

**THE ECONOMIC IMPACT OF A TERRORIST ATTACK ON
THE TWIN PORTS OF LOS ANGELES-LONG BEACH**

CREATE Report

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Abstract

The Los Angeles metropolitan region is a prime target for a terrorist attack. There are many specific targets: the Los Angeles International Airport (LAX), downtown high-rises, its theme parks, its freeways, and its ports, among many others. We have developed a spatially disaggregated economic impact model that can evaluate all of these and any other plausible attacks. In this paper, we estimate the economic impacts of an attack on the Los Angeles-Long Beach Twin Ports.

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Introduction

The Los Angeles metropolitan region is (because of its size, visibility and diversity) a prime target for a terrorist attack. There are many specific targets: the Los Angeles International Airport (LAX), downtown high rises (with the highest skyscraper – the US Bank Tower¹ – west of the Mississippi), its theme parks (e.g. Disneyland, Universal Studios), its freeways (some of the interchanges have the highest traffic densities in the United States), and its ports, among many. We have developed a spatially disaggregated economic impact model that can evaluate all of these and any other plausible attacks. As a representative example, in this research we consider moderate radiological bomb (so-called “dirty bomb”) attacks at the twin ports of Los Angeles and Long Beach. Because these two ports handle almost one-half of the United States seaborne international trade, any disruption of their trade is likely to have major economic impacts. However, this kind of attack is not the most dangerous imaginable because it would involve minimal destruction of infrastructure. Many of its impacts would be more psychological, and much would depend on the length of time before the authorities thought it safe to reopen the ports. Accordingly, our scenarios also include simultaneous attacks on freeway access to the ports that would magnify the adverse economic impacts. These would not only delay the emergency response but would also stretch out the disruption period because it would take a longer time to rebuild destroyed bridges (or construct temporary bridges), and alternative routes (in the port access region) are few and would be highly congested.

The Ports and the Local Economy

Tables 1 and 2 provide some basic data about the port’s role in the local economy. In a metropolitan region of 16.4 million people, the twin ports of Los Angeles and Long Beach account for 103 million tons of seaborne trade, the third largest port complex in the world (after Hong Kong and Singapore) and catching up fast. Directly and indirectly, the ports employ over half a million workers, accounting for almost seven percent of the region’s labor force. In terms of containerized traffic, the two ports ranks first and second nationally. To put it in perspective, its combined trade (imports and exports) of more than \$140 billion is equivalent to about 17 percent of the region’s gross regional product. Reflecting the national economy, imports are much more important than exports (\$90 billion compared with \$52 billion), and about one-half of the imports and two-thirds of the exports are to and from outside the region. In other words, the ports fulfill a national even more than a regional function. Thus, the Port of Los Angeles and the Port of Long Beach are of central importance to the regional economy, and the loss of transshipment capabilities at these sites has

¹ It is the tallest building in Los Angeles County, formerly known as the Library Tower. It is located in downtown Los Angeles at 633 West Fifth Street. With 73 floors, it stands at 1,018 feet in height. It is the tallest building between Chicago (the nation’s tallest building is the Sears Tower with 110 floors at 1,450 feet) and Southeast Asia (the Petronas Towers in Kuala Lumpur, Malaysia has 88 floors and is 1,483 feet tall). The building is the 7th tallest building in the United States and the tallest outside of Chicago, New York, and Atlanta. Although it is not adjacent to the central library, its former description as the Library Tower reflects the fact that the developers provided substantial funds for renovating the library in exchange for air rights. The building, designed by the architectural firm Pei, Cobb Freed & Partners, was completed in 1990. It is designed to withstand an 8.3 earthquake on the Richter Scale, but perhaps not a bomb attack.

profound impacts. We assume that both export and import flows currently using seaport facilities would terminate for as long as the ports were out of service (the issue of port diversion is addressed below).

“Dirty Bomb” Attacks

It is well known that the ports have been highly vulnerable since 9/11 because of the infrequency of container checks. On July 1, 2004, new rules were introduced to increase the degree of protection. The measures include replacing hand-held radiation detectors with stationary radiation screening devices analogous to the X-Ray screening of passenger luggage at airports and efforts to screen all containers (estimated at 11 million per annum through the twin ports). However, these more advanced measures will not be in place until much later, and their effectiveness has yet to be tested (see Chapters x and y). Also, although the details of the testing procedures are not fully known, it may be easier to plant *simultaneous* radiological bombs (assuming that terrorists have access to radiological material in the United States) on outbound rather than inbound freight, especially because the effects may not be very different if the bombs are set off at the perimeter (prior to passing through security) rather in the heart of the port terminals.

