Atta, et. al.,<sup>6</sup> a 1% reduction in the required reserve capacity, from 13% to 12%, due to the \$8.2 billion incremental expansion in transmission investment, would add an additional benefit of \$5.3 billion so that total benefits from expanding the transmission investment rises from \$12.6 billion to \$17.9 billion. In other words, the benefits from savings in reserve capacity when transmission networks expand are about half as large as for savings in lowering the generating costs.

Yet a further benefit from the added capacity would result from reducing the expected value of lost load. Estimating this benefit requires estimates of the value of lost load, “VLL,” to customers and on changes in the frequency or probability of transmission-related outages, “TROs”. Ofori-Atta et. al. report that, between 1999 and 2003 TROs averaged 2,159 GWh per year, or about 0.6 percent of U.S. retail sales. They estimate VLL for these TROs by multiplying the retail price of the power lost during outages by a loss factor that varies among residential, commercial, industrial, and other users. The loss factor is 54 for residential and increase to 119 for industrial. These are rough and ready estimates of loss ratios that do not vary with the timing or duration of the outage. The next step was to estimate the reduction in TROs if the added transmission investment of NPV \$8.2 billion were made over the 2003-2030 period and to translate this into a benefit measure as VLL fell with reduced TROs. The estimated VLL benefit from the NPV \$8.2 billion expansion was estimated to be \$50 billion in 2003\$. This calculation suggests that the biggest component of benefit from electric transmission network capacity expansion is VLL and yet this source of benefit is not reflected in a comparable revenue stream that provides incentives for transmission network expansion!

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<sup>5</sup> These figures are in addition to billions in network expansion merely designed to serve new generating capacity coming on line in the next 25 years. The NPV of \$8.2 billion in electric transmission investment would produce \$12.6 billion in NPV of gross benefits yielding a net benefit of \$4.4 billion

<sup>6</sup> Kojo Ofori-Atta, et. al., *op. cit.*

These estimates can be each be related to in terms of the previous figures. Consider three sources of marginal benefit rather than the two shown on the figures for simplicity. One is benefits due to lower generating cost, which we have previously designated as  $MB_L$ . The second, which has been estimated to be about half as large, is due to lower the cost of reserves to enhance reliability and promote recovery. Lastly, a third source of benefit, which is three times as large as the other two combined, arises from reducing the value of lost load (VLL) as TROs fall due to enhanced network reliability and resiliency. What the analysis makes clear is that the most important determinant of marginal benefit from transmission network expansion, the marginal benefit curve in the figure that should be dominant in determining optimal network size, is generally ignored when planning for transmission network expansion. The source of inefficiency in planning for capacity expansion is both because benefits are difficult to quantify and because time inconsistency and agency problems make difficult to attach a revenue stream of funding to the benefits from VLL to customers.

Benefits from enhancing homeland security could be viewed either as adding yet another source of marginal benefit to those discussed above, or perhaps as increasing the potential for TROs and thereby raising the value still further of capacity investments that reduce the value of lost load. The important point, which has been raised earlier, is that when costs of adding capacity to satisfy homeland security are evaluated using the framework in Figure 7.3, the likelihood that current and planned expansion of networks are amply justified by marginal benefits *other than* homeland security issues, means that only a portion, and perhaps even none, of the costs of expansion to satisfy homeland security concerns should be counted as costs of homeland security. The reason is that the cost of these expansions is likely less than marginal benefit from sources other than greater homeland security. Indeed, the current debate regarding hardening electric transmission networks and adding reserve capacity to transmit may be useful in prompting expansion that are already economically justified by benefits in the form of lower generation cost, lower cost of reserve capacity, and lower VLL due to less TRO experienced by customers even in the absence of homeland security issues. Under these circumstances, it would be incorrect to attribute all or even a substantial fraction of the costs of improving reliability and resiliency of electric transmission networks to homeland security requirements.<sup>7</sup>

#### **7.4 Measuring the Costs and Impacts of Service Outages**

Perhaps in response to the significant number of serious electric power outages in 1999 and 2003 as well as the promulgation of standards by the North American Electric Reliability Council (NERC) in 1997, recently there has been significant attention to measuring the costs of service outages, particularly to those related to natural disaster events. Of course, the costs of service outages avoided by improvements in the transmission network are actually benefits in terms of a benefit/cost analysis of homeland security efforts. However, this analysis is important to measuring cost of homeland security efforts because, as previous sections of this chapter have argued, the costs of transmission improvements should not be attributed to homeland security efforts if they can be justified by benefits to other types of damage avoided, particularly damage arising when disaster strikes.

