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## Estimating the Economic Consequences of Terrorist Disruptions in the National Capital Region: An Application of Input-Output Analysis

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# Estimating the Economic Consequences of Terrorist Disruptions in the National Capital Region: An Application of Input-Output Analysis\*

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## Abstract

This paper explores and demonstrates an innovative application of an input-output model for the assessment of the economic consequences of hypothetical disruption events. Such events in a region are first simulated and their affected areas estimated using a GIS-based geo-spatial simulation approach. Then, the consequences of the simulated events on the regional economy are estimated and disaggregated by industry and sub-region. The research is important because it develops a new simulation and input-output model approach to regional and national security analysis that offers promising results. Further, it provides a methodology for assessing the economic consequences of possible disruption events. Knowledge of economic impacts of disruptions is essential for determining and justifying appropriate protection and mitigation policies and measures.

**KEYWORDS:** critical infrastructure, economic impact, input-output analysis, National Capital Region

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## 1. Introduction

This paper presents a systematic method for estimating the economic consequences of terrorist disruptions on a functional economic region.<sup>1</sup> This methodology offers two important capabilities: (1) identifying opportunities to control for market or economic failure due to disruptions; and (2) disaggregation or allocation of the impact of the disruptions by sub-regions in a larger region, e.g., a metropolitan region, and by economic sector thus making it possible for costs, both of mitigation and reconstruction, to be allocated according to different probabilities or levels of geographic and sectoral exposure.

There are significant data availability and limitation issues facing such an undertaking. However, the goal of this research is to learn the extent to which an analysis of disruption induced economic effects can progress given these limitations and the specific data that will be needed to achieve a more definitive and robust modeling capability. Geographic area simulation modeling and an input-output analysis are used to illustrate the estimation the economic effects of disruptions. Two simulated disruption scenarios are presented below in an effort to demonstrate the methodology.

This paper is important because it is one of the first efforts to measure the potential economic impacts of a disruption at the functional economic region level in general and more specifically for the National Capital Region. Such estimates should greatly contribute to the development of a cost-benefit test or criterion for making decisions to undertake various and specific protection measures. As such, it would serve as a test to help prioritize various protection needs and measures and therefore to efficiently allocate resources to support protection measures.

The input-output approach used in this paper measures the economic effects. It does not measure such externality effects as loss of life, psychological effects, possible out-migration or relocation behavior or perpetuity effects, even though these effects may also have economic impacts.

The paper is organized in six parts including this Introduction. Part 2 and Part 3 describe the methodology and data used, respectively. Part 4 presents and illustrates the estimated economic costs for two disruption scenarios and in each case for different sectors and different sub-regions within the National Capital Region. Part 5 discusses other potential consequences of the disruption scenarios not estimated or measured by the input-output modeling approach. Part 6 presents conclusions and a discussion for needed future research.

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<sup>1</sup> A functional economic region is defined based on functional integration and economic structure and the extent of economic interdependence. A functional region is typically composed of areas that exhibit more interaction with one another than with outside areas. For an extended discussion of functional economic regions, please refer to Hoover (1971).

## 2. Methodology

Geographic area simulation and an input-output modeling are used to estimate the economic effects of potential disruption scenarios in the National Capital Region. However, the methodology could be applied to other sub-national areas.

### 2.1. Disruption simulation

In the disruption scenario simulations, a blast(s) or other interruption is assumed, which destroys the functionality of various infrastructure capacities in a region. These affected infrastructures may include, but are not limited to, road transportation routes, bridges, electricity network and substations, rail subway systems, long-haul and metropolitan area fiber network. This paper, however, does not intentionally distinguish one type of network from others in its analysis for two major considerations. First is that the infrastructure losses of networks are to a great extent interconnected. For example, an interruption in the power supply network will result in infrastructure losses in the subway systems and fiber networks. Second, by not distinguishing between different networks in the analysis, the details of various network interactions that are largely trivial are bypassed. Thus, this approach is intended to help policy-makers and planners focus on general regional infrastructure and economic impacts.

Two disruption scenarios in the National Capital Region serve as the examples for this analysis. The first is a collapse of the 14<sup>th</sup> Street Bridge and the other a failure of a major power plant<sup>2</sup> in the Region.