The extent of disruption may depend on the size of the bombs. As social scientists we have minimal knowledge of the technical aspects of radiation contamination and exposure, and our sole concern is with how these translate into a period of closure of the ports. Thus, the rest of this paragraph draws on the external technical literature. Hypothetically, we assume 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. Blast damage would be quite limited, with deaths and serious injuries within a range of about 15 meters and with very limited damage to physical infrastructure. The evacuation zone would include all areas with exposure > 1 REM, probably within the 5 -10 km² range, but this depends on weather conditions (wind speed, direction, precipitation, etc.). In any event, this would require the closure of both ports on health even more than on security grounds. The early phase of exposure lasts about 4 days (EPA guidelines); the time frame for intermediate and later phases is variable and subjective (weeks, months, even years). We ignore the plume beyond the port, which might extend several miles in one of a number of directions; however, it would be a very short-term event.

When the ports would be reopened would be a policy rather than a technical decision. For the purposes of our economic impact analysis, we assume two alternative closure times (the “bookends” of our analysis): 15 days and 120 days. The 15-day closure assumes no mitigating adjustments (e.g. major diversions to other ports and transport modes), while the 120-day closure also involves road access disruptions and might involve adjustments in behavior (e.g. exploring other sources for inputs and other transshipment points for sales). These closure periods are chosen for illustrative purposes; they seem reasonable, but it is easy to substitute alternative closure periods and make new impact estimates based upon them. We examine two different types of impact. The first and most obvious but the lesser type is the primarily local effects of the cessation of port activities (i.e. the effects of a decline in final demand for port services). The second type is the economic consequences of the interruption of trade flows, both imports and

exports. These affect the economic activities of all firms directly or indirectly involved in international trade throughout the region and beyond. These impacts, both in terms of output and jobs, are much larger than the local effects.

Precedent

To our knowledge, there has been no detailed prior study of the economic impacts of port disruption because of a terrorist attack. At first sight, the port strike of 2002 might offer some relevant information. However, the strike was confined to Los Angeles; Long Beach was unaffected. More important, the strike was anticipated for at least six months so that measures were already in place to mitigate its impacts; the timing of a terrorist attack, on the other hand, is unpredictable. Thus, what happened then is of very limited significance in evaluating the consequences of an unanticipated terrorist attack. Also, as the passing reference to the strike in Chapter 7 suggests, most estimates of the costs were grossly inflated. Media reports at the time of the 2002 ports strike widely quoted cost estimates of \$1 billion per day. The origins of this estimate are unknown, but it is much too high. Over 120 days, it would amount to about 15 percent of Gross Regional Product. Accordingly, it is a reference base of limited value.. Nevertheless, studying what happened before and during the strike may be helpful in the design of anticipatory and prevention strategies.

The Bridges

In this study, we consider supplementing radiological bomb attacks on the ports with the destruction of access bridges. We modeled the destruction of two major access bridges (on I-10 and I-710 south of the I-405 freeway) and the Vincent Thomas Bridge linking the two ports. The last of these is important because it would deny access to both Terminal Island and the Alameda Corridor (see below) from the west and would break the link between the two ports..

The Southern California Planning Model (SCPM)

Interindustry models are among the most widely used models to measure regional economic impacts. They attempt to trace all the impacts, including those of intra- and interregional shipments, usually at a high level of sectoral disaggregation. Being demand driven, they account primarily for losses via backward linkages.

The first Southern California Planning Model Version 1 (SCPM1) was developed for the five-county Los Angeles metropolitan region, and has the unique capability to allocate all impacts, in terms of jobs or the dollar value of output, to 308 sub-regional zones, mainly individual municipalities. This is the result of an integrated modeling approach that incorporates two fundamental components: input-output and spatial allocation. The approach allows the representation of estimated spatial and sectoral impacts corresponding to any vector of changes in final demand. Exogenous shocks treated as changes in final demand are fed through an input-output model to generate sectoral impacts that are then introduced into the spatial allocation model.

