Journal of Homeland Security and Emergency Management

Volume 5, *Issue* 1 2008 *Article* 39

Simulating the Economic Impacts of a Hypothetical Bio-Terrorist Attack: A Sports Stadium Case

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Simulating the Economic Impacts of a Hypothetical Bio-Terrorist Attack: A Sports Stadium Case*

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Abstract

The purpose of this paper is two-fold. First, we suggest an analytical framework to study the *full* economic impacts of hypothetical bio-terrorist attacks on various targets. We particularly emphasize the importance of estimating economic impacts that occur through systems and behavior linkages beyond direct losses. Second, we provide a case study that analyzes the economic impacts of an attack on a major league sports stadium. The estimated loss from the stadium attack ranges from $62 billion to $73 billion. The largest loss comes from the loss of lives, followed by the reduced demand for sports stadium visits. We demonstrate that available off-the-shelf impact models (in this case IMPLAN) can be utilized, via the development of detailed but plausible scenarios grounded in available data and literature.

KEYWORDS: economic impacts, bio-terrorism, sports stadium attack, input-output analysis

*The authors are grateful for the assistance of our colleagues at Battelle National Laboratories, especially Ketra Schmitt and David Winkel. We also thank our CREATE colleague Adam Rose. None of these individuals is responsible for any errors or omissions in this paper. Any opinions and findings expressed here are our own. This research was supported by the United States Department of Homeland Security through the Center for Risk and Economic Analysis of Terrorism Events (CREATE) under grant number 2007-ST-061-000001. However, any opinions, findings, and conclusions or recommendations in this document are those of the authors and do not necessarily reflect views of the United States Department of Homeland Security.

INTRODUCTION

The application of standard economic impact models to the study of hypothetical terrorist attacks is not as straightforward as might be expected. The models are more powerful and user-friendly than ever. But they are, after all**,** multipliers in search of appropriate multiplicands. Supplying the latter requires analysts to create plausible and detailed scenarios that can be fitted to the models.

This is the nature of the research reported here. The purpose of this paper is two-fold. First, we suggest an analytical framework to study the *full* economic impacts of hypothetical bio-terrorist attacks on various targets. In particular, we emphasize the importance of estimating economic impacts that occur through systems and behavior linkages beyond direct losses. Second, we provide a case study that analyzes the economic impacts of a hypothetical bio-terrorist attack on a major league sports stadium. Any large sports stadium is an attractive target for (bio-)terrorists attacks because it is a place of mass public gatherings on a predictable basis, often with minimal security controls (Australian Government Attorney-General's Department, 2006).

The estimated loss of a bio-terrorist attack on a stadium ranges from $62 billion to $73 billion. The largest loss comes from the loss of lives, followed by the reduced demand for sports stadium visits. By comparison, analysts using entirely different methods have found that the annual total cost of cancer in the U.S. is slightly more than $200 billion, including the costs of medical expenses and the costs of lost productivity because of illness and premature death (American Cancer Society, 2006). The annual cost of deaths from auto accidents has been put at $230 billion by the National Highway Traffic Safety Administration (2005).

ANALYTICAL FRAMEWORK

Figure 1 presents a general framework for analyzing the economic impacts of hypothetical bio-terrorist attacks using input-output analysis. We developed this analytical framework by further elaborating Rose’s (2006) conceptual framework for modeling total economic impacts of extreme events. For any type of bio-terrorism event, the first step is to create a hypothetical event scenario that has a sufficiently high probability of occurrence to justify investigation. Each scenario should define the type of bio-terrorist target, the size of the attack, and the expected size and time frame of direct damage and disruption.

Major direct costs include casualties, illnesses, contamination, and business interruption. Unlike natural disasters or other conventional terrorism events, property damage is expected to be minimal in the case of bio-terrorism events. The size of human and physical losses would be a function of many factors such as the kind, quantity, and quality of the bio agents released, climatic conditions, and emergency response. These damages can be estimated through a simulation model, which would incorporate a bio-agent dispersion model and epidemiological curves. There is a possibility of public resistance to re-occupancy of decontaminated facilities. This fear factor would result in more prolonged business interruption and potentially some type of property loss. We are unable to model these effects, and did not include these effects in our analysis. We expect the economic incentives to return facilities to service would dominate most decisions.

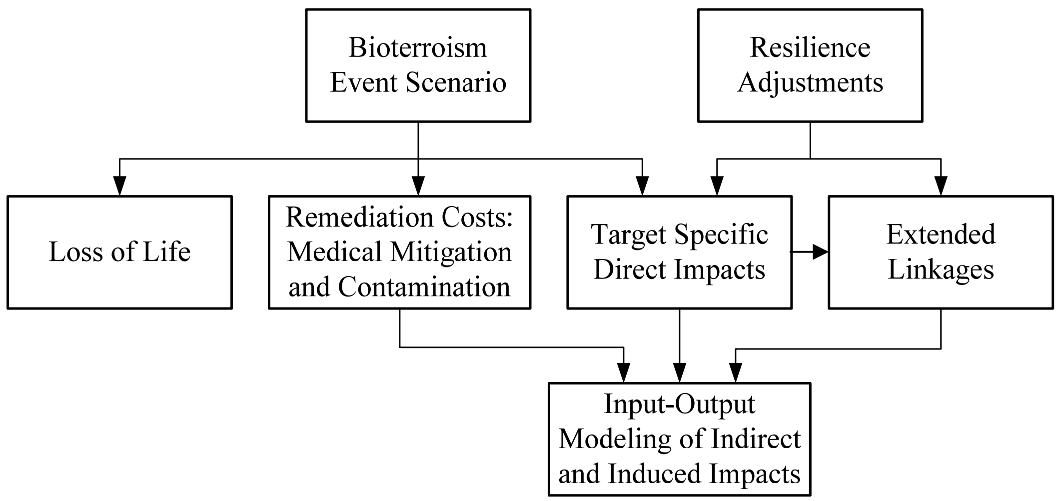


Figure 1. Analytical framework for impact studies of bio-terrorism attacks

In general, the economic impacts of bio-terrorism events can be estimated in three major categories: loss of life, remediation costs, and event/target specific impacts. It is standard to apply the value of a statistical life (VSL) to estimate the economic value of lives lost. We employ I-O modeling to estimate total impacts associated with the other two types of economic costs. This approach accounts for economic linkages between activities.

