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JOINT TRANSPORT RESEARCH CENTRE

Discussion Paper No. 2008-22
November 2008

*Economic Impact Analysis
of Terrorism Events:
Recent Methodological Advances
and Findings*

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Discussion Paper No. 2008-22

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Security, Risk Perception and Cost-Benefit Analysis

**ECONOMIC IMPACT ANALYSIS OF TERRORISM EVENTS:
RECENT METHODOLOGICAL ADVANCES AND FINDINGS**

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November 2008

The views expressed in this paper are the authors', and do not necessarily represent the opinions of either the University of Southern California or the International Transport Forum.

TABLE OF CONTENTS

ABSTRACT	3
1. INTRODUCTION	4
2. OPERATIONAL MODELS	5
3. APPLYING TWO OPERATIONAL ECONOMIC IMPACT MODELS TO SIMULATIONS OF A HYPOTHETICAL ATTACKS	7
4. TRANSNIEMO	11
REFERENCES	14

Los Angeles, November 2008

ABSTRACT

National security is a basic responsibility of national governments, but it is also intangible. What can economic analysis contribute? Benefit-cost analysis has rarely been applied because of the ambiguous and commons nature of the benefits. Our group at the University of Southern California's Center for Risk and Economic Analysis of Terrorism (CREATE) has worked to elaborate and apply economic impact analysis to describe the expected losses from various hypothetical terrorist attacks. Our innovation has been to add a spatial dimension to operational inter-industry models.

Plausible terrorist attack scenarios must include geographic detail. First, there is no generic national seaport, airport or similar targets. Second, most political decision makers represent geographic areas and have a keen interest in their local constituencies. Third, aggregation over spatial units may net out conditions where areas and sectors lose but others gain, especially if locations outside the impact area take over the functions that have been lost elsewhere. Fourth, by considering the spatial economy, interactions between places that rely on available infrastructure can be analyzed.

This paper describes our modeling approaches (a metropolitan region model and two national models) as well as several of the results that we have developed. Our models are not formal cost-benefit analyses, but they demonstrate large business interruption costs from these events, implying that the results provide a rationale for expenditures on the benefits of protection and mitigation. We will also discuss important directions in which models such as ours could become the basis of some type of cost-benefit analysis.

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1. INTRODUCTION

The U.S. did not suffer enduring economic losses from the attacks of September 11, 2001. Estimates of GDP losses range from \$22 to \$34 billion; estimates of structure losses range from \$27 billion to \$95 billion.¹ But the former have to be qualified by the fact that the nation was in a mild recession in 2001, making the identification of terrorism-induced GDP losses difficult. U.S. GDP in 2001 was more than \$10 trillion, indicating that the estimated losses were smaller than might have been feared.

Significant impacts on government expenditures came later via the wars waged in Afghanistan and Iraq and the increased budgets for homeland security measures. Furthermore, enough time has elapsed since 2001 to ease any fears of a long-term productivity and/or output shock. The economic downturn of 2007-2008 is explained by credit market contractions, the mortgage crisis and commodity price increases that probably have nothing to do with the events of 2001.

However, proper risk management and contingency planning require efforts to understand the nature of any future attacks better. After all, through most of the Cold War, planners and policymakers developed scenarios to simulate the losses from hypothetical nuclear attacks.

The threats of transnational terrorism are different. First, there have been relatively few annual average fatalities from terrorist attacks. (Sandler *et al*, 2008). Therefore, application of traditional cost-benefit analysis is probably inappropriate. Even if all fatalities could be averted, the benefits (the monetary value of deaths avoided using conventional statistical measures of the value of a life) are very small compared to the costs of achieving these benefits. Second, there is an uncountable number of global targets that terrorists consider attacking. It is impossible to protect them all.

These observations clarify the research challenge. The two realities cited make it important for homeland defense and national security decision makers to identify targets that are the most critical and harden these as much as possible. But how can these key targets be identified?

The task involves two research challenges. First, specify plausible attack scenarios. Given the capabilities of terrorists, which attacks could they plausibly execute? Second, estimate the economic losses from such attacks. Our interest is in the latter, but we rely on the work of other experts colleagues for the former.

In our work on a possible “dirty” bomb attack (i.e. a radiological device) on the twin ports of Los Angeles and Long Beach, we relied on the work of Rossoff and von Winterfeldt (2007),

¹ Sources summarized in Appendix Table A1.

who examined 36 possible attack scenarios and reduced these to the two most plausible. We used their scenario information to apply the Southern California Planning Model (version 2 is discussed in what follows, SCPM) and the National Interstate Economic Model (NIEMO) to estimate plausible business interruption losses by industry and by place in the greater Los Angeles metropolitan area and beyond. This discussion, elaborated in Section 3, which highlights one of several examples that we present in order to establish the point that spatially detailed information is essential.

We discuss several applications of both of our models, starting with an application of the models to the same hypothetical attack. We also introduce a third model currently being developed, TransNIEMO, which integrates features of each approach. It adds an interregional highway model to NIEMO, allowing us to trace the economic impacts of various hypothetical shipment disruptions anywhere on the national highway network, one which includes thousands of major bridges. Credible cost-benefit analysis of protecting key bridges or tunnels requires a model that integrates the economy with the highway network.

2. OPERATIONAL MODELS²

a. The Southern California Planning Model (SCPM)

Inter-industry models, based on the transactions flows between intermediate suppliers and end producers, are widely used to measure regional economic impacts. They trace all economic impacts, including those of intra- and interregional shipments, usually at a high level of sectoral disaggregation. They are usually demand-driven, although there are some supply-driven applications.

The input-output model component of both models discussed in this paper is from the Minnesota Planning Group's well-known IMPLAN model, which has a high degree of sectoral disaggregation (over 500 sectors). To make these data compatible with data from other sources, we aggregated them to 47 sectors, which we label the USC sectors. The second basic model component of SCPM is spatial; it allocates sectoral impacts across more than 3,000 small geographic zones (Traffic Analysis Zones, TAZs) throughout Southern California (the five-county region of greater Los Angeles). *The key capability of the model is to allocate the indirect and induced impacts generated by the input-output model spatially to these TAZs.* The direct impacts are always the final demand changes at the site of the attack (in this case, at the ports); the indirect effects trace the inter-industry linkages with other sectors, either forwards or backwards (locally, regionally, nationally and internationally); and the induced effects measure the secondary consumption impacts associated with the reduced spending of workers in both the direct and indirect sectors. To estimate the latter, we use a journey-to-work matrix that shows all the commuting flows between residential zones and workplace zones to trace wages earned back to the home, and then we use a journey-to-services matrix to trace retail and personal service purchases from the home to retail and

² Parts of the next two sections are drawn from Richardson, et al. (2008).

service establishments. This follows the logic first proposed by Ira Lowry (1964) and elaborated by Garin (1966). The journey-to-services matrix includes any trip associated with a home-based transaction other than the sale of labor to an employer. This includes retail trips and other service transaction trips, but excludes non-transaction-based trips such as trips to visit friends and relatives.