### 2.2. Geographic area simulation

Geographic area simulation is the primary method for determining the spatial parameters of infrastructure losses.<sup>3</sup> A routing frequency analysis is conducted before and after a particular disruption to calculate the impacts of the infrastructure losses. The routing frequency analysis uses a shortest path algorithm to calculate the frequency that a link is used in all combinations of shortest paths across the network. Areas that lose connectivity or accessibility are determined or estimated by calculating the routing frequency before and after the disruptions. The areas that lose a significant amount of connectivity from the disruptions are separated into a number of zones based upon their various impact magnitudes,

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<sup>2</sup> The analysis is based on data for a specific power plant, but is not acknowledged here because some of the information is potentially sensitive.

<sup>3</sup> The geographic area simulation in this paper was conducted by Dr. Sean Gorman, Dr. Laurie Schintler, Mr. Rajendra Kulkarni and associates through their patented methods. The authors graciously acknowledge their help and contribution.

such as 70%, 50%, 30%, and 10%. The advantage of the shortest path algorithm is that it is a rational assumption of traveler behavior. Travelers can use paths other than the shortest and find ways to bypass network bottlenecks, and government may intentionally alter non-shortest paths into more efficient routes. But extra travel distances and time have additional costs. In addition, new traffic bottlenecks would likely be created by other than shortest path traffic re-routing. The geographic parameters of the direct infrastructure losses in the region are used in the input-output analysis to calculate regional economic impacts.

### ***2.3. Input-output model***

Input-output (I-O) model and analysis was invented by Leontief (1941) who used it to analyze the interdependence of industrial sectors in a national economic system.<sup>4</sup> The Leontief I-O model, to a great extent, is a detailed accounting system of inter-industry activities within an economy. The basic I-O model is usually constructed from “product flow” data from one industry to another, in a specific geographic region, such as nation, state, county, or a metropolitan area. The fundamental information on product production and consumption, i.e., the exchange of goods between sectors, in an economic system can be developed and contained in an I-O transaction matrix. Leontief’s original work has been extended to incorporate interregional product flows, technological improvement, and various production methods (Hewings, 1985; Isard, 1960; Miernyk, 1965; Miller and Blair, 1985; Richardson, 1972). In addition to the desired and superior ability to describe and capture the entire economic system as a whole, recent economic data collection improvement by the U.S. Department of Census, Bureau of Economic Analysis, Bureau of Labor Statistics, and other governmental and private organizations, along with the availability of high-speed computers, make the I-O model one of the most important, popular and accurate methods for measuring the economic impacts on a region due to exogenous or endogenous policy and economic changes (e.g., Isard and Langford, 1971; Stimson, Stough, and Roberts, 2002). Consequently, the I-O model has been successfully applied in economic loss/impact estimation in electric power outage (Rose et al., 1997), hypothetical earthquakes (Okuyama et al., 1999), and hurricanes (Lamb, 1995).<sup>5</sup>

The economic impact resulting from an exogenous shock, e.g., a terrorist attack, can be further decomposed into three major parts which are direct, indirect and induced effects. The direct impacts are the effects, in terms of jobs, regional product or earnings, in the industrial sectors which are immediately (directly) affected by the shock. The indirect impacts are the secondary cross-sector effects

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<sup>4</sup> Wassily Leontief was awarded the Nobel Prize for his work in 1973.

<sup>5</sup> For an extended discussion on the use of I-O model in economic impact analyses or other alternative methodologies, please refer to Okuyama and Chang (2004).

caused by inter-industry transaction of goods and services. The induced impact represents the secondary effects resulting from household spending by employees directly and indirectly through the industrial sectors within an economic system. The ratio of the total effects to the direct effect defines the multiplier. For example, if a terrorist disruption occurs in a region's transportation industry. The direct impact of the disruption is estimated in economic terms such as the gross product, employment, revenue or other indicators, in the transportation sector. The indirect impact is estimated by the economic losses in other industrial sectors caused by the transportation service interruption. The induced impact is the sum of economic losses due to reduced household income and consequently reduced household spending in the entire economy. In sum, in this paper, the I-O model is used in order to provide an estimate of the total impact of a disruption incident on a region's economy, compared against the baseline scenario, i.e., the expected performance of the economy before the disruption.

#### ***2.4. Model overview***

This paper adopts the I-O model developed at the School of Public Policy of George Mason University for the National Capital Region in the late 1990s (Campbell, 1995).<sup>6</sup> It is recognized that this I-O model is somewhat out of date and thus may not fully be able to capture structural changes that have occurred because of the ongoing and increasing concentration of information technology services in the past decade in the Region. However, the primary goal of this research is to demonstrate the capability of I-O analysis and illustrate its potential for estimating disruption induced economic effects on a regional economy. Furthermore, based on our understanding of data availability and other limitations that are identified in this research, the I-O model is being updated with a GIS-based simulation component to achieve a more definitive, accurate and robust modeling capability.