The VSL is a critical component in estimating monetary costs of any fatality or health risks due to natural, environmental, and man-made hazards or analyzing the benefits of reducing these risks. The VSL can be defined as what a society is willing to pay for a marginal reduction in fatality risks (Fisher, Chestnut and Violette, 1989). The VSL is generally estimated based on either revealed or stated preference data (Kochi, Hubbell and Kramer, 2006). Because estimated VSL varies across studies using different methods and data, policy analysts typically use mean values drawn from multiple estimates. We use $5.4 million, which is obtained from a recent meta-analysis that used an empirical Bayesian pooling method (Kochi, Hubbell and Kramer, 2006).

Besides the human costs (casualties), a bio-terrorism attack would call for extensive medical services and decontamination activities. Direct costs of medical mitigation and decontamination are estimated by multiplying the average unit cost of each service by the quantity of total services required. We use unit costs of medical services from a recent cost-benefit study of counter measures against anthrax terrorism (Braithwaite, Fridsma and Roberts, 2006), adjusting to 2003 dollars using the Consumer Price Index for all urban consumers (CPI-U). We also assume that infected patients with severe symptoms need to be hospitalized for seven days on average (Kaufmann, Meltzer and Schmid, 1997), and that all potentially exposed people without severe symptoms would have one outpatient visit for medical services. Hospitalization cost per day and outpatient cost per visit used in this study are \$810 and \$75, respectively. Decontamination cost is assumed to be \$40 per ft^2.

While most previous studies treat these remediation costs as merely direct costs, the resources (expenditures) directed to these remediation activities are expected to have dual impacts on the economy. On the one hand, remediation activities draw on certain resources in the current economy that would have been used in other productive activities. This is certainly a cost to society regardless of whether it is paid for by government agencies or by private parties.

We assume that most of the remediation costs will be covered by the federal government in the case of bio-terrorism events. There are three possible funding sources of such government expenditures: increased taxes, increased deficit spending, and reductions in other government expenditures. Whatever the funding source, the economic consequences and hence our modeling approach would be similar: increased tax liabilities that will ultimately reduce household consumption; and increased deficit expenditures or reduced public expenditures on other programs would affect future household consumption and would have opportunity costs. Thus, we model the remediation costs as reduced overall household consumption using the expenditure pattern of households in the \$35,000-\$50,000 income bracket.

On the other hand, resources directed to remediation activities would also have stimulative effects on the economy. These positive impacts can offset the local economic losses to some extent when the resources come from outside the region in the form of insurance payments or financial assistance. We model these positive impacts as increased final demand in corresponding economic sectors. These sectors include hospital sectors for medical mitigation and waste management and environmental consulting services for decontamination. The net economic impacts will depend on the relative size of output multipliers associated with the relevant industrial sectors.

A related question in modeling remediation costs involves the social costs of taxation. It is widely recognized that there are considerable social costs when transferring the purchasing power of taxpayers to the government (Slemrod and Yitzhaki, 1996). Broadly stated, the costs consist of administrative, compliance, and marginal welfare costs (Tran-Nam et al., 2000). The compliance costs incurred by taxpayers are estimated to range from 5 to 7 percent of the income tax collected (Slemrod and Sorum, 1984). We know of no empirical estimate for administrative costs of U.S. income taxes. However, studies for other countries suggest that they are usually 1 percent or less of collected revenues (Evans, 2003).

Marginal welfare costs (often referred to as deadweight losses) of the U.S. income tax due to the distortion of resource allocation have been estimated to be around 25 cents per revenue dollar (Parry, 2002). We believe that this cost is partly taken into account by our modeling approach when we reduce overall consumption of taxpayers and estimate multiplier effects. Thus, we consider only operating (administrative and compliance) costs of taxation in reducing households' final demand, using a conservative value of five percent. Thus, we take out $1.05 from overall household consumption for each extra dollar of government expenditure on remediation activities.

Finally and most importantly, we have to model bio-terrorism event/target specific impacts beyond remediation costs and ordinary multiplier effects. These event/target specific impacts occur through behavioral and system linkages, and are often much larger than the direct damages and the ordinary multiplier effects (Rose, 2007). One important aspect of risk-related behavior is that it can be socially amplified or attenuated (Pidgeon, Kasperson and Slovic, 2003, Renn et al., 1992). When fears are heightened in the case of terrorism, people tend especially to "neglect probability" and are likely to show excessive risk aversion (Sunstein, 2003). The risk aversion of consumers directly translates into reduced demand for goods and services involved, e.g., air travel demand decline in the wake of the 9/11 events. Amplified risk perceptions and risk-related behavior may lead to additional economic impacts of more than an order of magnitude.

While many theoretical and conceptual models explaining the structure of the social amplification of risk have been proposed, much more research still needs to be done in quantifying behavioral changes in response to actual or hypothetical terrorism events. Thus, we choose to rely on available information concerning the aftermaths of historical events when predicting the target specific impacts of hypothetical bio-terrorism attacks. This approach is similar to benefit-transfer or value-transfer, which is the application of monetary unit values or functions obtained from one non-market valuation study to other policy decision environments (Brookshire and Neill, 1992, Spash and Vatn, 2006). This value-transfer approach is most valid when the conditions of the primary study and policy application are well defined (Luken, Johnson and Kibler, 1992). Thus, we need to draw as much as possible upon historical events that are akin to a hypothetical terrorist attack scenario. Because the data on terrorism are rather tenuous, however, we provide a range of estimates rather than a point estimate.

In the final step of the economic impact analysis, we apply the 2003 IMPLAN® national I-O model, available from the Minnesota IMPLAN Group, Inc. (MIG), to estimate indirect and induced effects. All direct impacts combining remediation and event/target specific impacts are inputs to the I-O model as final demand changes, and Type II multipliers are used to estimate the total economic impacts.

There is an important caveat to approaches such as ours. Input-output analysis is well known to consist of the application of fixed multipliers. Yet, market economies are defined in terms of the ability to adjust as agents respond to price signals. Most such adjustments, however, are beyond the short run. Many of the losses that our analyses depict could then be recouped. It bears repeating that we are only calculating one-year losses. In the longer term, agents adjust their behavior to mitigate impacts and possibly recoup their losses.