SCPM endogenizes traffic flows. It uses TAZs for traffic nodes. This feature of the model is important, because many types of terrorist attack are likely to induce changes in supply, including infrastructure capacity losses that will contribute to reductions in network level service and increases in travel delays.

Because traffic flows are endogenous, any change in economic activity that affects the travel behavior of individuals or the movement of freight will influence how the transportation network is used, and these impacts will work themselves out as a change from one network equilibrium to another. This means that the model has the important capability to estimate losses from concurrent attacks against shipping, infrastructure and productive capacity.

Treating the transportation network and its capabilities explicitly endogenizes the otherwise exogenous travel behavior of households and intraregional freight flows, achieving consistency across network costs and origin-destination requirements. The model makes explicit distance-decay (i.e. the decline in the number of trips with increasing distance) and congestion functions (the build-up of traffic congestion and delay costs as particular routes attract more traffic when other parts of the network are disrupted).

This capability allows us to determine the geographical location of indirect and induced economic losses; essentially, we are endogenizing route and destination choice. This also enables us to allocate indirect and induced economic losses over TAZs in response to port-related direct losses in trade, employment and transportation accessibility more accurately. See Cho *et al.* (2001) for a technical summary of an earlier version of this model).

A flow chart of the model is shown in Figure 1.

b. NIEMO (the National Interstate Economic Model)

In pursuing our research goal of creating operational models with sectoral and spatial detail, the choice of approaches involved difficult trade-offs. The use of linear economic models is justified by various factors, including the richness of the detailed results achieved at relatively low cost. NIEMO, for example, includes approximately 6-million multipliers. The principal insight that drives our research is that, with some effort, it is possible to integrate data from MIG, Inc.'s IMPLAN state-level input-output (IO) models with commodity flow (interstate shipments) data from the Department of Transportation's Commodity Flow Survey (and some other sources) for all individual States. The details of how NIEMO was constructed can be found in Park *et al* (2007). Essentially the model is an operational version of the Chenery-Moses multi-regional input-output model (MRIO) that involves the 50 U.S. states (plus the District of Columbia) and the 47 USC sectors. A flow chart of this model is shown in Figure 2.

And just as there are demand-driven and supply-driven, input-output models, we have developed demand-driven and supply driven versions of NIEMO. In each case, the supply-driven approach is most plausibly applied for the case of short-run disruptions.

The interruption of purchasing by firms will have short term multiplier effects and the interruption of sales can also have short-term multiplier effects. Interrupting port services can cause both kinds of problems. Interrupted export opportunities suggest the application of the demand-side model. The case of interrupted imports is less clear because some are for final users while some are supplies to intermediate users.

3. APPLYING TWO OPERATIONAL ECONOMIC IMPACT MODELS TO SIMULATIONS OF A HYPOTHETICAL ATTACKS

a. The Los Angeles/Long Beach Harbors

There are two adjacent ports in Southern California. Though administered separately, we treat them as one. The Los Angeles/Long Beach ports' role in the local and national economy is widely recognized. In a metropolitan region of more than 16.4 million people with a labor force of almost 7.5 million, the twin ports account for 111 million tons of seaborne trade, and are the fifth largest port complex in the world after Hong Kong, Singapore, Shanghai and Shenzhen. Directly and indirectly, the two Los Angeles ports employ 600,000 workers, accounting for more than seven percent of the region's labor force. In terms of containerized traffic, the two ports rank first and second nationally. Their combined import and export trade flows of \$300 billion (2004 data) is equivalent to about 30 percent of the greater Los Angeles area gross regional product. Reflecting trends in the national economy, imports are much larger than exports. About one-half of the imports and two-thirds of the exports are to and from outside the region. The ports fulfill a national function; any loss of transshipment capabilities at these sites would have profound impacts both locally and nationally.

Such impacts would be much wider than a short-term deprivation of imported purchases by consumers or deferred export sales by producers. The supply chains for imported raw materials and intermediate inputs are would be interrupted and, as a result, the productive capacity of firms both inside and outside the region is reduced.

In the first application discussed, we assume that both export and import flows currently using local seaport facilities would terminate for as long as the ports were out of service. We have not yet modeled port diversion, but plan to do so in future research probably beginning with a survey of fleet operators.

We have applied SCPM to explorations of simultaneous radiological bomb attacks on the twin ports of Los Angeles and Long Beach. These could either be brought in by containers or planted within the country very close to the port perimeter, assuming that the terrorists have access to suitable radioactive material within the United States. The extent of the disruption would depend on the size of the bombs. Following Rossoff and von Winterfeldt (2007), we assumed the explosion of two small RDDs (radiological dispersal devices), each of them containing 5lbs of high explosive, more or less simultaneously at the two ports. The attack would require the closure of both ports on health even more than on security grounds. When

the ports might reopen would be a policy rather than a technical decision, but without the transportation access the reopening would have minimal consequences

Although we estimated that the closure of the Los Angeles and Long Beach Ports for anywhere from 15 to 120 days (for the latter case we combined the radiological bomb attacks with conventional bombs blowing up three key access bridges/overpasses), Panel B of Table 1 shows the range of possible losses for various scenarios involving the plume of radioactive effects. Panel C is a summary of worst-case effects from port closure *and* plume effects. It could cost the U.S. economy almost \$49 billion – or more than 322,500 person-years of employment. Recall that SCPM actually reports results in much greater detail, to the level of census tracts or traffic analysis zones if required.

b. Plume Effects of the Harbor Attack

SCPM also made it possible to measure the economic impacts of plume effects in terms of household disruption, business losses and the decline in real estate values. This part of the simulation is discussed separately because it illustrates the complexity (and the benefits) of estimating traffic impacts simultaneously with economic impacts. The numbers shown are somewhat speculative, but our best estimate is a \$4 billion loss in output and close to a decline of 42,600 person-years of employment. Blast damage would be limited, with deaths and serious injuries within a range of perhaps 50 meters and with moderate damage to physical infrastructure, except at ground zero. The outer evacuation zone would include all areas with exposure > 1 REM. We assume a hypothetical radiation plume, a long narrow ellipse 4 kilometers long and more than 200 meters wide with an inner and more contaminated zone of about 100 meters radius (an area of 0.03 km²); there are standard formulae for converting releases of Curies of radiation to plume areas and shapes, subject to wind direction and other climatic conditions. In the ports case, the wind usually comes in from the South West, so the plume would not affect Los Angeles International Airport or other strategic locations except for the ports themselves. The critical early phase of exposure lasts about 4 days (EPA guidelines); the time frame for intermediate and later phases is variable and subjective, and could range from weeks to years. We assume a one-week evacuation in the Outer Zone. With respect to the Outer Zone, this may be conservative because some firms and households may only slowly return with a lag after given permission to return. Health factors may dictate an immediate evacuation, but because the health effects are long-term, the decision to allow a return will be determined more by political than scientific considerations.