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<sup>7</sup> A similar conclusion to this analysis has been reached by Lave, Apt, and Morgan (2005).

The literature on impacts of disasters events that damage the electric transmission network has been reviewed recently in an edited volume by Yokuyama and Chang.<sup>8</sup> Serious electrical outages give rise to effects that multiply through the interindustry structure of a regional economy. Ultimately the sensitivity of firms in a particular industry to outages depends as much as the electric intensity of their suppliers as of their own production. Firms whose suppliers need electric power as a major, essential input can be very sensitive to interruptions. Fortunately these indirect sources of sensitivity are easily observed using regional input-output models where the local interindustry structure is revealed.

Two features of the disaster recovery period make it difficult to measure the impacts of an electric power disruption. First, whatever electric capacity remains intact tends to be allocated by non-market processes rather than by price. Second, inflows of transfer payments from insurance and government tend to sustain consumption demand even if earnings fall but the demand is distorted toward reconstruction activities. Rose, et al. attempted to model this process by combining a regional input-output model with an input-output model that allocated scarce energy inputs during the post disaster experience.<sup>9</sup> Unfortunately, there is no way to produce statistical estimates of the precision with which such models work.

While the probability of failure or outage in electric supply is fairly well understood in the literature, the second determinant of loss, resilience, is less well defined. Resilience consists of robustness, the extent of failure in the presence of an adverse event, and rapidity of restoration. The transmission system may be hardened to promote robustness but restoration requires personal, equipment, supplies and planning. In order to determine the cost of improvements in resilience, it is necessary to be able to model the relation between inputs and robustness and restoration time. Clearly the challenge in measuring the cost of resilience is the development of an optimal plan for using inputs. At this point, the models necessary to construct such optimal plans do not seem apparent.<sup>10</sup> Of course, once constructed, the costs of such optimal plans for resilience would have to be partitioned among beneficiaries and not just attributed to homeland security as has been discussed in this chapter.<sup>11</sup> Perhaps the greatest challenge to such optimal planning models is determining the actual VLL for different users but it is also true that modeling the relation between costs of labor, equipment, and materials and outputs of resilience is also a challenge at this time.

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<sup>8</sup> Yasuhide Okuyama and Stephanie E. Chang, (2004).

<sup>9</sup> Adam Rose, et. al., (1997).

<sup>10</sup> For example see the general discussion in Masanobu Shinozuka and Stephanie E. Chang, (2004).

<sup>11</sup> For an illustration of a general attempt to apply benefit/cost analysis to electric distribution disruption planning see, Yoshiharu Shumuta, (2004).

## General References

Boardman, Anthony E., David H Greenberg, Aidan R. Vining, David L Weimer, (2002), *Cost-Benefit Analysis: Concepts and Practice*, (New Jersey: Prentice Hall).

Brookings Institution Project on Homeland Security, (2002), *Protecting the American Homeland: Chapter 6 Principles for Providing and Financing Homeland Security*, (May), <http://www.heritage.org/Research/HomelandDefense/em833.cfm>

Bruck, Tilman, (2004), "An Economic Analysis of Security Policies," Households in Conflict Network Working Paper 06, (November).

Congressional Research Service, (2004), "Government Activities to Protect the Electric Grid," order code RS21958, (February 4).

Congressional Research Service, (2002), "The Economic Effects of 9-11: A Retrospective Assessment," order code RL31617, (September 27).

De Rugy, Veronique, (2005), "What Does Homeland Security Spending Buy?" AEI Working Paper #107, (April 1).

Government Accountability Office, (2004), "Homeland Security: Communication Protocols and Risk Communication Principles Can Assist in Refining the Advisory System," GAO-04-682, (June).

Hoibjn, Bart, (2002), "What will Homeland Security Cost?" Federal Reserve Bank of New York Economic Policy Review, (November), 8(2), pp12-33.

Hummels, David, (2001), "Time as a Trade Barrier," Global Trade Analysis Project Working Paper 17, Purdue University.

Klick, J., and Alexander Tabarrok, (2005) "Using Terror Alert Levels to Estimate the Effect of Police on Crime," *Journal of Law and Economics*, (April) 48, pp 267-279.

Kokoski, M. and Smith, V. K., "A General Equilibrium Analysis of Partial Equilibrium Welfare Measures: The Case of Climate Change.

Kunreuther, Howard, Geoffrey Heal, and Peter Orszag, (2002), "Interdependent Security: Implications for Homeland Security Policy and Other Areas," Brookings Institution, Policy Brief #108.