ECONOMIC COSTS ESTIMATION

Stadium Attack Scenario

A successful terrorist attack on a stadium can potentially cause massive casualties and high-impact imagery, and hence gain terrorists high-profile publicity (Australian Government Attorney-General's Department, 2006). Our analysis is based on the scenario that terrorists release a bio agent in a stadium where a National Football league (NFL) game is playing for an attendance of 75,000 spectators. A desktop analysis using Hazard Prediction and Assessment Capability (HPAC) employing notional biological agents, urban density and weather conditions predicted a range of potential consequences. This economic scenario models an attack in which 20,000 illnesses and 7,000 casualties occur among the attendees. In this scenario, the bio agent would contaminate a neighboring area of 5.5 km^2 and would cause an additional 11,000 illnesses and 3,600 deaths.

We expect that the entire contaminated area including the stadium would be quarantined for one month immediately after the biological attack occurs. The affected public spaces and roads will be open after this initial one-month quarantine period. However, it will take much more time to decontaminate individual buildings in the contaminated area. We assume that 50 percent of the contaminated buildings will be not be habitable until six months after the attack, and that it would take one year to complete the decontamination.

Remediation Costs

Direct remediation costs are listed in Table 1. We assessed the quantity of remediation activities required based on the scenario descriptions and applied the unit costs of each service. We assumed that all attendees at the football game and residents in the contaminated neighboring area are potentially exposed to the released biological agents and would need to have at least one outpatient examination or treatment. The number of residents in the area is calculated by using the average population density of the ten largest U.S. urbanized areas.

Table 1. Direct remediation costs

Remediation costs	Direct costs ($)	Calculation
Medical mitigation		
Hospitalization	175,770,000	31,000 total illnesses • $810/day • 7 days
Outpatient	4,734,600	63,128 potentially exposed[1] • $75/per visit
Decontamination	110,000,000	2,750,000 ft^2 • $40/$ft^2$

Note: 63,128 potentially exposed = 55,000 uninfected attendees + 8,128 residents in the neighborhood; 8,128 residents = 5.5km^2 • 1,478 residents/km^2 (average population density in 10 largest urbanized areas).

As explained in the previous section, remediation activities are costs to the economy, but at the same time have some stimulating effects. We estimated total economic impacts for both positive and negative shocks using the IMPLAN 2003 national model. Although the estimated amount of these direct costs plus taxation costs (5 percent) is about $305 million, the actual reduction in final demand from the household sector is about $286 million after taking into account the demand for foreign products (imports), which do not directly contribute to U.S. regional or national production. The net effect was about $154 million because Type II multipliers for decontamination and medical sectors were larger than for overall household consumption sectors. See Table 2.

Economic Impacts Through Behavior and System Linkages

A successful terrorist attack would have extended economic impacts through behavior and system linkages. A biological attack on an NFL stadium would likely scare many sports fans away from most major stadium visits for some period. However, there is little research or data available on the impacts of historical stadium terrorism events. Further, the magnitude of any of historical stadium terrorism events is so small that they have little bearing on estimating the impacts of our stadium scenario. Thus, we have chosen to draw upon behavior changes after two other historical terrorism events: the September 11th attacks and the Bali night club bombing.

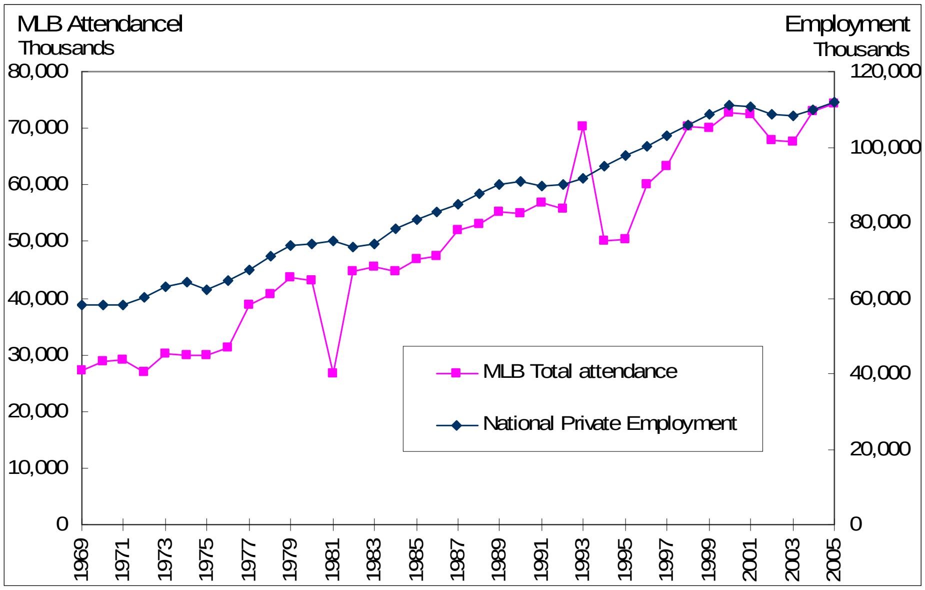
Table 2. Direct, indirect, and induced impacts of remediation costs