The more speculative economic impact consequences of a radiological bomb attack relate to the radiation plume. They depend on many variables: the size of the bomb, the amount of the radioactive release, the wind direction and prevailing climatic conditions, and the downwind population and business densities. Moreover, much depends on the public policy reaction, for example, whether to mandate an evacuation, and, if so, when to allow people to come back; or whether to proceed in a more measured if less cautious manner. Given these uncertainties, we report here only our best estimate of the *maximum* economic impacts of the plume to compare with the economic effects of the interruption of trade to and from the ports. By maximum, we mean under a reasonable set of assumptions.

Net input-output effects are very modest because shopping and services consumption shifts to other locations outside the plume area. Specifically, we assume in the first year after the

attack a 25 percent drop in residential property values, a 25 percent reduction in retail trade, and a 10 percent fall in other business activities, and also that these businesses leave the region. An alternative assumption is that the businesses might relocate elsewhere in the region in which case the impacts would be primarily redistributive from a spatial perspective and the net effects would be minimal.

As for travel behavior, we assume that driving through the plume area, with attendant advice about rolled-up windows, the use of air conditioning and regular car washing, will be permitted rather than the more extreme measure of closing entry and exit roads, especially the freeways. However, there are network effects as the average length of personal trips increase as plume area residents are forced to shop and access services outside their neighborhoods. Although there are fewer total trips, longer trips and more congestion results in significantly higher network costs. Our calculations of the additional network costs yield an estimate of \$1.63 billion, based on a personal trip imputed cost of \$13 per hour and a freight trip cost of \$35 per PCE (Passenger Car Equivalent, based on the convention that one truck is the equivalent of 2.25 cars).

Based on the U.S. Census of 2000, there were 401,147 persons living in the 30 TAZs of the impact area. The evacuated population would be 377,442. Table 1 (Panel B) summarizes the input-output consequences of reduced economic activity and lower property values in the outer plume area. The total output loss is more than \$4.1 billion, of which only a small part, about \$167 million, is associated with the decline in property values. Two-thirds of the losses take place within Los Angeles County and almost one-quarter leak outside the region. In terms of employment, the total job losses are 44,555 person-years of employment.

c. Plume effects of an attack on the Los Angeles CBD

To further illustrate our approach and for comparison, we have also undertaken another study of a radiological bomb attack, in this case on a prominent downtown Los Angeles office building. A radiological bomb attack on downtown Los Angeles might be a \$6 billion event. If a similar attack were mounted in more CBD-oriented metropolitan areas (such as New York, Chicago or San Francisco), the economic impacts would be much larger. An attack on downtown would be much less damaging than a similar attack on the ports because the economic disruptions resulting from closure of America's largest port complex (in terms of \$ of trade) would be far greater than a disruption to Los Angeles' modest financial and office sector.

An important difference between an attack on the ports and an attack on downtown is that the critical public policy reactions might vary significantly in the two cases. In the ports case, there would be more economic pressure for the ports to reopen quickly and it would be feasible to put the port workers and/or the military back to handling trade (with protective clothing and equipment if necessary). In the downtown case, there are public spaces and more of the general public involved, and this might imply much more caution in allowing activities to resume sooner rather than later, especially in the inner plume zone.

d. NIEMO simulation of an attack on the Los Angeles/Long Beach harbors.

We have not applied NIEMO to precisely same attack on the Los Angeles and Long Beach Ports discussed previously. But Table 2 shows results from the simulation of a slightly different scenario. The point that we want to make is that the sub-metropolitan results available from SCPM can be derived along with relevant state-by-state impact information. NIEMO applications to studies of this type are made possible by detailed (sector-specific and monthly) waterborne trade information from WISERTrade for each major seaport.

The loss of export opportunities lends itself to demand-multiplier analysis. Interrupted seaport export opportunities, then, are the final demand changes that are processed by NIEMO. And we chose to be conservative and avoided also using a supply multiplier for the loss of imports. So only direct effects of import losses are included. Combining these, we see that total damage resulting one-month closure of the three largest U.S. Seaports compare to the costs of an LA/LB closure in approximate importance of their size. NIEMO's information on the effects on the other states showed, in each instance, that the impacts where in approximate proportion to the size of the state and its nearness to the port that was affected.

e. Other model applications

Table 3 summarizes some of the other NIEMO applications. We include results from our study of a hypothetical terrorist attack on other major seaports as well as on U.S. theme parks.

The seaports study (Park, et al., 2007) was carried out in the same way as the NIEMO application to Los Angeles-Long Beach described in the previous section. As before, multiplier effects are applied to the interrupted export opportunities while only the direct effects of lost import opportunities are included. Again, state-level impacts were roughly in proportion to the size of the state as well as its distance from the attack. Congressional representatives from anywhere can use these results for an estimate of how a distant port supports their local economy – and thereby assess their constituents' willingness to support its protection or reconstruction.

NIEMO is also useful for assessing the value of a variety of targets. Theme parks attract a national and an international clientele. They may also attract the attention of terrorists for the reason that terror can be a psychological as much as an economic weapon. For this application, we identified 13 major parks (including two clusters of parks) that may be tempting targets in light of their size and prominence. We gathered information on the number of annual visitors as well as the average length of stay and the nature and size of expenditures for each visit. We tested park closure for one month followed by 30 percent operations for the next six months followed by slow recovery to full operations by the eighteenth month after the attack. This schedule of reduced visits defined the direct effects that were used for runs of NIEMO.

Various scenarios were studied. Were there impacts only on the theme park that was attacked? Or were there psychological spillover effects that affected visits to other major parks? And for each scenario, were there substitutions by visitors to, for example, the major national parks? Total losses were sensitive to these assumptions. Results are shown in Table 3.

4. TRANSNIEMO

Work in progress involves adding a representation of the national highway network to NIEMO. We call this TransNIEMO. Whereas the endogenization of interstate trade flows is an important step, it is equally important to consider the media over which trade flows occur. In discussions of possible terrorist targets, it is clear that these lifelines include important targets. All of this is all the more important in an era of dispersed settlement, increased container shipping and distribution centers.

The application of TransNIEMO involves three major steps:

- i. Use NIEMO to estimate baseline interstate trade flows and allocate the portion using the highway network to shortest path routes.
- ii. Estimate increased costs due to re-routings on the modeled highway network system prompted by specific losses of network links, and
- iii. Conduct state-by-state economic impact analysis by applying NIEMO again, to capture effects of decreased household consumption, resulting from price increase of products shipped via second-best routes.

The core idea of TransNIEMO involves the estimation of increased costs on the highway network system for a plausible scenario, e.g., destruction of a bridge. Figure 3 shows the framework for developing the model. The first major step in developing this model is to allocate commodity trade flows to the highway network, which accommodates approximately 73 percent of total trade flows. The National Highway Planning Network (NHPN) has about 452,000 miles of roads, of which the Freight Analysis Framework (FAF) contains 245,500 miles. This includes 46,380 miles of Interstate Highways, 162,000 miles of National Highway System (NHS) roads, 35,000 miles of other national roads, and 2,125 miles of urban streets and rural minor arterials and many bridges and tunnels. However, rail, air, and water networks cannot be ignored, and we plan to address integrating the other modes in future research.