The first model component is now built upon the Minnesota Planning Group's well-known IMPLAN input-output model which has a high degree of sectoral disaggregation (509 sectors). The second basic model component is used for allocating sectoral impacts across 308 geographic zones in Southern California. The key is to adapt a Garin-Lowry style model for spatially allocating the induced impacts generated by the input-output model. The building blocks of the SCPM1 are the metropolitan input-output model, a journey-to-work matrix, and a journey-to-nonwork-destinations matrix. This is a journey-to-services matrix that is more restrictively described as a "journey-to-shop" matrix in the Garin-Lowry model.

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 transaction trips, but excludes non-transaction-based trips such as trips to visit friends and relatives. Data for the journey-to-services matrix include all trips classified by the Southern California Association of Governments as home-to-shop trips, and a subset of the trips classified as home-to-other and other-to-other trips.

The key innovation associated with SCPM1 is to incorporate the full range of multipliers obtained via input-output techniques to obtain detailed economic impacts by sector and by submetropolitan zone. SCPM1 follows the principles of the Garin-Lowry model by allocating sectoral output (or employment) to zones via a loop that relies on the trip matrices. Induced consumption expenditures are traced back from the workplace to the residential site via a journey-to-work matrix and from the residential site to the place of purchase and/or consumption via a journey-to-services matrix (see Richardson *et al.*,1993) for a further summary of SCPM1.

Incorporating the Garin-Lowry approach into spatial allocation makes the transportation flows in SCPM1 exogenous. These flows are also relatively aggregated compared with transportation models, defined primarily at the level of political jurisdictions (most transportation models use Traffic Analysis Zones [TAZs] which are much smaller). However, with no explicit representation of the transportation network, SCPM1 has no means to account for the economic impact of changes in transportation supply. Terrorist attacks are likely to induce such changes, including capacity losses that will contribute to reductions in network level service and increases in travel delays. SCPM1 does not account for such changes in transportation costs, underestimating the costs of any exogenous shock.

In this study we use a more refined version of SCPM that endogenizes traffic flows by including an explicit representation of the transportation network. We call this SCPM2 (see Figure 1). Models of this type are based on data from a variety of different sources. Consequently updating and reconciling data resources is an ongoing activity. Currently, we are also developing a much more sophisticated model that:

- revisits and re-evaluates many of the fundamental assumptions of SCPM2;
- accounts for nonhighway access to the ports;
- involves a much more detailed sectoral-spatial allocation of economic activity within the Southern California five-county region (Gordon *et al.*, 2004); and
- also integrates this updated SCPM2 with an interstate freight model (the National Interstate Economic Model, i.e. NIEMO).

We call the full model SCPM2004. This latter model is still in the course of the development, and the current analysis will be re-estimated when the new version of the model is available. Hence, it should be emphasized that the results reported here are very provisional and incomplete.

SCPM2 results are computed at the level of the Southern California Association of Governments (SCAG) 1,527 traffic analysis zones, and could then be aggregated (if desired) to the level of the 308 political jurisdictions (cities and different types of unincorporated areas) defined for SCPM1. These jurisdictional boundaries routinely cross traffic analysis zones. Results for traffic analysis zones that cross jurisdictional boundaries are allocated in proportion to area. Like SCPM1, SCPM2 aggregates to 17 at the local level the 509 sectors represented in the IMPLAN I-O model. Treating the transportation network explicitly endogenizes otherwise exogenous Garin-Lowry style matrices describing the travel behavior of households, achieving consistency across network costs and origin-destination requirements. The model also accounts for intraregional freight flows. SCPM2 makes distance decay and congestion functions explicit. This allows us to determine the geographical location of indirect and induced economic losses by endogenizing choices of route and destination. This better allocates indirect and induced economic losses over zones in response to direct port-related losses (wherever these losses may occur) in trade, employment and transportation accessibility (see Cho *et al.*, 2001, for a further summary of SCPM2).

Business Interruption

The major impact of port closure (especially from a radiological bomb that does little physical damage) is its effects on businesses. The traditional way to estimate business interruption is via an *ex post* survey of individual firms (e.g. Gordon, Richardson and Davis, 1998). This method has its problems: the representativeness of the sample (especially in a large metropolitan area) and the need to undertake the survey after the event. The approach adopted here is much simpler, although by necessity it focuses on economic sectors rather than individual firms. Also, it has the advantage of an *ex ante* estimate that is very important to measure the resources that might need to be allocated to prevention, mitigation and restoration. Very simply, we shut off exports to and imports from the ports via our freight model and the sectors affected suffer a decline in final demand of sales and/or indirect supplies.