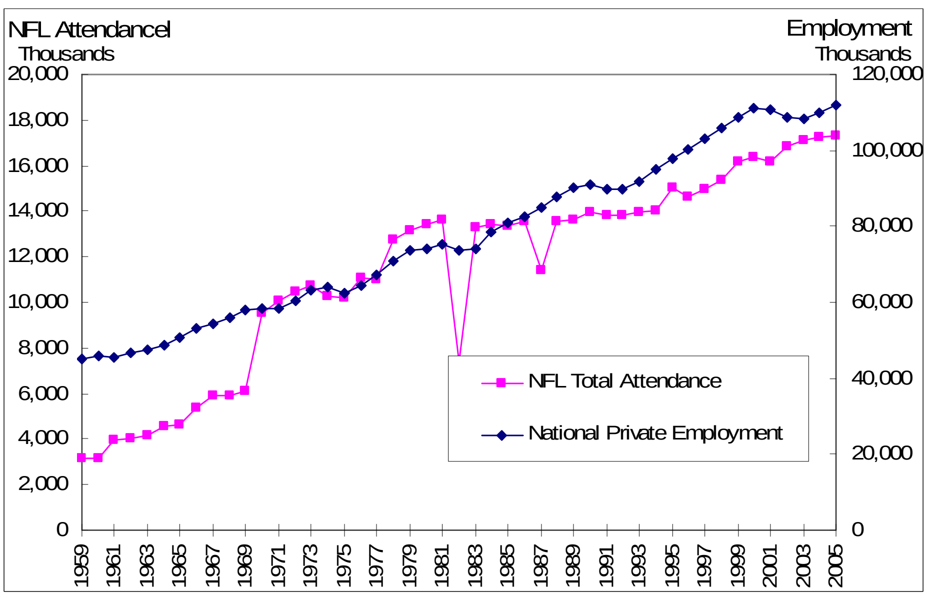
NAICS 2 digit sectors	Remediation expenditures (+)				Reduced household expenditure (-)				Net
($ thousand)	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total	Total
Agriculture	0	1,899	6,991	8,890	1,306	6,820	5,010	13,136	-4,247
Mining	0	2,000	4,062	6,062	173	4,384	2,911	7,468	-1,406
Utilities	0	4,396	8,934	13,330	5,907	3,985	6,403	16,295	-2,965
Construction	0	3,272	2,785	6,058	0	2,968	1,996	4,964	1,094
Manufacturing	0	43,754	77,771	121,525	43,182	45,629	55,740	144,550	-23,025
Wholesale Trade	0	7,919	19,396	27,315	13,150	9,179	13,901	36,231	-8,916
Transport. & Warehousing	0	11,537	13,450	24,987	4,286	10,079	9,640	24,005	981
Retail trade	0	1,986	33,560	35,546	37,185	1,863	24,053	63,102	-27,555
Information	0	13,179	24,374	37,553	12,551	14,071	17,469	44,091	-6,538
Finance & insurance	0	16,393	40,610	57,003	24,994	21,317	29,106	75,418	-18,415
Real estate & rental	0	30,753	27,723	58,475	14,442	18,440	19,869	52,752	5,724
Prof. & tech. services	110,000	29,932	21,300	161,232	4,210	18,986	15,266	38,462	122,770
Management of companies	0	5,964	6,234	12,198	0	6,982	4,468	11,450	748
Admin. & waste services	0	27,537	10,951	38,489	975	10,675	7,849	19,499	18,990
Educational services	0	401	5,003	5,404	3,530	205	3,586	7,320	-1,917
Health & social services	180,505	141	43,037	223,683	42,591	377	30,845	73,812	149,870
Arts & recreation	0	1,134	5,932	7,066	4,315	1,400	4,252	9,967	-2,901
Accomm. & food services	0	5,898	18,680	24,578	18,487	2,801	13,388	34,676	-10,098
Other services	0	5,491	17,914	23,404	12,795	4,266	12,839	29,900	-6,495
Gov't & non NAICS	0	2,682	34,348	37,030	32,046	2,133	24,618	58,797	-21,767
Institutions					10,033	0	0	10,033	-10,033
TOTAL	290,505	216,267	423,056	929,827	286,158	186,561	303,210	775,929	153,899

Reduced professional sports game attendance after the September 11th attacks

Stein et al. (2004) report that a survey of the psychological consequences conducted about two months after the 9/11 events revealed that 11 percent of the respondents avoided large gathering places including sports stadiums. Figure 2 presents the attendance trends in two big professional sports leagues, the National Football League (NFL) and the Major League Baseball (MLB).

Most of the significant short-term disturbances in attendance were due to special incidents within each professional sport league, including the creation of new teams, increased number of games scheduled, and players' strikes. In recent NFL history, players' strikes in 1982 and 1987 resulted in large drops in attendance while small jumps in 1995, 1999, and 2002 indicate the addition of new teams to the league. Strikes also are apparent in 1972, 1981, 1994, and 1995.





Notes: 1. NFL data come from Team media guides, Official NFL Record & Fact Books, 1984-2005, ESPN.com, and NFL.com. Downloaded from http://studentwebs.coloradocollege.edu/~a_campbell/datastats.htm.

2. MLB data for 1969-2000 come from the *Journal of Statistics Education* data archive, http://www.amstat.org/publications/jse/datasets/MLBattend.dat.

3. More recent MLB data from http://studentwebs.coloradocollege.edu/~a_campbell/datastats.htm.

Figure 2. Trends in attendance to NFL and MLB games prior to and after the 9/11 attacks

Thus, it seems reasonable to conclude that the deviation in attendance relative to the normal trend during 2001 and 2002 seasons was due to the 9/11 events. The 9/11 terrorism events had only moderate impacts on the two stadium sports, with about a 1.4 percent drop in attendance for the NFL games in 2001 and about 6.5 percent drops in MLB attendance in 2002 and 2003. Note that the 2001 season of the MLB was almost over by the time of the 9/11 attacks. We also found that there was negligible impact on the two major arena sports, i.e.d., the National Basketball Association (NBA) and the National Hockey League (NHL).

Because the 9/11 terrorism events were not a direct attack on a sports stadium, the effects on stadium visits reflect people's general avoidance of gathering places, not stadia in particular. However, it is reasonable to expect that a bio-terrorism attack direct on a sports stadium would have much larger impacts with respect to stadium attendance.

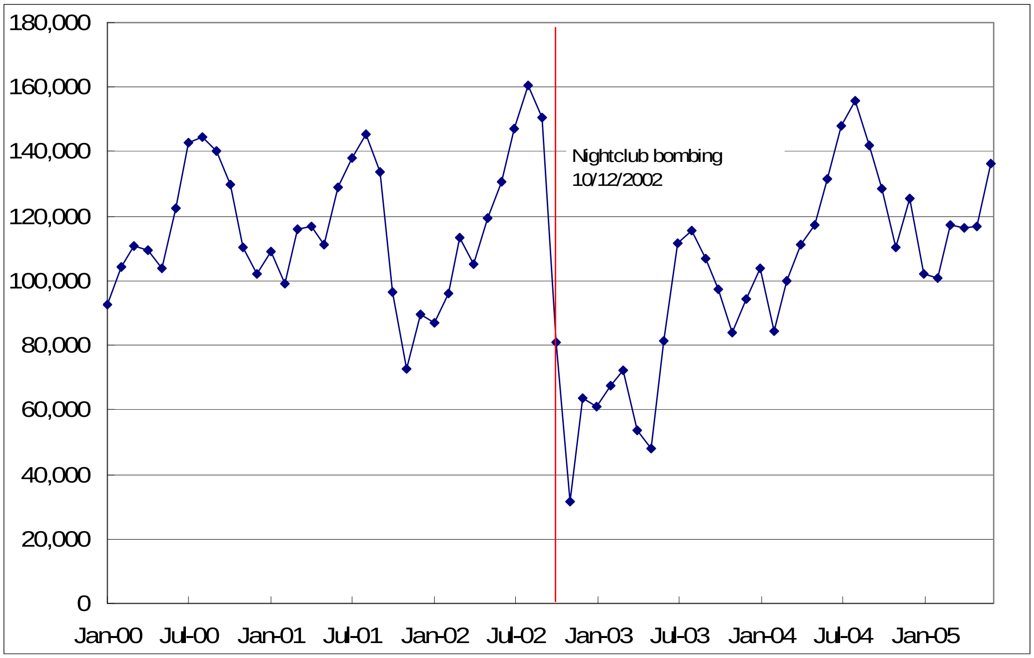
Reduced tourist visits to Indonesia after the Bali night club bombing