Not surprisingly, combining the FHWA FAF network with NIEMO to create TransNIEMO involved many data manipulation and management challenges, because the FAF network seems to have been compiled from multiple sources. In addition, modeling transportation flows on a national network connecting urban centers includes requirements not associated with metropolitan level models. In particular, the national network is very complex. Economic space must be represented in a more aggregate way, making procedures for allocating freight demand to physical facilities much less obvious than in the metropolitan case. Our group has invested considerable attention in identifying meaningful, computationally tractable means of representing the details of the national economy in a way that articulates with the national highway network.

We have, to date, made good progress and expect TransNIEMO to be operational very soon. We expect to apply it to the determination of the economic losses associated with the loss of any major highway link. This approach can also be the basis for assessing the value of any particular link, should a cost-benefit analysis rather than an impact study be necessary.

5. OTHER STUDIES

Our group undertook studies of two other terrorist issues that rely much less on our modeling methodologies. One is an attack on the airline system. One of the studies monitored the repercussions of the 9/11 attack. The loss estimates were large. When compared to the estimated costs of countermeasure deployment, it appears that the deployment is justified for a wide range of probabilities of attack. Using airport-level data to study the impact of the September 11th terrorist attacks on domestic air travel in the United States, the estimates are similar to those made by Ito and Lee (2005), who used nationally aggregated data in previous work. The study also found that 9/11 may have had more adverse impacts on large airports than on small airports. This could be the result of 9/11's various impacts (including its impact on risk perceptions and security procedures) being relatively severe in the case of large airports. It is also possible, however, that this result was the result of changing trends in the market for air travel. There was no evidence that east coast airports were more adversely affected than west coast airports, and it is possible that a companion study of international air travel would reveal somewhat different, perhaps stronger, results.

The second study used IMPLAN's national input-output model. A national model is preferred because the state-by-state airline revenue losses are difficult to estimate in light of the geographically dispersed nature of airline carriers and related infrastructure and vendors. In this case, the research considered the effects of a ground-based rocket attack on a single airplane. The scenario examined a seven-day shut-down of the entire U.S. air transportation system, followed by a two-year period of recovery, using the post-9/11 experience of the system as a basis for analysis. The overall loss estimates for the two years range from \$214 billion to \$420 billion. There have been two other precursor attempts to model a disruption of the U.S. air transport system. Balvanyos and Lave (2005) estimated consumer surplus losses from an air travel shut down and reported that the estimated loss would be up to \$2 billion per day. Santos and Haines (2004) have published results from an input-output impact simulation of a 10-percent air transport system shutdown (\$12 billion of direct effects). These authors derived input-output multipliers of 1.2 (Type I) and 3.6 (Type II) for the U.S. to estimate a range of total losses from \$14.2 billion to \$43 billion for the year. Although our numbers are much higher, all the studies tend to justify that protective investments are justified, unless the probability of attack is perceived as very low.

Our research group also undertook two companion studies of the possible effects of border closure associated with a pandemic avian flu outbreak. This could be either a natural event or a planned terrorist attack. Such an attack might lead to an extreme response, border closure. This would include no international migration, no international travel and no commodity trade (apart from oil imports) for a full year. The economic costs are very high, about \$2.1 trillion, and the impacts vary from state to state (Gordon et al., 2008). Interestingly, the magnitude of estimated costs is close to the cited median dollar value of expected loss of life (386,000 deaths according to Murray et al., 2006). However, a problem

with this type of research is how can we model extreme events? Most available models focus on perturbations at the margin. Yet, policy makers are compelled to think about events beyond the margin. For example, work by RAND researchers on the effects of nuclear attack makes use of “scenario analysis” and “strategic gaming” exercises that rely fundamentally on expert judgment (Meade and Molander, 2007; see also Carter, et al., 2007).

The second study (Rose et al., 2008), using a macroeconomic model (the REMI model) predicted a reduction in GDP of as much as \$1.4 trillion measured in 2006 dollars, or about 10.5 percent of GDP (Rose et al., 2008). Employment losses were predicted to be over 22 million, or more than 12 percent below base levels. The authors suggested that these estimates might be upper bounded, and that inclusion of several aspects of resilience, such as input substitution and domestic excess capacity, might reduce them.

6. CONCLUSIONS

This paper sums up some of the research that our economic modeling team at CREATE has been working on for the past three years. The research is both methodological and substantive. The methodological innovation is to emphasize the spatial dimensions of the economy. This requires trade flows and the networks over which they flow be recognized in the models. The substantive approach is to consider the business interruption consequences of bomb attacks, both radiological and conventional, at the twin ports of Los Angeles-Long Beach. The economic impacts are very substantial. Although the potential loss of life from terrorist attacks attracts more attention and, no doubt, would have serious psychological effects, the business interruption impacts are large enough to persuade terrorists that economic targets are as “productive” as human targets.

How can our modeling approaches support standard benefit-cost analysis? We introduced our approach by noting that it is comparatively simple to apply and that its findings could aid policy makers concerned with hardening vital facilities. We can also indicate that our models emphasize network effects and are, therefore, a prerequisite to cost-benefit analysis. The marginal value of any facility is only known once the system-wide losses of its removal are known. But system-wide losses can only be estimated once adaptations and substitutions have been examined. This is the value of TransNIEMO and explains our high hopes for its widespread application.

Our position is that, both, plausible terrorist attack scenarios and the proper models to use must include geographic detail. There are several reasons for this. First, there is no such thing as a generic national seaport or airport or other similar target. Second, most political decision makers represent geographic areas and have a keen interest in these constituencies. Third, aggregation over spatial units may net out important distinctions because there may be situations where there are areas and sectors with losses but others with gains, especially if locations outside the impact area take on the functions that have been lost. Fourth, by considering the spatial economy, interactions between places that rely heavily on the available infrastructure, including major seaports and airports, can be analyzed.