As discussed in the previous part of the paper, the affected area by a terrorist disruption is spatially divided into four zones (70%, 50%, 30%, and 10% zones) based on magnitude of impact. Direct economic effects for each affected zone are based on the infrastructure losses that occur as a consequence of disruption(s). A random selection of businesses in each zone is made according to each zone's magnitude of impact parameter. For example, in the 70% impact zone, 70% of all businesses are randomly chosen; 50% of all businesses within the 50% zone are randomly chosen, and so on. The random selection approach is adopted here is to primarily demonstrate the use of the model. However, a more realistic selection approach in the further studies would be based on aspects of

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<sup>6</sup> For a detailed discussion on the model, please refer to Campbell, 1996a and 1996b.

each firm's business continuity plans which have been developed and enhanced after the September 11<sup>th</sup> attack. It is further assumed that these businesses lose their entire business capacity and thus that all employment<sup>7</sup> and revenue are suspended during the impact period characterized by the absence of communications and physical accessibility.

The impact duration period, that is, the recovery period from the disruptions, is determined by expert opinion using reasonable impact assumptions. In practice this means that experts base their judgments on experience from disruptions that have occurred as a consequence of similar natural and non-natural disruptions. In so doing, each impact zone's direct economic consequences can be calculated by summing daily lost employment (in terms of working days) or lost sales revenue across the duration period.

The entire direct economic consequences for the National Capital Region are the sum of the direct economic impacts in the impact zones. Employment loss estimation obtained from the aforementioned zonal impact analysis serves as the primary measure of the direct economic consequences. The direct losses are then used in the I-O analysis to determine the total economic impact of the disruptions.<sup>8</sup>

### **3. Data**

#### ***3.1. About the region***

The U.S. National Capital Region is defined for this study as the Washington Statistical Metropolitan Area, less two counties in the State of West Virginia. As such it consists of the District of Columbia and 21 political jurisdictions in Virginia and Maryland (Table 1).

#### ***3.2. Business establishment inputs***

In the I-O model, direct economic effects resulting from the disruption incidents are used to estimate the indirect and induced economic consequences on the Region. As heretofore discussed, the total number of lost working days in all of the directly impacted areas can be calculated. In addition, according to the 2-digit Standard Industrial Classification (SIC)<sup>9</sup> information of each business entity

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<sup>7</sup> Lost employment here refers to the number of person-working-days lost due to an incident.

<sup>8</sup> It is recognized that the National Capital Region, as the seat of the US federal government, may result in national and international impacts if disruptions happen. These are not however estimated here.

<sup>9</sup> The input-output model used for this analysis was constructed in the late 1990s with sectors defined by SIC categories. A new input-output model needs to be constructed based on NAICS categories that would enable modeling impacts in terms of more contemporary structural (sectoral) economic parameters.

within the impacted areas, the lost employment is further disaggregated into its corresponding SIC categories. Next, these SIC-based employment data, that reflect working day losses, must be converted into annual employment losses as the I-O model estimates effects on an annual basis. Consequently, the SIC-based employment data are divided by total annual working days (250 days) in order to obtain annualized data for the impact sectors. Additionally, it is assumed that both disruption scenarios – involving the loss of the 14<sup>th</sup> Street Bridge or the failure of the power plant – occur in 2003. The reason for selecting 2003 for the analysis was to be able to accommodate available business establishment data. All of the information on business establishments in the Region is obtained from Arcview Business Analyst, 2003 Edition.

### ***3.3. Data and data collection issues***

Despite the usefulness of the I-O model of the Regional economy used to produce estimates for this paper, efforts to construct a current I-O model were compromised and slowed by limited data availability and controlled government data access. In the end, the data availability problem made it impossible to update the late 1990s model or to construct a new model in the time available for this study. Our request to state employment officials for access to unsuppressed employment and wages by industry data from the BEA for the period 1969-2003 made in June of 2005 was, with one exception, not granted. The adoption of the Confidentiality Information Protection and Statistical Efficiency (CIPSES) Act by the U.S. Government is, as we are told by officials at BEA and BLS, responsible for the delays and decision to decline our request for the data as government officials have attempted to develop an understanding of its reach. Unfortunately, it appears that the balance between protection and access has been missed or lost and that the future will bring greater restrictions to data access. This paper argues in favor of access to essential data on behalf of the advancement of necessary and security relevant research.