We also studied tourist behavior in the wake of the night club bombing on the Indonesian island of Bali on October 12, 2002. This terrorist attack by an extremist Islamist group killed 202 tourists and injured 209. As shown in Figure 3, it took approximately one and a half years for tourist visits to Bali to recover to the previous levels. For the one-year period after the attack (Oct 2002 to Sept 2003), the number of tourists visiting Bali dropped by about 35 percent compared to the one year period before the attack (Oct 2001 to Sept 2002).

It is widely reported that terrorism significantly diminishes tourism. International tourism is especially vulnerable as there are many substitutable international tourist destinations. Thus, we consider this Bali night club bombing case as the upper bound of the decrease in professional sports game attendance in the wake of a bio-terrorism attack on an NFL stadium.

Recovery scenarios of professional sports game attendance and substitutes

We assume that any professional sports games would be cancelled for one month after the hypothetical biological attack on an NFL stadium, which translates to about an eight percent reduction in annual attendance at professional sports games. We expect that a significant proportion of sports fans would avoid attending sports games even after the professional sports league resumes play. In the absence of actual stadium terrorism events of the comparable size, we decided to test high and low impact scenarios drawing upon the cases of the 9/11 attacks and the Bali bombing.



Source: Bali Tourism Board.

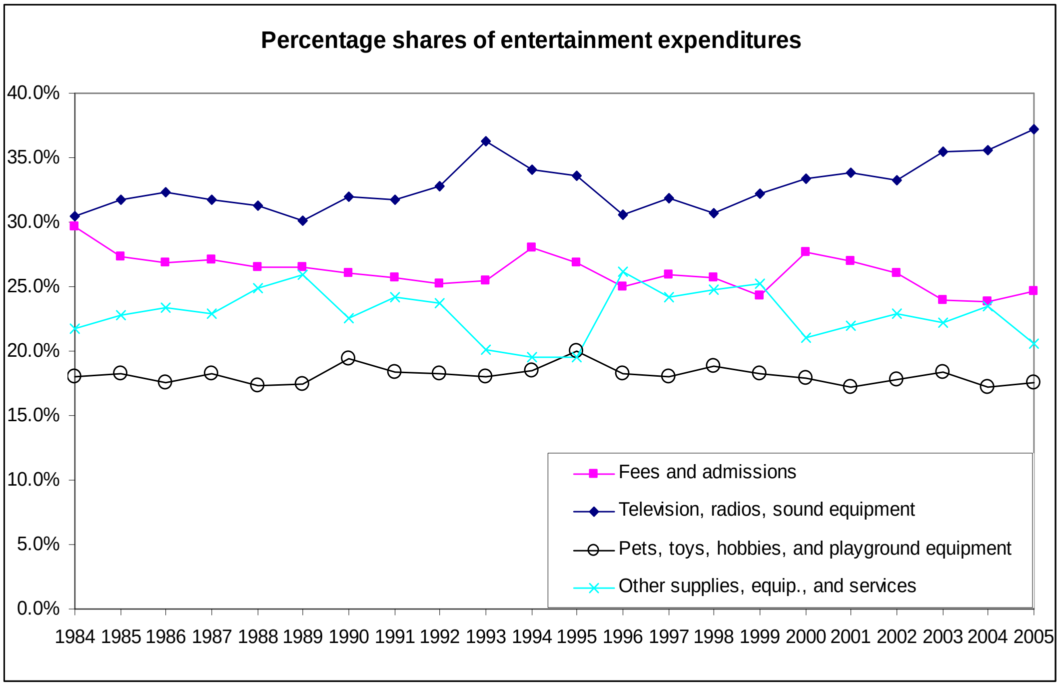
Figure 3. Tourist arrivals to Bali after the nightclub bombing

In the low-impact scenario, we assume a seven percent reduction in the demand for sports game visits after reopening professional leagues. Thus, the total impact in the first year will be about a 15 percent decrease. We assume the demand would recover by the end of the first year after the attack in this low-impact scenario. In the high-impact scenario, we assume a 40 percent reduction in attendance during the first year, including the first month shutdown. We also assume that the impact would last into the second season at a level of ten percent in the high impact scenario.

- Low impact scenario: 15 percent decrease for the first year
- High impact scenario: 40 percent decrease for the first year and 10 percent decrease for the second year

What would be the substitute activities that people might choose instead of attending professional sports games? Where and how much would sports fans spend money that they saved by avoiding stadium visits?

The first alternative could be watching sports games on home TV. With the introduction of high definition (HD) digital broadcasting and HD TV's typically with a large screen, sports fans can increasingly enjoy televised sports via relatively high quality images. Thus, we expect that sports fans who avoid stadium visits would spend more money on purchasing digital TV equipment and cable TV network sports packages. Indeed, the consumer expenditure survey results for the 2000s show that expenditures on TV, radio, and sound equipment generally move opposite the expenditures on fees and admissions, which include professional sports game visits. See Figure 4.



Source: Consumer Expenditure Survey, 1984-2005, Bureau of Labor Statistics, U.S. Department of Labor.

Figure 4. Percentage shares of entertainment expenditures by subsector

The second alternative to sports game visits can be personal exercise activities. Some proportion of sports spectators may become consumers of fitness and recreational sports. Finally, people may spend more time with family at home or in community parks. There is little economic impact in this case. However, we exclude from the list of substitutes activities involving other entertainment sectors such as museums and amusement parks, because a stadium attack would also motivate people to avoid visits to other public gatherings.