Kunreuther, Howard, Erwann Michel-Kerjan, (2003), "Assessing, Managing and Financing Extreme Events: Dealing with Terrorism," NBER working paper no 10179, (December).

Lakdawalla, Darius and Zanjani, George H. (2002), "Insurance, Self-Protection, and the Economics of Terrorism," NBER Working Paper No. W9215, (September).

Lave, L., Apt, J., and Morgan, G., "Worst Case Electricity Scenarios: The Benefits and Costs of Prevention," presented at the Aug. 2005 CREATE Symposium on the Economics of Terrorism, University of Southern California.

Lipton, E. (2005, June 5). Report Presses Easy Ways to Fix Airline Security. *The New York Times*. Retrieved June 6, 2005, from <http://www.nytimes.com/2005/06/05/national/05secure.html?#>

Loy, James M., Robert G. Ross, (2002), "Global Trade: America's Achilles' Heel" *Journal of Homeland Security*, (February).  
(<http://www.homelandsecurity.org/journal/articles/displayArticle.asp?article=33>)

Major, J.A. (2002). "Advanced Techniques for Modeling Terrorism Risk," *Technical Report*. Guy Carpenter and Company, Inc.

Office of Management and Budget, (2003). *Draft 2003 Report to Congress on the Costs and Benefits of Federal Regulation*, Part VII.

OECD Maritime Transport Committee, (2003), "Security in Maritime Transport: Risk Factors and Economic Impact," (July).  
<http://www.oecd.org/dataoecd/19/61/18521672.pdf>

Portney, Paul, et. al. (1994). "Symposia: Contingent Valuation." *Journal of Economic Perspectives*, (Autumn).

Rose, A., "Analyzing Terrorist Threats to the Economy: A Computable General Equilibrium Approach," in P. Gordon, J. Moore, and H. Richardson (eds.) *Economic Costs and Consequences of a Terrorist Attack*, Cheltenham, UK: Edward Elgar Publishing Co., forthcoming.

Rosenzweig, Paul, (2002), "The Chemical Security Act: Using Terrorism as an Excuse to Criminalize Productive Economic Activity," Heritage Foundation website, Executive Memorandum #833, (September 12).  
<http://www.heritage.org/Research/HomelandDefense/em833.cfm>

Shaw, D. (1992). Searching for the opportunity cost of an individual's time. *Land Economics*, 68(1), 107 - 115.

Shoven, J. and Whalley, J. (1992), *Applying General Equilibrium*. (Cambridge, U.K., Cambridge University Press).

Smith, V. Kerry (1985), "Supply Uncertainty, Option Price, and Indirect Benefit Estimation," *Land Economics*, 61 (August): 303-307.

Smith, V. Kerry, Daniel G. Hallstrom, (2004), “Designing Benefit-Cost Analysis for Homeland Security Policies” (August, 11<sup>th</sup>).

Smith, V. Kerry, George Van Houtven, and Subhrendu K Pattanayak (2002), “Benefit Transfer via Preference Calibration: ‘Prudential Algebra’ for Policy,” *Land Economics*, 78(1): 132-152.

Trajtenberg, Manuel (2003), “Defense R&D Policy in the Anti-Terrorist Era,” NBER Working Paper No. 9725, (May).

U.S. Department of Transportation. (1997). Departmental Guidance for the Valuation of Travel Time in Economic Analysis. *Office of the Secretary of Transportation, U.S. Department of Transportation*. Retrieved June 10, 2005, from <http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf>

U.S. Department of Transportation. (2003). Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis. *Office of the Secretary of Transportation, U.S. Department of Transportation*. Retrieved June 10, 2005, from [http://ostpxweb.dot.gov/policy/Data/VOTrevision1\\_2-11-03.pdf](http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf)

### References for San Francisco Orange-Alert Analysis

Airports Council International. (2005). 2004 North America Traffic Report: Total Passengers. Retrieved August 9, 2005, from <http://www.aci-na.org/asp/traffic.asp?art=215>.

Blumenthal, R.G., (2003, February 17). Will the market turn colors over code-orange alert? *Barron's*, 83 (7), 12.

Boardman, A.E., Greenberg, D.H., Vining, A.R., & Weimer, D.L. (2001). *Cost-benefit analysis: Concepts and practice* (2<sup>nd</sup> ed.). Upper Saddle River, NJ: Prentice Hall, 399.

Bureau of Justice Statistics. (2003). Law Enforcement Management and Administrative Statistics Database. Retrieved August 13, 2003, from <http://bjsdata.ojp.usdoj.gov/dataonline/Search/Law/Local/RunLawLocalSelectedTables.cfm>.