There are, however, alternatives for obtaining the data that are needed for constructing the inter-sectoral table of the model. One of these is to purchase one of the similar commercially available models. These models are relatively expensive and for the most part appear to use step down procedures beginning with national level data. Such models will not produce estimates that are as accurate as ones constructed from the bottom up with local data. The model used for this study, while out of date, is constructed from the bottom up and thus more accurate, according to specialists in the fields of regional economics/science (e.g., Hewings, 1985; Miernyk, 1965; Stimson, Stough, and Roberts, 2002). Another alternative is to use proprietary data sources to acquire the data elements needed that are not readily available through federal government sources. This will add some cost to

the construction of a bottom up model but would not be so high as to be prohibitive.

#### **4. Disruption Scenarios and Major Findings**

Two disruption scenarios, the failure of the 14<sup>th</sup> Street Bridge and of a power plant, are examined and their economic consequences in terms of the losses of employment, output, and income on the Region are estimated. In addition, the economic losses are further disaggregated by sectors or by geographic and political boundaries.

##### ***4.1. The 14<sup>th</sup> street bridge disruption scenario***

###### *4.1.1. Description of the simulation*

The 14<sup>th</sup> Street Bridge disruption scenario simulates a blast(s) that destroys the functionality of the two adjacent and parallel vehicular Bridges across the Potomac River, and also the infrastructures that use the Bridge as a right of way. This blast, however, does not affect the electricity supply network or rail Metro service across the Potomac. Specifically, the impacted infrastructures are the road transportation network, long-haul fiber network, and the metropolitan fiber network. The simulation identifies four areas or zones that lose a significant amount of connectivity from the blast.<sup>10</sup> The first four zones represent affected areas whose impact magnitude parameters are 70%, 50%, 30%, and 10% respectively. The duration period, that is, the recovery period, is determined under the conservative impact assumptions that it will take four business days to restore connectivity and accessibility in the 70% impact zone, three business days in the 50% zone, two business days in the 30% zone, and one business day in the 10% zone.

###### *4.1.2. Results*

Table 2 presents the estimated economic impacts on the National Capital Region. It is estimated that there will be 340,000 workdays lost.<sup>11</sup> Annually, there would be a total employment loss of 1,360 persons, including 920 direct and 440 indirect and induced job losses. The employment multiplier is 1.48, that is to say, any single job directly lost from a disruption incident, in this case the destruction of the 14<sup>th</sup> Street Bridge, will result in 1.48 annual job losses in the National Capital Region. Table 2 also presents the estimated output and income losses in the Region under the disruption scenario. It is estimated that the Region's annual total

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<sup>10</sup> Maps are classified by the Department of Homeland Security and are not shown here.

<sup>11</sup> The total number of working days lost, e.g., 340,000, is calculated as: 340,000=1360 (# of employees)\*250 (# of working days).

output and income will decrease by \$86.4 million and \$26.2 million respectively. The output multiplier is 1.78, while the income multiplier is 1.5.

Table 3 presents a sectoral breakdown of the estimated economic impacts resulting from the loss of the Bridge. The most heavily impacted part of the National Capital Region's economy is the service sector. It is estimated that, during the time the disruption occurs and its immediate aftermath and recovery, the Region would lose 880 jobs (annualized), \$39.5 million in output (annualized), and \$14.3 million (annualized) in income in the service sector.

In addition to the sectoral analysis, Table 3 shows that the other major regional economic indicators will be negatively impacted by the disruption incident as well. Total consumption will decline by over \$35 million, consumption of services by over \$22 million, state and local governmental expenditures by over \$7 million, and total personal income by more than \$35 million. The government expenditure figures above do not include the cost of potential risk reduction measures. Rather, they solely reflect governmental budgetary impact based on lost tax revenue.

Table 4 presents a sub-regional breakdown or distribution of the economic consequences in the National Capital Region. It is estimated that the Virginia side of the Region would suffer more than 50% of the economic consequences on all three economic indicator dimensions: employment, output and income. In addition, the District experiences more economic impacts than the Maryland side of the Region. For example, among the total of 1,360 lost jobs, the Virginia side would lose 835 jobs, the District 381, and the Maryland sub-regions 144. The disproportionately large and significant impacts on the Virginia side of the region are due in great part to the fact that the 14<sup>th</sup> Street Bridge is located on the border between the District and Virginia. As a result, the Maryland part of the Region, located several miles from the attack location, suffers the least economic losses.