Without any substantiated information on relevant substitutions and cross-elasticities, we assume that one-half of the reduced final demand in "spectator sports" goes to the substituting sectors. We assume that equal thirds of this budget for substitutes goes to each of the three substitution sectors: "audio and video equipment," "cable networks and program distribution," and "fitness and recreational sports centers."

Estimation of total impacts of reduced demand for spectator sports

The indirect and induced impacts of reduced demand for spectator sports and substitution activities are estimated using 2003 IMPLAN data. The upper panel in Table 3 (low impact scenario) shows impacts by two-digit NAICS sectors. The lower panel (high impact scenario) suppresses details because sectoral patterns are the same as for the results from the low impact scenario.

Table 3. Direct, indirect, and induced impacts of reduced stadium visits

Low impact scenario	Reduced sports attendance (-)				Substitutions (+)				Net
($ million)	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total	Total
Agriculture	0	2.2	46.2	48.4	0	2.5	15.2	17.7	-30.7
Mining	0	2.0	26.9	28.9	0	5.3	8.8	14.1	-14.8
Utilities	0	6.6	59.1	65.7	0	14.8	19.4	34.2	-31.4
Construction	0	6.1	18.4	24.6	0	10.0	6.1	16.0	-8.5
Manufacturing	0	32.4	514.3	546.7	272.6	184.4	169.0	626.0	79.3
Wholesale Trade	0	5.8	128.3	134.0	0	44.1	42.1	86.3	-47.8
Transport. & Warehousing	0	12.4	88.9	101.4	0	28.3	29.2	57.6	-43.8
Retail trade	0	2.6	221.9	224.5	0	5.0	72.9	77.9	-146.6
Information	0	29.1	161.2	190.3	272.6	201.4	53.0	526.9	336.6
Finance & insurance	0	27.9	268.6	296.5	0	41.8	88.2	130.1	-166.4
Real estate & rental	0	37.1	183.3	220.4	0	75.4	60.2	135.7	-84.8
Prof. & tech. services	0	35.5	140.9	176.4	0	97.7	46.3	144.0	-32.4
Management of companies	0	6.4	41.2	47.7	0	24.1	13.5	37.7	-10.0
Admin. & waste services	0	27.1	72.4	99.5	0	25.8	23.8	49.6	-49.9
Educational services	0	0.2	33.1	33.3	0	0.5	10.9	11.4	-21.8
Health & social services	0	1.8	284.6	286.4	0	0.0	93.5	93.5	-192.9
Arts & recreation	1,635.6	184.3	39.2	1,859.1	272.6	19.8	12.9	305.3	1,553.8
Accomm. & food services	0	5.0	123.5	128.5	0	8.2	40.6	48.8	-79.7
Other services	0	5.0	118.5	123.4	0	24.1	38.9	63.0	-60.4
Gov't & non NAICS	0	4.0	227.1	231.2	0	7.2	74.6	81.9	-149.3
TOTAL	1,635.6	433.5	2,797.7	4,866.8	817.8	820.6	919.3	2,557.7	2,309.1
High impact scenario									
Season 1 total	4,361.7	1,155.9	7,460.6	12,978.3	2,180.9	2,188.2	2,451.4	6,820.5	6,157.7
Season 2 total	1,090.4	289.0	1,865.2	3,244.6	545.2	547.1	612.9	1,705.1	1,539.4
TOTAL	5,452.1	1,444.9	9,325.8	16,222.8	2,726.1	2,735.3	3,064.3	8,525.7	7,697.1

Note: 2003 final demand for spectator sports was $10,904 million.

In the low-impact scenario, the assumed 15 percent reduction in sports attendance costs $4.9 billion in output loss including direct, indirect and induced impacts. However, substitution effects offset these costs by about $2.6 billion. The net economic loss is about $2.3 billion. In the high impact scenario, the net effects of the first and second year are estimated as losses of $6.2 and $1.5 billion, respectively.

Business Interruption Costs in Surrounding Areas

In addition, businesses in neighboring communities would also be severely disrupted. Applying average employment density for the top-ten largest U.S. cities (1,471jobs/km^2) calibrated based on the 2000 Census Transportation Planning Package (CTPP) data, we estimate that 8,091 jobs would be disrupted or relocated from the contaminated area of 5.5km^2.

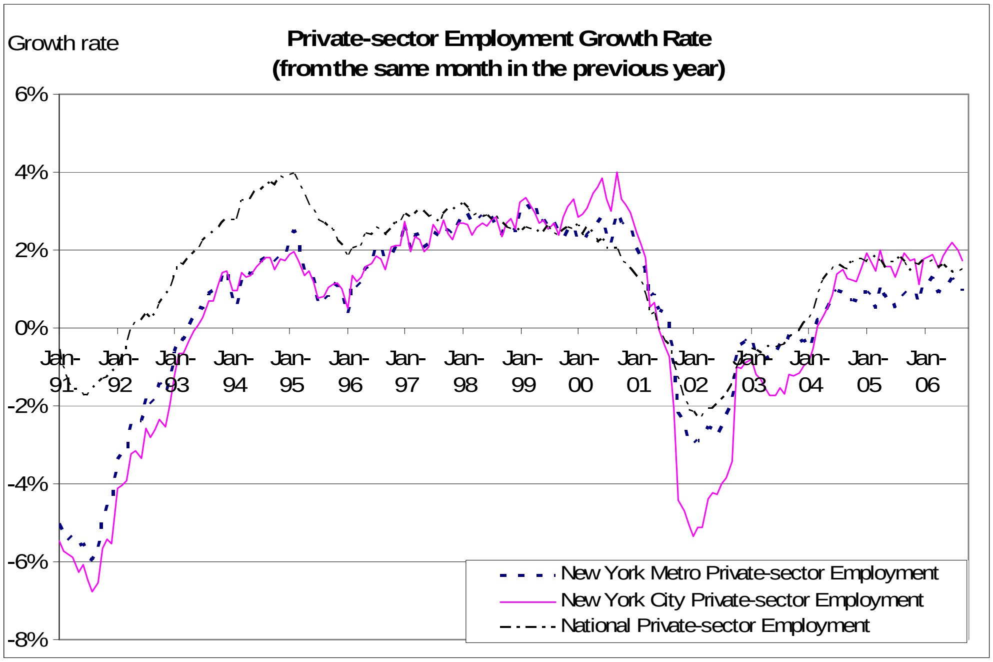
There are two possible ways to estimate the business interruption costs. First, one can create relocation scenarios for these businesses and estimate total economic losses. Second, one can estimate aggregate metro-wide employment disruptions with reference to a historical event such as the aftermath of the 9/11 attacks and translate these into economic losses. We have chosen the second method for two reasons. First, it is difficult and arbitrary to create business relocation and closure scenarios. And second, economic losses estimated via the first method do not take into account metro-wide economic impacts resulting from reduced tourism and infrastructure disruptions.