Department of Homeland Security. (2005). Protected Critical Infrastructure Information (PCII) Program: Frequently Asked Questions For Submitters. Retrieved May 12, 2005, from <http://www.dhs.gov/dhspublic/display?theme=92&content=3756>.

Ensor, D., King, J., MacVicar, S., Starr, B., & Frieden, T. (2003, May 22). Threat level to remain at ‘orange’ through holiday: Security stepped up around nation amid warnings. *CNN.com*. Retrieved May 15, 2005, from <http://www.cnn.com/2003/US/05/22/terror.main/>.

Federal Bureau of Investigation. (2004). Uniform Crime Report: 2003. Retrieved May 8, 2005, from [http://www.fbi.gov/ucr/cius\\_03/xl/03tbl06.xls](http://www.fbi.gov/ucr/cius_03/xl/03tbl06.xls).

Feldmann, L. (2003, June 20). Terror alerts run risk of crying wolf: The public is largely indifferent to color-code warnings as attacks have not materialized. *The Christian Science Monitor*. Retrieved May 15, 2005, from <http://www.csmonitor.com/2003/0603/p03s01-ussc.html>.

Fimrite, P. and Goodyear, C. (2003, March 20). Bridge incident attests to heightened security level. *SFGate.com*. Retrieved August 9, 2005, from <http://sfgate.com/cgi-bin/article.cgi?f=/c/a/2003/03/20/MN248423.DTL>.

Government Accountability Office. (2002). Impact of terrorist attacks on the world trade center. GAO-02-700R. Washington, D.C. Retrieved April 30, 2005, from <http://www.gao.gov/new.items/d02700r.pdf>.

Government Accountability Office. (2004). Homeland security: Communication protocols and risk communication principles can assist in refining the advisory system. GAO-04-682. Washington, D.C. Retrieved April 12, 2005, from <http://www.gao.gov/new.items/d04682.pdf>.

Harris, R. (2003, July). What price security? Companies have been slow to make costly antiterrorism investments. But their low-key moves may be making them less vulnerable. *CFO: Magazine for Senior Financial Executives*. Retrieved May 15, 2005, from [http://www.findarticles.com/p/articles/mi\\_m3870/is\\_9\\_19/ai\\_105460796](http://www.findarticles.com/p/articles/mi_m3870/is_9_19/ai_105460796).

ICF Consulting. (2003). Measuring the economic costs of terrorist attacks. *ICF Perspectives*. Retrieved May 5, 2005, from [http://www.icfconsulting.com/Markets/Homeland-Security/doc\\_files/costs\\_terrorist.pdf](http://www.icfconsulting.com/Markets/Homeland-Security/doc_files/costs_terrorist.pdf).

Jordan, L.J. (2005, May 10). Ridge: Homeland cautious on alert level. *SFGate.com*. Retrieved May 14, 2005, from <http://sfgate.com/cgi-bin/article.cgi?file=/n/a/2005/05/10/national/w140948D25.DTL>.

Jordan, L.J. (2005, May 12). D.C. scare puts alert system to the test. *SFGate.com*. Retrieved May 14, 2005, from <http://sfgate.com/cgi-bin/article.cgi?file=/n/a/2005/05/12/national/w053549D54.DTL>.

Kee, H.K., Burrell, C., Koopman, J., Cabanatuan, M., & Gledhill, L. (2003, February 8). U.S. on 'high' terror alert: Officials fear al Qaeda will strike at soft targets. *SFGate.com*. Retrieved May 14, 2005, from <http://sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2003/02/08/MN226129.DTL>

King, J., Ensor, D., & Frieden, T. (2003, May 20). United States goes on orange alert: Officials 'chatter' hints U.S. attack might be planned. *CNN.com*. Retrieved May 13, 2005, from <http://www.cnn.com/2003/US/05/20/terror.main/>.

Klick, J. & Tabarrok, A. (2005). Using terror alert levels to estimate the effect of police on crime. *Journal of Law and Economics*, XLVIII, 267 – 279.

New York City Partnership and Chamber of Commerce. (2001). Working together to accelerate New York's recovery: Economic impact analysis of the September 11<sup>th</sup> attack on New York City. Retrieved May 12, 2005, from <http://www.nycp.org/reports/ImpactStudy.pdf>.

Office of Management and Budget. (2003). *2003 Report to Congress on Combating Terrorism*. Retrieved May 11, 2005, from [http://www.whitehouse.gov/omb/inforeg/2003\\_combat\\_terr.pdf](http://www.whitehouse.gov/omb/inforeg/2003_combat_terr.pdf).