REFERENCES

- Balvanyos, T. and L. B. Lave (2005) "The Economic Implications of Terrorist Attack on Commercial Aviation in the USA," report to the Center for Risk and Economic Analysis of Terrorism (CREATE), University of Southern California, Los Angeles.
- Carter, A.B., M.M. May and W.J. Perry (2007) "The Day After: Action Following a Nuclear Blast in a U.S. City" *Washington Quarterly*, 30: 19-32.
- Cho, S., P. Gordon, J. E. Moore, II, H. W. Richardson, M. Shinozuka, and S. E. Chang (2001) "Integrating Transportation Network and Regional Economic Models to Estimate the Costs of a Large Urban Earthquake," *Journal of Regional Science*, 41 (1): 39-65.
- Garin, R.A. (1966) "A Matrix Formulation of the Lowry Model for Intrametropolitan Activity Allocation" *Journal of the American Institute of Planners* 32: 361-364.
- Gordon, P, J.E. Moore, II, J.Y. Park, and H.W. Richardson (2007), "The Economic Impacts of a Terrorist Attack on the U.S. Commercial Aviation System", *Risk Analysis* 27:505-512.
- Gordon, P, J.E. Moore, II, J.Y. Park and H.W. Richardson (forthcoming) in "The Economic Impacts of Border Closures: A State-by-State Analysis" in H.W. Richardson, P. Gordon and J.E Moore II *Global Business and the Terrorist Threat*. Cheltenham, UK, Northampton, MA, USA: Edward Elgar.
- Ito, H. and D. Lee (2005) "Assessing the Impact of the September 11 Terrorist Attacks on U.S. Airline Demand" *International Journal of the Economics of Business*, 57:75-95.
- Lowry, I.S. (1964) *A Model of Metropolis* Report RM 4125-RC. Santa Monica: Rand.
- Meade, C. and R.C. Molander (2007) *Considering the Effects of a Catastrophic Terrorist Attack*. Santa Monica, CA: Rand, Center for Terrorism and Risk Policy.
- Murray, C.L., A.D. Lopez, B. Chin, D. Feehan and K.H. Hill (2006), "Estimation of potential global pandemic influenza mortality on the basis of vital registry data from the 1918-20 pandemic: a quantitative analysis," *The Lancet*, 368, 2211-18.
- Park, J., P. Gordon, J. E. Moore, II, and H. W. Richardson (2007) "Simulating the State-by-State Effects of Terrorist Attacks on Three Major U.S. Ports: Applying NIEMO" in H.W. Richardson, P. Gordon, and J. E. Moore, II (eds.). *The Economic Consequences of Terrorism*, Cheltenham, UK, Northampton, MA, USA: Edward Elgar, 208-234.
- Richardson, H.W., P. Gordon, J. E. Moore, II, S. Kim, J. Park, and Q. Pan (2007) "Tourism and Terrorism : the National and Interregional Economic Impacts of Attacks on Major U.S. Theme Parks" in H.W. Richardson, P. Gordon, and J. E. Moore, II (eds.). *The Economic*

Consequences of Terrorism, Cheltenham, UK, Northampton, MA, USA: Edward Elgar, 235-253.

Richardson, H.W., P. Gordon, J. E. Moor, II, J. Park and Q. Pan (2008) "The Economic Impacts of Alternative Terrorist Attacks on the Twin Ports of Los Angeles and Long Beach" in J. M. Quigley and L. A. Rosenthal (eds.) *Risking House and Home: Disasters, Cities, and Public Policy*, Berkeley, California: Berkeley Public Policy Press, 173-19

Rose, A., R.B. G. Asay, D. Wei and B. Leung (forthcoming) "Macroeconomic Impacts of Shutting down the U.S. Borders in Response to a Security or Health Threat" in H.W. Richardson, P. Gordon and J.E Moore II *Global Business and the Terrorist Threat*. Cheltenham, UK, Northampton, MA, USA: Edward Elgar.

Rossoff H. and D. von Winterfeldt (2007) "A risk and economic analysis of dirty bomb attacks on the ports of Los Angeles and Long Beach" *Risk Analysis* **27** (3): 533-554.

Sandler, T., D.G. Arce and W. Enders (2008) *Terrorism* Copenhagen Consensus 2008 Challenge Paper.

Santos, J. R. and Y.Y. Haimen (2004) "Modeling the Demand Reduction Input-Output (I-O) Inoperability Due to Terrorism of Interconnected Infrastructures" *Risk Analysis*, **24**:6, 1437-1451.

TABLE 1. SCPM Impact Studies

Studies	Scenarios	Impact Areas	Direct Output Loss (\$Million)	Total Output Loss (\$Million)	Direct Job Loss	Total Job Loss	Passenger Travel Cost Loss ^a (\$Million)	Freight Travel Cost Loss ^b (\$Million)	Total Travel Cost Loss (\$Million)	Total Loss (\$Million)
Port Closure	15-Day Closure of the Ports of Los Angeles and Long Beach ^{1, 2}	City of Los Angeles	264	423	1,187	2,640				
		City of Long Beach	69	88	502	657				
		Los Angeles Region	946	1,522	4,354	9,606				
		Out of Region	1,782	2,736	8,050	16,914				
		Total	2,728	4,259	12,404	26,521	24	25	49	4,284
	120-Day Closure of the Ports of Los Angeles and Long Beach ^{1, 2, 3}	City of Los Angeles	2,114	3,386	9,496	21,116				
		City of Long Beach	554	700	4,009	5,249				
		Los Angeles Region	7,564	12,179	34,831	76,850				
		Out of Region	14,256	21,892	64,401	135,316				
		Total	21,820	34,071	99,232	212,165	-207	117	-90	34,189
	One Year Closure of the Terminal Island ²	City of Los Angeles	2,849	4,538	13,087	28,503				
		City of Long Beach	621	816	4,143	5,787				
		Los Angeles Region	9,991	16,115	45,749	101,485				
		Out of Region	18,687	28,755	84,920	178,482				
		Total	28,678	44,870	130,669	279,967	-395	337	-58	45,207
Plume	All people in the plume area will evacuate for one week and they can travel through the plume area through highway and local roads	County of Los Angeles	0	0	0	0				
		Los Angeles Region	0	0	0	0				
		Out of Region	0	0	0	0				
		Total	0	0	0	0	-4,818	-436	-5,254	-5,254

	All businesses in the plume area are shut down for a week.	County of Los Angeles	0	0	0	0				
		Los Angeles Region	0	0	0	0				
		Out of Region	0	0	0	0				
		Total	0	0	0	0	-3,970	-923	-4,893	-4,893
	Property values in this area drop by 25% for a year, then come back to their original values	County of Los Angeles	86	118	1,163	1,498				
		Los Angeles Region	86	138	1,163	1,702				
		Out of Region	19	29	168	278				
		Total	104	167	1,332	1,981	104	-2	101	269
	Retail business drops by 25% for one year, due to customers not wanting to drive into these areas, then come back to their original levels	County of Los Angeles	0	0	0	0				
		Los Angeles Region	0	0	0	0				
		Out of Region	0	0	0	0				
		Total	0	0	0	0	68	21	89	89
	The impact area lost 25% Retail and 10% other businesses. The impacted businesses are gone rather than relocated to other part of the region.	County of Los Angeles	1,755	2,519	21,156	29,000				
		Los Angeles Region	1,755	2,981	21,156	33,828				
		Out of Region	576	970	4,856	8,741				
		Total	2,331	3,950	26,013	42,574	-232	-50	-281	3,669
	The impact area lost 25% Retail and 10% other businesses. They will be relocated to the area with maximum attractiveness to the origin and also within 30 minute travel time from the origin	County of Los Angeles	0	0	0	0				
		Los Angeles Region	0	0	0	0				
		Out of Region	0	0	0	0				
		Total	0	0	0	0	-290	-38	-328	-328