## ***4.2. Power plant disruption scenario***

### *4.2.1. Description of the simulation*

In this scenario, a failure of the power plant and its associated substations and transmission lines is simulated. The plant uses both natural gas from pipelines and coal as fuel to produce electricity. Because of the dependence on two sources of fuel for energy production, a gas pipeline failure resulting from a disruption from a hypothetical blast results in the failure of the Plant and the loss of some transportation infrastructure (roads). In the simulation model, transmission lines, gas pipelines, and roads are removed and the aggregate connectivity loss is calculated in order to estimate the direct infrastructure impact and service losses.

Similar to the 14<sup>th</sup> Street Bridge scenario, the areas that lose a significant amount of connectivity from the blast are separated into five zones.<sup>12</sup> The first four zones represent affected areas with impact magnitude parameters of 70%, 50%, 30%, and 10% respectively. In addition to the connectivity loss there are also areas that are heavily stressed from the rerouting of power. These areas, the so-called fifth zone, with the highest levels of rerouting stress have a high probability of incurring service failure due to cascading effects as huge amounts of rerouted demand works its way through the remaining operating parts of the regional power grid. The fifth zone has subsumed the voltage rerouted from the failed areas and, if there is not enough available capacity to absorb the additional voltage, these power sources in turn fail. As a result, the fifth zone or the cascading zone is assumed to experience a 50% loss of service.

A random selection of businesses from each zone is carried out according to each zone's level of impact. The duration period, that is, the recovery period, is determined under an optimistic set of assumptions. It is assumed that it would take seven business days to restore connectivity and accessibility in the 70%, 50%, 30%, and 10% impact zones and would take one business day to restore service in the cascading zone.<sup>13</sup>

#### 4.2.2. Results

Table 2 presents the economic impact of the loss of the power plant on the National Capital Region economy under assumptions described above. This disruption is estimated to produce 3,250,000 days of lost work. On an annualized basis this means that there will be a total employment loss of 13,000 persons,<sup>14</sup> including 9,250 direct and 3,740 indirect and induced losses. The employment multiplier is 1.40, that is to say, any single job lost from a disruptive incident, in this case, the failure of the power plant, will result in a total of 1.40 job losses in the National Capital Region. Similarly, Table 2 also presents estimates of the output and income losses in the National Capital Region under the disruption scenario. It is estimated that the Region's annual total output and income will decrease by \$862.5 million and \$326.3 million, respectively. The output multiplier is 1.70, and the income multiplier is 1.43.

Table 3 presents a sectoral analysis of the economic impacts resulting from the loss of the power plant. It is evident that the most impacted sector in the National Capital Region is again the service sector. This occurs because the

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<sup>12</sup> Maps are classified by the Department of Homeland Security and are not shown here.

<sup>13</sup> The duration (recovery) periods in the impacted areas will depend on the nature of the attack/disruption, specific damaged facilities and/or equipment, and the availability of recovery crews.

<sup>14</sup> The total number of working days lost, e.g., 3,250,000, is calculated by:  $3,250,000 = 13,000 * 250$ .

Region's economy is a heavily service dependent economy with little employment in manufacturing (2-3%). It is estimated that, during the immediate aftermath and recovery period, the Region would lose 7,780 jobs, \$341.8 million in output, and \$195 million in income in its service sector. In addition to the sectoral analysis, Table 3 shows that major regional economic indicators will experience decreases from the disruptive incident as well: total consumption will decrease by over \$357 million, consumption of services by over \$209 million, state and local governmental expenditures by over \$68 million, and total personal income by over \$404 million.

Table 4 presents a jurisdictional breakdown of the economic consequences in the National Capital Region. Similar to the 14<sup>th</sup> Street Bridge scenario, the Virginia side of the Region still experiences the majority of the entire economic consequences of the failure of the power plant. This may be because the power plant, though located on the Maryland side of the region, serves large parts of the Virginia side of the Region. It also may be in part because more of the population of the region lives in the Virginia part of the region. As a result, the majority of the affected areas resulting from the failure of the power plant are in the Virginia part of the Region (Figure 2). The Maryland side of the region with this scenario is the second most impacted area. Of the total of 13,000 lost jobs in the Region, the Virginia side loses 7,934, the Maryland side 3,039, and the District 2,027. The increased impact on the Maryland side with this scenario can be explained by the fact that the power plant is located in Maryland.