Quantifying the Economic Effects of a Terrorist “Dirty Bomb” Attack on the Twin Ports and Port-Related Transportation Access

This research applies SCPM2 to quantify the potential economic impact of a terrorist attack (more specifically moderate-sized radiological bombs) on the twin ports of Los Angeles and Long Beach, California, and on nearby transportation infrastructure affecting freeway access to the ports. The duration of the disruption determines the length of time for which firms throughout the region will be non-operational or operating below normal levels of service. This allows the calculation of exogenously prompted reductions in demand by these businesses. These are introduced into the interindustry model as declines in final demand. The I/O model translates this production shock into direct, indirect, and induced costs. The indirect and

induced costs are spatially allocated in terms consistent with the endogenous transportation behavior of firms and households. Thus, interrupted trade at the ports is converted into lost economic output and employment, and the effects are modeled zone by zone over the Southern California region as a whole. The results of the modeling show that distributed losses related to these events in Southern California and beyond could exceed \$34 billion, and cost more than 212,000 jobs (measured in person-years of employment).

The spatial economic impact model is able to calculate direct losses within an impact area as well as the distributed economic effects of these losses throughout the regional economy. The model also calculates the geographical economic impacts of disruption to the transportation network. Direct losses arise from lost opportunities to produce goods and services and, in the case of the ports, the capacity to ship goods. Indirect and induced losses arise as people and businesses in the impacted areas become unable to work or generate income as a result of the event. Indirect losses are the losses to suppliers whose products and services are no longer purchased by directly impacted firms and households. Induced losses are losses in secondary consumption as direct and indirect workers are laid off.

For this study, the ports are assumed to be closed for 15 days in the “no bridge damage” scenarios. If a port attack is combined with destroying access bridges, we assume that the impacts extend over 120 days. The 120-days assumption is based on the experience with the La Cienega Boulevard bridge on the I-10 Santa Monica Freeway after the Northridge earthquake which took 4.5 months to rebuild, despite substantial incentives to the construction company. The port could reopen in the reconstruction phase of the bridge damage cases, but trade would be very severely disrupted. In terms of economic impacts, we assume that the differences in bridge damage and no damage scenarios *for the same time period* are primarily reflected in network performance results. These assumptions are for illustrative purposes, but they are easy to adjust. Longer or shorter interruption periods can be scaled proportionately and/or a period of partial operation could be introduced to account for the facilities’ gradual return to service. In other words, our results are illustrative rather than definitive.

Potential damage to the transportation infrastructure in Southern California implies additional impacts over and above the effects of the radiological bombs. For the purpose of this study, freeway segments close to the destroyed bridges were assumed to be closed. The SCPM2 representation of the transportation network includes freeways, state highways, and high design arterials. Small surface streets are not included in the model.

Some degree of trade activity could be possible despite port closures because some trade can be shifted to other ports and some purchases can be diverted to domestic suppliers.. However, these changes are unlikely to occur in the short run. We analyzed six basic scenarios (with subsets: “local” impacts and total impacts), but in the interests of space we will report only three cases here: the local effects on the both ports closed down for 15 and 120 days without bridge damage and the total impacts 120 days with bridge damage:

- Scenarios 1 and 2: The Port of Los Angeles is closed for a period of 15 days (no bridge damage) or 120 days (key bridges destroyed), and all import and export trade is interrupted.

- Scenarios 3 and 4: The Port of Long Beach is closed for a period of 15 days (no bridge damage) or 120 days (key bridges destroyed).
- Scenarios 5 and 6: Both ports are closed for a period of 15 days (no bridge damage) or 120 days (key bridges destroyed).

Tables 3 and 4 show the “local” impacts in the most affected zones in both ports over 15 days and 120 days. Many of these impacts are located close to the ports. The “local” direct losses accrue only in the port and nearby zones (TAZs), but indirect and induced losses can accumulate throughout the region. When both ports are closed down, the direct job loss in the port TAZs is 687 over 15 days and 5,495 over 120 days. The total job loss (including the indirect and induced losses, and the jobs lost outside the region) is 1,258 over 15 days and 10,061 over 120 days, of which more than two-thirds occur within the region, primarily in Los Angeles County. In terms of output, the total impacts are \$138.5 million and \$1,107.6 million, with more than one-half in Los Angeles County.