Worst Case Port Closure and Port Plume	One Year Closure of the Terminal Island	County of Los Angeles	8,662	13,434	53,369	97,535				
		Los Angeles Region	11,745	19,096	66,905	135,313				
		Out of Region	19,263	29,724	89,776	187,223				
		Total	31,009	48,820	156,682	322,541	-627	288	-339	48,877
Downtown Los Angeles	Exit Scenario, for All Businesses and Households Moving out of the Inner and Outer Impact Zones ^{*4}	City of Los Angeles	2,304	2,941	7,257	13,389				
		Los Angeles Region	2,304	5,175	7,257	34,983				
		Out of Region	313	726	1,363	5,408				
		Total	2,617	5,901	8,620	40,391				5,901
	Relocation Scenario, for All Businesses and Households Moving out of the Inner and Outer Impact Zones and Relocating in the Region ^{*4}	City of Los Angeles	1,567	1,567	5,099	5,099				
		Los Angeles Region	0	0	0	0				
		Out of Region	0	0	0	0				
		Total	0	0	0	0				0
	Hybrid Scenario, Inner Zone Firms Exit While Outer Zone Firms and Households Relocate ^{*4}	City of Los Angeles	2,162	2,771	6,643	12,503				
		Los Angeles Region	2,220	4,968	6,643	33,157				
		Out of Region	284	656	1,200	4,843				
		Total	2,504	5,624	7,843	38,000				5,624

Notes: a. Personal trip cost is assumed to be \$13.00 per passenger car equivalent (PCE) per hour.
b. Freight trip cost is assumed to be \$35.00 per PCE per hour.

Citations: Port Closure

1. H. W. Richardson, P. Gordon, J. E. Moore, J. Park and Q. Pan (2008), "The economic impacts of alternative terrorist attacks on the twin ports of Los Angeles – Long Beach," in J. M. Quigley, and L. A. Rosenthal, eds., *Risking House and Home: Disasters, Cities, Public Policy*, Berkeley, California: Berkeley Public Policy Press.
2. Gordon, P., J. Moore, H. W. Richardson, and Q. Pan (2006) "The costs of a terrorist attack on Terminal Island at the twin ports of Los Angeles and Long Beach," in J. Haveman and H. Schatz, eds., *Protecting the Nation's Seaports: Balancing Security and Cost*, Public Policy Institute of California.
3. Gordon, P., J. Moore, H. W. Richardson, and Q. Pan, (2005) "The economic impacts of a terrorist attack on the twin ports of Los Angeles – Long Beach," in H. W. Richardson, P. Gordon, and J. E. Moore, eds., *The Economic Impacts of Terrorist Attacks*, Cheltenham, UK: Edward Elgar Publishing.

Downtown LA

4. Pan, Q., Gordon, P., J. Moore, and H. W. Richardson (2008) "Economic impacts of terrorist attacks and natural disasters: Case studies of Los Angeles and Houston," in Daniel Z. Sui and Susan L. Cutter (ed.) *Geospatial Technologies and Homeland Security: Research Frontiers and Challenges*, Springer.
5. Pan. Q. , H. W. Richardson, P. Gordon, and J. Moore (2007) "The Economic Impacts of a Terrorist Attack on the Downtown Los Angeles Financial District," *Spatial Economic Analysis* (submitted and under review)

TABLE 2: Sum of Intra- and Interstate Impacts Associated with a 120-day Shutdown of the Ports of Los Angeles and Long Beach (\$M)

Location	Impacts	Interstate Impacts Calculated via NIEMO							
Southern CA	4,874.58	AL	106.35	IN	209.76	NE	99.9	RI	19.14
Rest of CA	5,545.64	AK	12.17	IA	142.25	NV	51.6	SC	66.12
Direct Impact: Exports:	16,233.20	AZ	211.83	KS	126.21	NH	28.48	SD	26.52
Direct Impact: Imports	56,107.13	AR	100.69	KY	115.05	NJ	167.	TN	132.92
US Total	89,817.26	CO	123.88	LA	307.54	NM	26.1	TX	1,546.39
Rest of World	492.02	CT	63.28	ME	21.25	NY	216.38	UT	125.31
World Total	90,309.29	DE	20.04	MD	45.09	NC	130.76	VM	9.51
		DC	2.47	MA	86.01	ND	19.22	VA	66.99
		FL	123.19	MI	216.96	OH	303.19	WA	313.64
		GA	102.26	MN	133.34	OK	106.47	WV	41.75
		HI	21.31	MS	57.91	OR	198.81	WI	208.17
		ID	48.57	MO	141.71	PA	243.81	WY	25.71
		IL	279.47	MT	64.21				

TABLE 3. NIEMO Impact Studies

Source of Economic Impact	Targets	Total Economic Impacts (\$M)					Base-year, Duration, and Model
		Supply-side (or Imports)		Demand-side (or Exports)		Total	
		Direct Impacts	Indirect Impacts	Direct Impacts	Indirect Impacts		
Sea Ports Shut Down ^{1,2}	LA / LB,	14,222	0	4,115	4,921	23,258	2001, one-month, and demand-driven NIEMO
	Houston	3,219	0	3,141	3,690	10,050	
	NY / NW	6,700	0	4,694	5,430	16,824	
Theme Parks Shut Down ³	Cluster A (FL)			14,185	10,736	24,921	2004, 18 months, and demand-driven NIEMO
	Cluster B (CA)			13,470	10,146	23,616	
	NV			11,944	8,991	20,935	
	FL (i)			11,884	8,974	20,858	
	CA (i)			11,933	9,006	20,939	
	OH (i)			11,886	8,988	20,874	
	OH (ii)			11,871	8,975	20,846	
	NJ (i)			11,866	8,949	20,815	
	CA (ii)			11,899	8,981	20,880	
	NJ (ii)			11,851	8,939	20,790	
	PA			11,836	8,941	20,777	
	VA			11,818	8,929	20,747	
	IL			11,839	8,942	20,782	

Citations:

1. Park, J.Y., P. Gordon, J. E. Moore II, and H. W. Richardson, L. Wang, 2007, "Simulating The State-by-State Effects of Terrorist Attacks on Three Major U.S. Ports: Applying NIEMO (National Interstate Economic Model)"p.208-234, in H.W. Richardson, P. Gordon and J.E. Moore II, eds., The Economic Costs and Consequences of Terrorism. Cheltenham: Edward Elgar.
2. Park, J.Y., 2008, "The Economic Impacts of a Dirty- Bomb Attack on the Los Angeles and Long Beach Port: Applying Supply-driven NIEMO," Journal of Homeland Security and Emergency Management, 5 (1), Article 21.
3. Richardson, H. W., P. Gordon, J. E. Moore, II, S.J. Kim, J.Y. Park, and Q. Pan, 2007, "Tourism and Terrorism: The National and Interregional Economic Impacts of Attacks on Major U.S. Theme Parks," p.235-253, in H.W. Richardson, P. Gordon and J.E. Moore II, eds., The Economic Costs and Consequences of Terrorism. Cheltenham: Edward Elgar.