## 5. Other Consequences

Despite the ability to estimate the total, indirect and induced economic consequences of disruptions and other events on the National Region using I-O analysis, this approach is not able, nor is it designed to estimate the costs of all possible detrimental consequences of a disruption. As a result, the economic consequences estimated using the I-O model measure only certain types of effects that are relevant when considering protection and/or mitigation measures. What is more, in some cases, factors that are not reflected in the I-O model alone, e.g., loss of life, may well provide powerful justification by themselves for implementing protection and mitigation measures.

Other detrimental results of a disruption may include, but are not limited to, loss of life, adverse psychological effects, the exodus or out-migration of residents and perpetuity effects. The economic consequences of the disruption scenarios developed in this paper do not include the economic effects of these types of effects.

Regarding the loss of life, in the first scenario, the removal of the 14<sup>th</sup> Street Bridge, some vehicles on the Bridge during the hypothetical blast would fall into the river and some of the occupants would likely die. Historical data

indicate that bridge collapses can cause significant casualties and injuries. For example, in 1967, the U.S. 35 Silver Bridge between Point Pleasant, WV, and Gallipolis, OH, collapsed, killing 46 people and injuring 9 when 31 of the 37 vehicles on the bridge fell into the Ohio River or onto the Ohio shore. Similarly, in 1987, the Schoharie Creek Bridge in the New York State collapsed. Five vehicles fell into the river, and ten occupants died. In light of these numbers and the fact that the 14<sup>th</sup> Street Bridge is one of the busiest traffic routes in the National Capital Region, death tolls resulting from the failure of the Bridge would likely be much higher unless the disruption occurred in the middle of the night. It is possible to predict the range of the death tolls by using the information of the number and the type of cars traveling over the Bridge, but this prediction is beyond the focus of this research which is intended to estimate the economic impact of a hypothetical disruption. In the second scenario, the blast destroying the gas pipelines supplying the power plant in densely population areas would also likely cause human injuries and loss of life.

In addition to the potential loss of life from disruptions like the scenarios presented above, there are also severe adverse psychological consequences. This is because the disruptions directly affect businesses' and consumers' perceptions toward the Region's or the nation's economy and security and therefore influence, if not pessimistically, their long-term investing and spending plans. For example, as documented by business and consumer confidence indices, which reflect businesses' and consumers' willingness to invest and spend, psychological well-being was seriously affected by terrorist attacks in the U.S. on September 11<sup>th</sup>, 2001. The loss of confidence slowed down economic recovery from the attack and contributed to an associated economic recession.<sup>15</sup>

Out-migration from the region due to fear or the lack of economic opportunities may be a third type of consequence from the disruption scenarios. The out-migration response is likely to be of a threshold nature. That is, if the disruption is relatively minor or even intermediate in scale (for example, the 14<sup>th</sup> Street Bridge or power plant disruption scenarios) out-migration would appear to be a minimal response. However, if multiple disruptions occur in an area and or a massive disruption occurs, such as was the case in New Orleans as a consequence of the hurricane Katrina, many residents would view remaining in the region a much riskier decision. Out-migration where residents perceive high risk from potential disruptions is likely to be higher. More research is needed to deepen the understanding of this potential response and its likely economic consequences (e.g., increased labor cost, reduced quality of the regional labor force, reduced investment).

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<sup>15</sup> <http://isu.indstate.edu/guell/ecn100/Sept11th.PDF>.

Some economists (e.g., Button & Taylor, 2002) recognize a long term systemic impact effect that is somewhat like a slow snowballing effect that builds over time as the consequence of an initial action or disruption, e.g., the impact of the initial Disney investment in the Orlando Region may be viewed as over time being a trigger that created an enormous investment and thus impact on that region's economy and development but this was not estimated or knowable at the time of the initial investment. This may be what is or has happened as a consequence of Hurricane Katrina in New Orleans. In the National Capital Region there is a potential for such perpetuity like effects that would arise because of the psychological magnification of the impacts due to the Region's status as the nation's capital. This type of effect is difficult to measure *ex ante* as illustrated with by the Orlando-Disney example noted above. Economists are aware of perpetuity effects because *ex poste* experience has revealed them and made possible their measurement. This potential effect is mentioned here because it is possible the behavioral response to disruptions like the ones simulated here may be magnified because the Region is the nation's capital and thus psychologically may be perceived as more than a short term effect to the economy of the Region.