Posner, R.A. (2004). *Catastrophe: Risk and response*. New York: Oxford University Press.

Reese, S. (2005). "Homeland Security Advisory System: Possible issues for congressional oversight." Congressional Research Service. Retrieved April 13, 2005, from <http://www.fas.org/sgp/crs/RL32023.pdf>

Schneider, M. (2003, March 12). Shorter lines at Disney mean lower attendance: Park faces further crowd dips. *The Miami Herald*. Retrieved May 15, 2005, from <http://www.miami.com/mld/miamiherald/news/state/5369419.htm>

Security boosted in orange alert. (2003). *Airports*, 20(51).

Sostek, A. (2003, August). Orange crush: The confusion and cost of complying with national terror alerts are driving cities to question the whole system. *Governing Magazine*. Retrieved April 13, 2005, from <http://www.governing.com/archieve/2003/aug/security.txt>

Sunstein, C. (2002). *Risk and reason: Safety, law, and the environment*. New York: Cambridge University Press.

Sunstein, C. (2003). Terrorism and probability neglect. *Journal of Risk and Uncertainty*, 26(2).

UCLA International Institute. (2003). RAND tries to model risks of terrorist attacks. Retrieved May 13, 2005, from <http://www.international.ucla.edu/article.asp?parentid=3713>.

U.S. Census Bureau. (2005). Annual Estimates of the Population for Counties: April 1, 2000 to July 1, 2004. Retrieved May 15, 2005, from <http://www.census.gov/popest/cities/tables/SUB-EST2004-04-06.xls>

U.S. Conference of Mayors. (2003). Survey on cities' direct homeland security cost increases related to war/high alert. Retrieved April 14, 2005, from [http://usmayors.org/uscm/news/press\\_releases/documents/survey\\_032703.pdf](http://usmayors.org/uscm/news/press_releases/documents/survey_032703.pdf).

U.S. Department of Transportation. (2003). Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis. *Office of the Secretary of Transportation, U.S. Department of Transportation*. Retrieved June 10, 2005, from [http://ostpxweb.dot.gov/policy/Data/VOTrevision1\\_2-11-03.pdf](http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf)

U.S. President. (2002). Directive. Directive on the Homeland Security Advisory System, Homeland Security Presidential Directive 3. *Weekly Compilation of Presidential Documents* 38, no. 11 (18 March): 394 – 397.

Viscusi, W.K., and Aldy, J.E. (2003). The value of a statistical life: A critical review of market estimates throughout the world. *National Bureau of Economic Research*.

White House. (2003). National Strategy for the Physical Protection of Critical Infrastructures and Key Assets. Retrieved May 9, 2005, from [http://www.dhs.gov/interweb/assetlibrary/Physical\\_Strategy.pdf](http://www.dhs.gov/interweb/assetlibrary/Physical_Strategy.pdf).

## References for Decreasing Vulnerability of the Transportation Systems: The Case of the Electric Transmission Network

Kojo Ofori-Atta, Elliot Roseman, Bansari Saha, Scott Stuart, Marc Lipschultz and Jonathan Smidt, "Profiting from Transmission Investment: A Holistic, New Approach to Cost/Benefit Analysis," *Public Utilities Fortnightly*, (October =, 2004) pp. 72-77.

Joskow, Paul L., "Restructuring, Competition, and Regulatory Reform in U.S. Electricity Sector," *Journal of Economic Perspectives*, Vol 11, No 3, (Summer, 1997) pp. 119-138.

Okuyama, Y. and Chang, S.E. *Modeling Spatial and Economic Impacts of Disasters*, (Springer-Verlag: New York) 2004.

Rose, A., Benavides, J., Chang, S., Szczesniak, P., and Lim, D., "The Regional Economic Impact of an Earthquake: Direct and Indirect Effects of Electricity Lifeline Disruptions," *Journal of Regional Science*, (1997) Vol. 37, pp. 437-458.

Shinozuka, M. Chang, S.E., "Evaluating the Disaster Resiliency of Power Networks and Grids," in Yasuhide Okuyama and Stephanie E. Chang, *Modeling Spatial and Economic Impacts of Disasters*, (Springer-Verlag: New York) 2004, pp. 289-310.

Yoshiharu S, Benefit Cost Analysis for Renewal Planning of Existing Electric Power Equipment, in Yasuhide Okuyama and Stephanie E. Chang, *Modeling Spatial and Economic Impacts of Disasters*, (Springer-Verlag: New York) 2004, pp. 257-288.

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