Figure 1. Southern California Planning Model (SCPM) 2005 Flow Chart

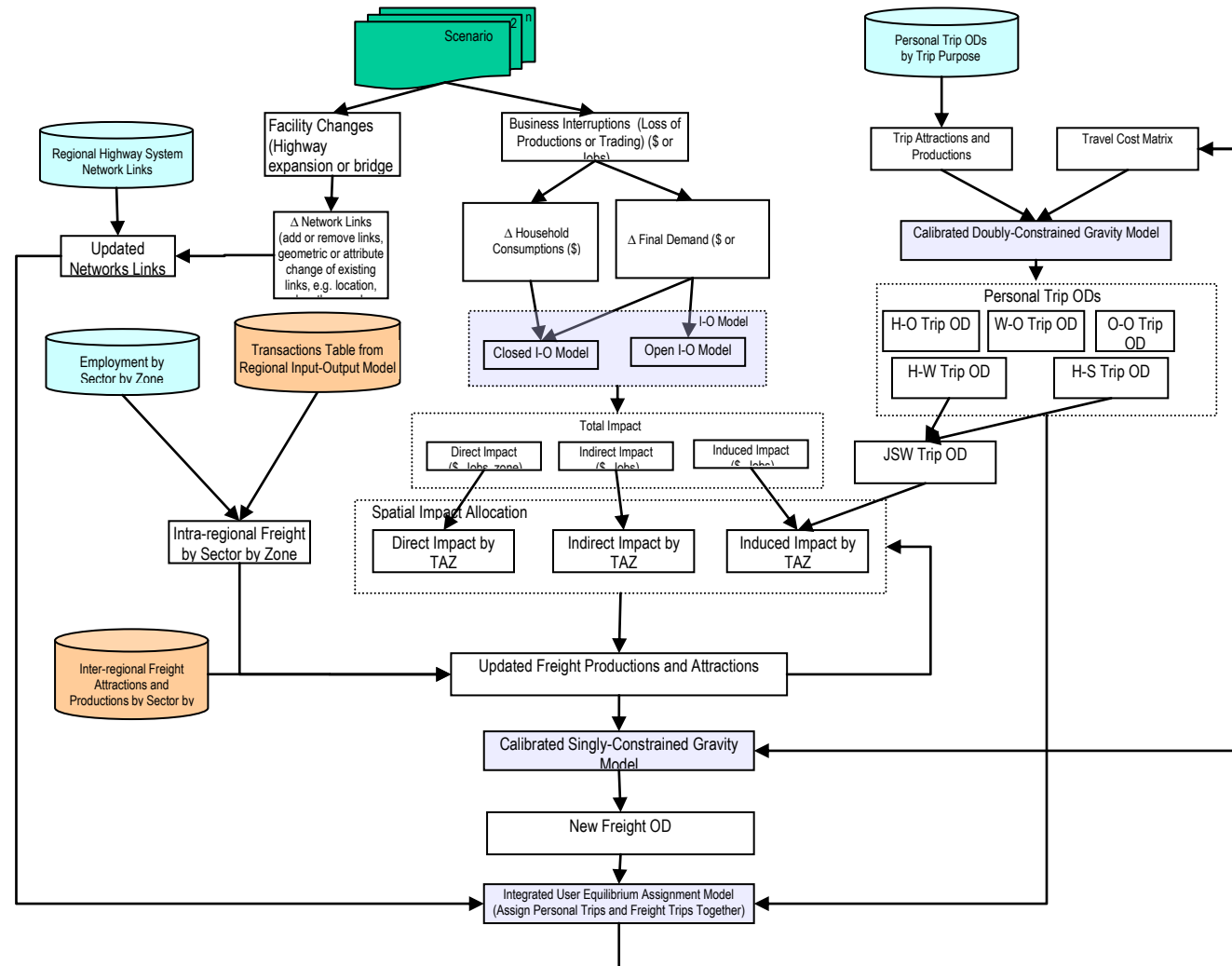


Figure 1 Notes:

1. Baseline is established when all the changes (Δ network, Δ final demand, and Δ Household Consumptions) are zero
2. Initial travel cost matrix is established by loading empty personal and freight trip ODs to road network
3. User equilibrium is approached by multiple loops until the changes of objective function values become flat.
4. H-O, W-O, O-O, H-W, H-S are home-other, work-other, other-other, home-work, and home-shop trip matrix.
5. JSW is journal-shop-to-work trip matrix.
6. Inter-regional freight attractions and productions are inbound and outbound freight trips at major freight generators (ports, airports, rail yards, warehouse/distribution nodes, and highway entry-exit points).

Please see “Assembled and processed freight shipment data by developing a GIS-Based origin-destination matrix for Southern California freight flows,” “Freight Data Assembling and Modeling: Methodologies and Practice,” and “Estimating Freight Flows for Metropolitan Area Highway Networks Using Secondary Data Sources” for details about inter-regional freight data collection and processing.

Figure 2. National Interstate Economic Model (NIEMO)