## **6. Discussion and Conclusions**

### **6.1. Economic consequences**

In this paper, the geographic area simulation and the I-O model of the Regional Economy have generated informative estimates of direct infrastructure losses and the resulting economic consequences in the National Capital Region.

The results of the I-O model show that a disruption event, which takes place outside a particular sub-region, can impact that sub-region as well. For example, the Bridge failure on the border between Virginia and the District of Columbia will impact the Maryland part of the Region that is located miles from the disruption site. In addition, the closer the disruptive incident is to a jurisdiction, the greater the economic consequences it will tend to experience with of course the caveat that it depends in part on the relative size of the sub-region where the incident occurs as well as the other sub-parts of the region. This finding provides important insights regarding the appropriateness of joint policy efforts of protection and mitigation within the National Capital Region. It also shows that the distribution of mitigation costs will vary depending on the sub-regional location and the type (including place) of the incident.

The modeling and estimation methodologies used in the analyses conducted herein do not capture (estimate) all of the consequences that may result from disruptive attacks. While the analyses conducted herein estimate the cost of many of the economic effects they do not measure the economic effects of possible loss

of life, psychological impacts, possible exodus of people that might be induced by such acts or perpetuity effects. With more resources to develop informed estimates of these possible effects the methodology used herein could provide estimates of the costs of loss of life, psychological impacts and out-migration.

### ***6.2. Future model improvements***

The I-O model demonstrated in this paper can be improved, if necessary data is made available. A new I-O model for the region needs to be constructed that reflects the changes in the structure of the regional economy. This model would use NAICS data instead of SIC data and would be specified in such manner that the economic consequences would be easily distinguishable by sector and jurisdiction. In addition, a deeper understanding of the cost of mitigation measures and a more refined scenario description would be desirable. Another model improvement would be to directly incorporate various protection and mitigation measures into the GIS simulation thus enabling estimation of the effects with and without policy and specific protection decisions and protocols.

### ***6.3. Conclusions***

This systematic approach to estimating the economic effects of a terrorist attack on the National Capital Region represents a major step for bringing a more rational and small-geographic-area specific understanding to policy and management decision making regarding potential safety and security issues resulting from terrorist threats. Combined with the geographic area simulation model, the I-O model offers a promising approach because it is able to capture and reflect direct, indirect and induced effects on the Region's economy. In addition, it is also able to estimate disaggregated geographic and sectoral impacts.

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**Table 1: Political Jurisdictions in the Study Region**

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|                      |    |
|----------------------|----|
| District of Columbia | DC |
| Calvert              | MD |
| Charles              | MD |
| Frederick            | MD |
| Montgomery           | MD |
| Prince George's      | MD |
| Arlington            | VA |
| Clarke               | VA |
| Fairfax              | VA |
| Fauquier             | VA |
| Loudoun              | VA |
| Prince William       | VA |
| Spotsylvania         | VA |
| Stafford             | VA |
| Warren               | VA |
| Alexandria City      | VA |
| Fairfax City         | VA |
| Falls Church City    | VA |
| Fredericksburg City  | VA |
| Manassas City        | VA |
| Manassas Park City   | VA |

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**Table 2: Economic Impact on the National Capital Region**

|   | <b>14<sup>th</sup> St. Bridge</b> | <b>Power Plant</b> |
|---|-----------------------------------|--------------------|
| <b>Work Days (day)</b>                      |                                   |                    |
| Total Working Day Loss                      | <b>-340,000</b>                   | <b>-3,250,000</b>  |
| Total Direct Working Day Loss               | -230,000                          | -2,312,500         |
| Total Indirect and Induced Working Day Loss | -110,000                          | -935,000           |
| <b>Employment (person)</b>                  |                                   |                    |
| Total Annualized Employment Loss            | <b>-1360</b>                      | <b>-13000</b>      |
| Direct Annualized Employment Loss           | -920                              | -9250              |
| Indirect Annualized Employment Loss         | -440                              | -3740              |
| Employment Multiplier                       | 1.48                              | 1.40               |
| <b>Output (million \$)</b>                  |                                   |                    |
| Total Annualized Output Loss                | <b>-86.4</b>                      | <b>-862.5</b>      |
| Direct Annualized Output Loss               | -48.3                             | -506.2             |
| Indirect and Induced Annualized Output Loss | -38.1                             | -356.3             |
| Output Multiplier                           | 1.79                              | 1.70               |
| <b>Income (million \$)</b>                  |                                   |                    |
| Total Annualized Income Loss                | <b>-26.2</b>                      | <b>-326.3</b>      |
| Direct Annualized Income Loss               | -15.5                             | -228.4             |
| Indirect and Induced Annualized Income Loss | -10.6                             | -98.0              |
| Income Multiplier                           | 1.68                              | 1.43               |