Employment disruptions in the New York metropolitan area after the 9/11 attacks

Figure 5 shows the percentage employment growth rates before and after the 9/11 attacks in the city of New York, the New York metro area, and the U.S. The national economy entered a recession in early 2001 and the events of 9/11 deepened the recession in New York city and the surrounding metropolitan area. The employment growth rates of New York city and metro appear to have recovered to the national level after one year following 9/11.

To eliminate the influence of the economic recession and accurately estimate the net impact of the 9/11 events, we estimated vector autoregression (VAR) models following Bram, Orr and Rapaport (2002), in which employment growth in New York city and metro area is explained by its own lags and lagged national employment growth. We let the order of the VAR process (the number of lags) be determined based on the Corrected Akaike Information Criterion (AICC). Three and seven lags were used in New York city and the metro models, respectively. We used employment data series from the Current Employment

Survey by the U.S. Department of Labor's Bureau of Labor Statistics after seasonal adjustment via the X-11 ARIMA procedure and first-order differencing.



Source: U.S. Department of Labor, Bureau of Labor Statistics, Current Employment Survey.

Figure 5. Private sector employment growth rates

The time series models can be expressed as

$$e_t = c_2 + \sum_{i=1}^{m} \gamma_{1i} e_{t-i} + \sum_{i=1}^{m} \gamma_{2i} E_{t-i} + \varepsilon_{2t}\,, \tag{1}$$

and

$$E_t = c_1 + \sum_{i=1}^{m} \beta_{1i} e_{t-i} + \sum_{i=1}^{m} \beta_{2i} E_{t-i} + \varepsilon_{1t}\,, \tag{2}$$

where

e_t = The growth of non-farm employment in New York city or metro, and.

E_t = The growth of non-farm employment in the U.S.

Figure 6 presents the paths of predicted and actual employment levels in New York city. Figure 7 provides the same data for the metro area. The predicted employment paths reflect their own past trend as well as the national trend. Both charts show that employment levels had almost recovered to the predicted level within one year after 9/11. We conclude that the difference between the actual and predicted employment levels represent the employment disruptions associated with the 9/11 attacks net of nationwide economic recession impacts. Average net employment losses for the first year were 49,600 (1.36 percent) and 64,700 (0.77 percent) in New York city and its metropolitan area, respectively.

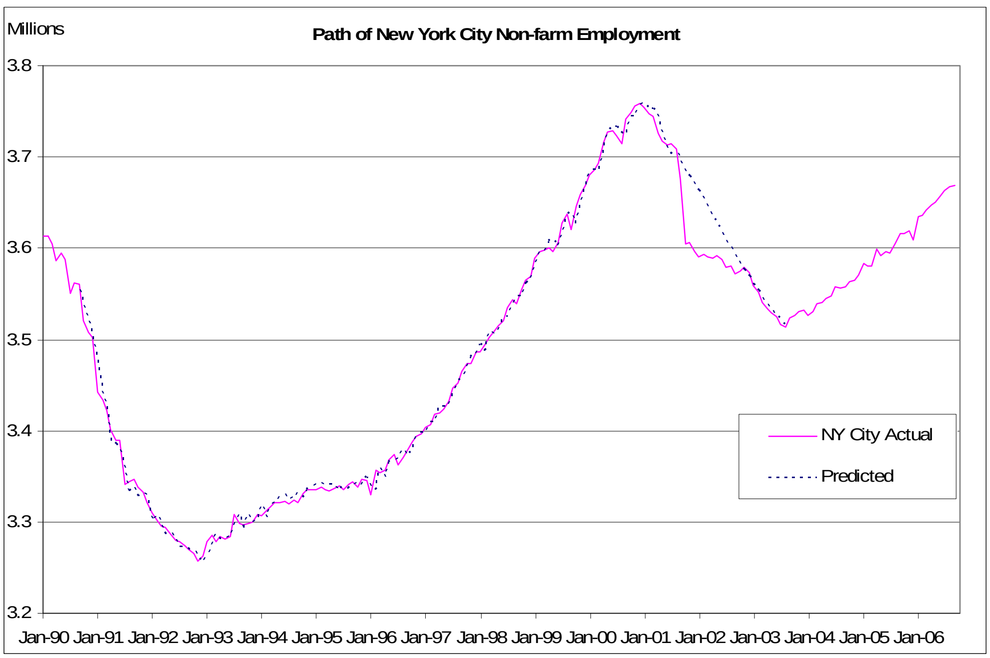


Figure 6. Path of New York city non-farm employment

Estimating business interruption costs

The events of 9/11 caused a relocation of 138,000 jobs from among the 941,800 jobs located in New York's downtown at the time. This resulted in employment losses of 49,600 and 64,700 in New York city and the surrounding metropolitan area, respectively. This employment disruption includes all economic impacts net of the recession effect, which include business disruption by infrastructure shut-down, temporary business closure for relocation, and reduced economic activities from reduced tourism.