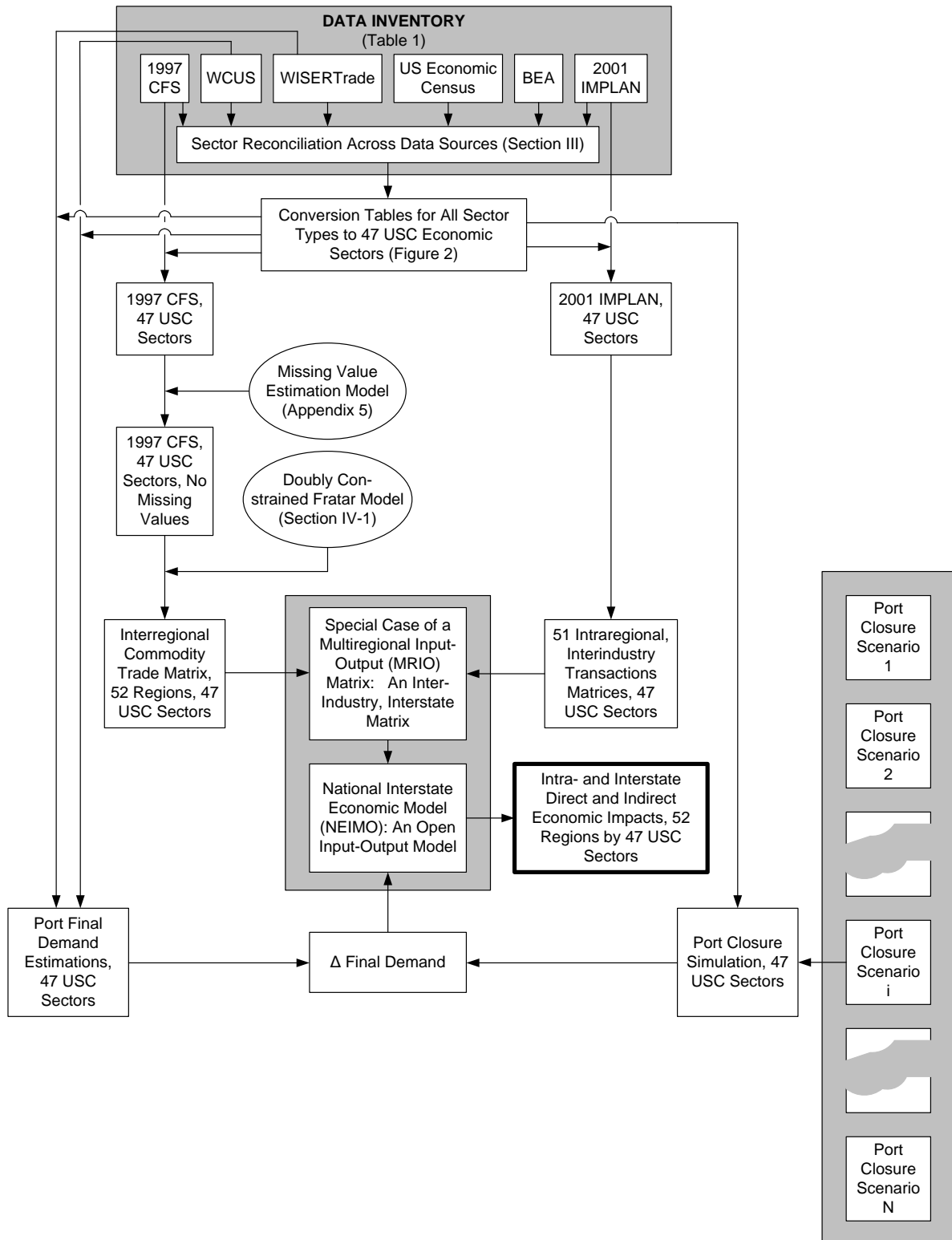


Figure 3. TransNIEMO: NIEMO Plus the Road Network

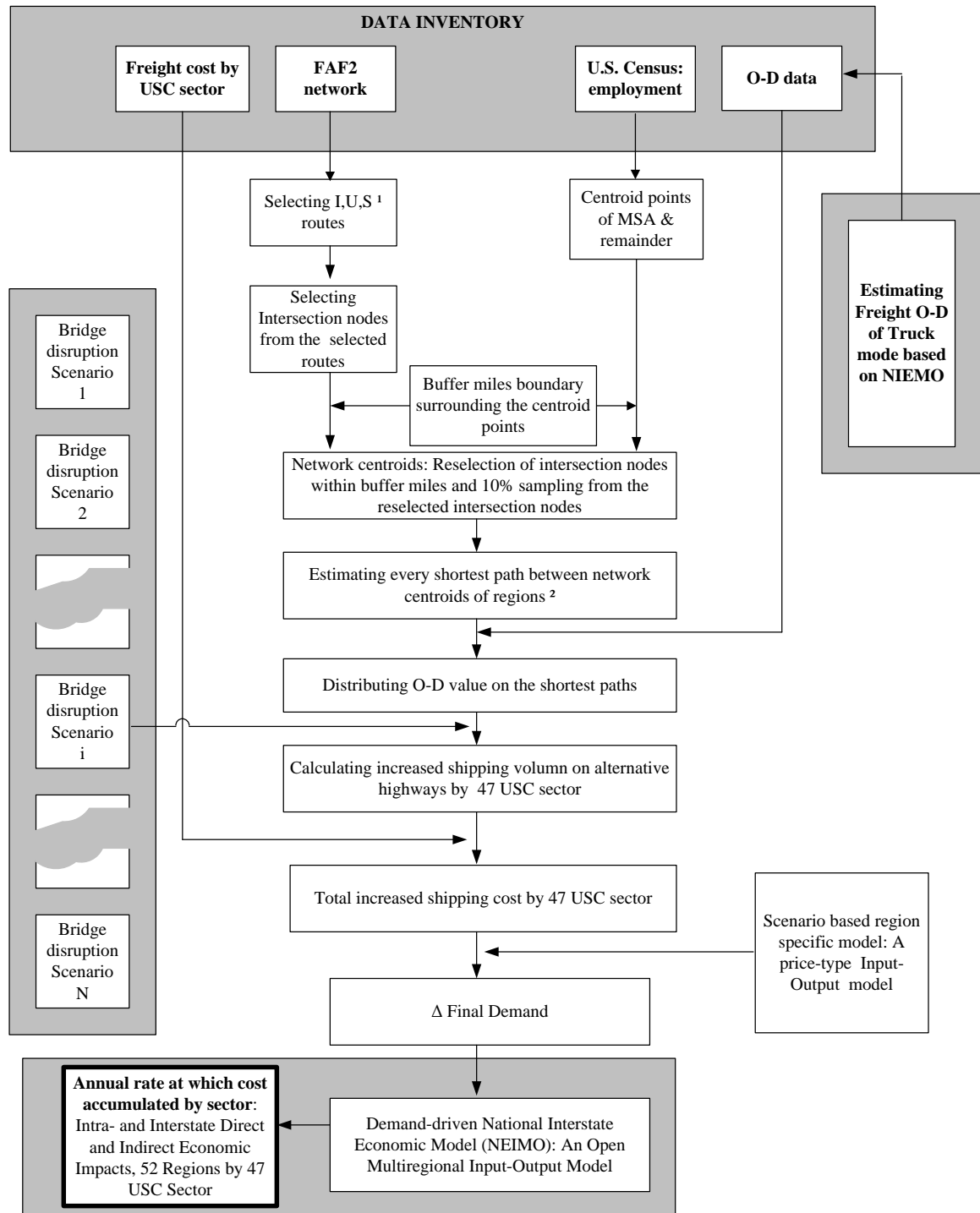


TABLE A1: Estimates of the Costs of the 9/11 Attack

Total Costs (billions)	Capital Losses	Job Losses	Loss of Life	Airlines Losses	Disability	Travel	GDP ¹ /GCP	Other Costs	Total
New York City									
Bram et al. (2002)	21.6	3.6-6.4	7.8						33-36
Chernick & Haughwout (2006)	30						11.5	0.897	
Ito & Lee (2005)				1.1					
Looney (2002)	27.2								27.2
NY Governor and State Division of the Budget ² (2001)	33.8							20.2	54
NY State Ways and Means Committee (2002)			11					16	27
NY State Senate Finance Committee ³ (2002)	33	15.145	4-6			4.6		0.341	57.1-59.1
NYC Office of the Comptroller (2002)	21.8		8.7		0.944		52.3-64.3	0.943	82.8-94.8
NYC Partnership and Chamber of Commerce ⁴ (2002)	44		10	0.75-1.0		7-11		7.6	83
United States									
DeVol et al. (2002)				1.1			175		176.1
NY State Senate Finance Committee ³ (2002)		424.4					639.3		639.3

Notes:

1. GDP is only used in the total estimate when it would not double count other costs. Some articles do not contain a total cost as they only examined specific aspects of the economy. Individual costs do not necessarily add up to total costs as some studies are incomplete.
2. It is unclear how the NYC Partnership and Chamber of Commerce counts different types of costs.
3. The NY State Senate Finance Committee uses the estimated amount of compensation claims for potential earnings. This article is also used twice: once for national losses and once for New York City losses. For the capital costs they used figures calculated by the NY Governor and State Division of the Budget and the New York City Mayor's Office.
4. The NY Governor and State Division of the Budget count \$3 billion as losses from 9/11 that is actually part of a separate economic stimulus package, according to the GAO study, "Impact of Terrorist Attacks on the World Trade Center."

Assembled by Philip Partyka-Hall.