**Table 3: Sectoral Economic Impact: National Capital Region**

|   | <b>14<sup>th</sup> St. Bridge</b> | <b>Power Plant</b> |
|---|-----------------------------------|--------------------|
| <b>Employment (person)</b>              |                                   |                    |
| Agriculture & Mining                    | 0                                 | -180               |
| Construction                            | -40                               | -680               |
| Manufacturing                           | -60                               | -740               |
| Communications & Utility                | -80                               | -850               |
| Retail & Trade                          | -180                              | -1630              |
| Financial, Insurance, & Real Estate     | -80                               | -700               |
| Services                                | -880                              | -7780              |
| Government                              | -40                               | -440               |
| <b>Subtotal</b>                         | <b>-1360</b>                      | <b>-13000</b>      |
| <b>Output (million \$)</b>              |                                   |                    |
| Agriculture & Mining                    | -0.5                              | -10.0              |
| Construction                            | -4.2                              | -61.9              |
| Manufacturing                           | -4.8                              | -58.3              |
| Communications & Utility                | -13.2                             | -158.9             |
| Retail & Trade                          | -12.6                             | -113.0             |
| Financial, Insurance, & Real Estate     | -10.8                             | -112.2             |
| Services                                | -39.5                             | -341.8             |
| Government                              | -0.6                              | -6.5               |
| <b>Subtotal</b>                         | <b>-86.4</b>                      | <b>-862.5</b>      |
| <b>Income (million \$)</b>              |                                   |                    |
| Agriculture & Mining                    | -0.1                              | -2.9               |
| Construction                            | -1.2                              | -18.2              |
| Manufacturing                           | -1.4                              | -17.8              |
| Communications & Utility                | -2.9                              | -34.8              |
| Retail & Trade                          | -3.3                              | -29.4              |
| Financial, Insurance, & Real Estate     | -1.7                              | -16.2              |
| Services                                | -14.3                             | -195.0             |
| Government                              | -1.3                              | -12.2              |
| <b>Subtotal</b>                         | <b>-26.2</b>                      | <b>-326.3</b>      |
| <b>Regional Indicators (million \$)</b> |                                   |                    |
| Total Consumption                       | -35.6                             | -357.4             |
| Consumption of Services                 | -22.0                             | -209.8             |
| State and Local Government Expenditures | -7.2                              | -68.4              |
| Total Personal Income                   | -35.3                             | -404.5             |

**Table 4: Sub-Regional Economic Impact: National Capital Region**

|                                  | <b>14<sup>th</sup> St. Bridge</b> | <b>Power Plant</b> |
|----------------------------------|-----------------------------------|--------------------|
| <b>Work Days (day)</b>           |                                   |                    |
| Total Working Day Loss           | <b>-340,000</b>                   | <b>-3,250,000</b>  |
| DC                               | -95,348                           | -506,680           |
| MD side                          | -35,971                           | -759,768           |
| VA side                          | -208,681                          | -1,983,552         |
| <b>Employment (person)</b>       |                                   |                    |
| Total Annualized Employment Loss | <b>-1360</b>                      | <b>-13000</b>      |
| DC                               | -381                              | -2027              |
| MD side                          | -144                              | -3039              |
| VA side                          | -835                              | -7934              |
| <b>Output (million \$)</b>       |                                   |                    |
| Total Annualized Output Loss     | <b>-86.4</b>                      | <b>-862.5</b>      |
| DC                               | -23.5                             | -115.2             |
| MD side                          | -9.1                              | -198.7             |
| VA side                          | -53.7                             | -548.7             |
| <b>Income (million \$)</b>       |                                   |                    |
| Total Annualized Income Loss     | <b>-26.2</b>                      | <b>-326.3</b>      |
| DC                               | -7.2                              | -50.7              |
| MD side                          | -3.0                              | -75.5              |
| VA side                          | -16.0                             | -200.1             |