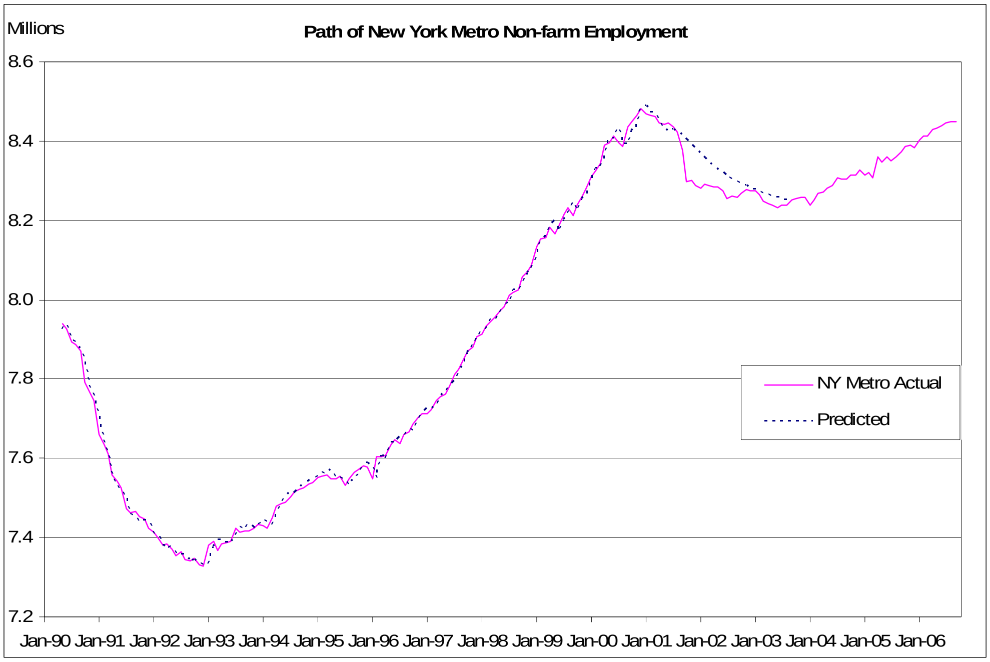


Figure 7. Path of the New York metro non-farm employment

Based on the relocation need for 8,091 jobs in our scenario, and applying the same job loss ratio as in the aftermath of the 9/11 attacks (47 percent = 64,700/138,000), we estimate that there would be about 3,793 jobs lost for one year. Then, we distributed the total employment disruption across two-digit NAICS sectors based on the average industrial composition in the top-ten largest U.S. metropolitan areas. Finally, we converted the employment losses to output losses using labor productivity (output per unit employment) by industry obtained from the IMPLAN 2003 national database. See Table 4. In doing so, we also took into account the higher productivity of metropolitan workers compared to the national average.

Hill and Irnya (2005) provide productivity differences (gross product per job) among different types of places, Manhattan, the rest of the New York CMSA, and the U.S. for 2004. In their estimation, the productivity of Manhattan workers and New York metro workers were 2.18 and 1.12 times the national average, respectively. Some portions of these productivity differences are due to differences in industrial mix. We decompose productivity gains in the New York CBD and metro area due to industrial mix differences by comparing the total output level estimated based on the national average sectoral productivities and the value estimated based on the national averages for industrial composition and productivity. These industrial mix effects account for 19 percent and 4 percent of

Table 4. Business interruption costs

	Expected employment losses	Industrial composition in top 10 largest metros	Output per employee ($1,000)	Expected output losses ($million)
Ag., forestry, fishing and mining	22	0.6%	118.61	2.6
Construction	242	6.4%	121.37	29.4
Manufacturing	513	13.5%	340.18	174.4
Wholesale trade	152	4.0%	153.84	23.4
Retail trade	432	11.4%	61.65	26.6
Transport. and warehousing and utilities	213	5.6%	164.32	34.9
Information	162	4.3%	306.67	49.8
FIRE and rental and leasing	326	8.6%	193.61	63.1
Prof., administration, waste management	480	12.7%	101.37	48.7
Educational, health and social services	771	20.3%	76.44	59.0
Arts, recreation, accomm. and food services	282	7.4%	53.90	15.2
Other services (except public admin.)	198	5.2%	59.43	11.8
TOTAL	3,793			538.9

the productivity differences for the New York CBD and metro area, respectively. Thus, we applied a productivity factor of 1.08 for metropolitan workers after controlling for industrial mix effects. That is, we estimated that the productivity of metro workers in each industry is, on average, 8 percent higher than the national average.

There could be nationwide macro economic impacts beyond the economy of the stricken metropolitan area, but we predict that the long-term macro economic impacts of a single terrorist attack on a sports stadium in an individual city would be minor. Several studies support this idea, finding that the long-term economic consequence of the unprecedented 9/11 attacks, which took nearly 2,800 lives, was not economically significant although it facilitated business relocation within the New York metropolitan area ((Chernick, 2005).

CONCLUSIONS

Table 5 summarizes the total economic costs of a hypothetical bio-terrorist attack on a professional sports stadium. Obviously, the loss of lives is the largest component of the total economic costs. Economic impacts incurred by reduced demand for sports game attendance were also large, ranging from about $5 to $16 billion. The net effect is still substantial, even after accounting for substitution effects from consumers' redirected demands. The economic effects of

Table 5. Summary of total economic costs

a) Low impact scenario

($thousand)	Direct	Indirect	Induced	Total
Loss of lives				-57,240,000
Remediation expenditures (+)	290,505	216,267	423,056	929,827
Reduced household spending (-)	-286,158	-186,561	-303,210	-775,929
Reduced demand for sports attendance (-)	-1,635,638	-433,480	-2,797,730	-4,866,848
Substitutions (+)	817,818	820,591	919,293	2,557,702
Business interruption costs (-)				-538,875
TOTAL				-61,952,949

b) High impact scenario

($thousand)	Direct	Indirect	Induced	Total
Loss of lives				-57,240,000
Remediation expenditures (+)	290,505	216,267	423,056	929,827
Reduced household spending (-)	-286,158	-186,561	-303,210	-775,929
Reduced demand for sports attendance (-)	-5,452,126	-1,444,933	-9,325,763	-16,222,822
Substitutions (+)	2,726,063	2,735,306	3,064,312	8,525,680
Business interruption costs (-)				-538,875
TOTAL				-73,308,923

expenditures on remediation activities and taxes to fund these activities almost cancelled each other. Finally, communities near the stadium attack are also expected to suffer more than one-half billion dollars of business interruption costs.

The formal study of the economic impacts of terrorist attacks is a new field. This research explores ways to develop and apply scenarios that describe hypothetical but plausible attacks, with a focus on bio-terrorist attacks. We show that available off-the-shelf impact models (in this case IMPLAN) can be usefully applied. We also show that such application requires the development of detailed, compelling, and plausible scenarios grounded in available data and literature.

There are two reasons for conducting the research. First, policy makers can be guided in their mitigation allocations by improved estimates of the economic severity of various events. Second, researchers can study our approaches, elaborate them and apply them to a broader and longer list of possible terrorist attacks.

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