However, these impacts are relatively small compared to the business interruption effects of the cessation of international trade which affects exporters in terms of the loss of sales and importers, especially in the form of intermediate inputs (e.g. petroleum). Table 5 examines the full range of impacts for both ports. Destroying the bridges severely complicates the problems for the ports. The ports could reopen and shippers could resort to congested surface streets, but at an extreme efficiency cost. The key result combining the impacts on the two ports with the bridges down scenario over 120 days represents the maximum impact scenario. The economic losses amount to more than \$34 billion of lost output and 212,165 person-years of employment. In this case, not much more than one-third of the impacts occur within the region, of which about two-thirds of the local impacts are within Los Angeles County. These numbers underline two key points: the closure of the ports can have major economic consequences and the ripple effects are national, not merely regional.

We developed several maps to show the spatial consequences of each scenario; however, we show only one (Map 1 displays the higher “bookend,” i.e. maximum impact). The important point shown in the map is that in the trade interruption cases the output losses are widely diffused throughout the region. The closure of the ports is not a local event. However, it is not even a regional event. It is a national event and an international event. This explains why the ports are such a significant target.

There are mitigation strategies that could be put in place (these include shipments to and from other ports, transfer of supplies of intermediate goods to domestic sources involving a modal shift from the ports to truck or rail, traffic management measures to get around the destroyed bridges). However, these mitigation measures cannot be included in the model; hence, their effects are discussed in general terms.

Transportation Impacts

The impacts on the transportation network are of two kinds, each offsetting the other. If the ports are closed there are obviously many fewer freight trips to and from the port which will reduce the traffic load on the region. On the other hand, with these critical bridges down congestion increases on the network. The net effect is not predictable *ex ante*. Transportation delays are measured in terms of Passenger Car Unit (PCU) hours and \$ millions.. The number of freight trips declines in each scenario. However, the methodology assumes that the lower level of service resulting from destroyed bridges has no additional trip deterrence effect. Also, the model assumes that the number of auto trips remains constant. These results are shown in Table 6. The monetary value of the transportation impacts are found in Table 7. Negative values represent reductions in delay relative to the baseline. These reductions in delay are because of the container trucks that can no longer access the ports. However, there is an improved level of service for other tripmakers because of this, but being forced from the freeways to the surface streets increases congestion costs. We have no information on the income distribution of automobile drivers so we assume two values, \$6.50 and \$13.00, for travel time, with the true value perhaps somewhere in between. For the purpose of elaboration, we focus on the higher values of Scenario 6 (the 120-day closure of both ports with the bridge interruptions). They suggest that the traffic congestion adds almost \$648 million of delay costs, all of them because of the additional costs to automobile drivers. Freight travel costs are consistently reduced in all scenarios because of canceled freight trips.

From the results above, it is clear that the costs associated with even a moderate radiological bomb at the ports and associated freeway access disruptions result in substantial direct, indirect, and induced costs flowing from lost economic opportunities. This dollar amount over a period of 120 days could be more than \$34 billion, primarily because of the interruptions to export and import flows at the ports. The greatest increase in transportation delays would occur in cases where port trade flows are diverted to other ports and to other modes (for example, bringing in intermediate inputs from outside the region may add to traffic congestion because of the possibility of longer intrametropolitan freight trips). These effects are not modeled.

As a comparison to the results reported here, Cho *et al.* (2001) used a similar methodology to calculate the economic losses associated with a hypothetical magnitude 7.1 earthquake on the Elysian Park blind thrust fault under downtown Los Angeles. They calculated that an earthquake of this type could produce as much as \$135 billion in total costs, with a median amount of \$102 billion. The scenarios defined here amount to as much as 24.2 percent of their maximum estimate (or 73 percent if converted to dollars per year; the earthquake has even more long-lasting effects). This enables a comparison to be made between the economic impacts of a terrorist attack and those of a plausible natural catastrophe.

A Strategic Question

Our study shows that a simultaneous terrorist attack on the ports and major access routes would be much more damaging to the economy than an attack on the port alone, primarily because it takes much longer to rebuild the bridges than to reopen the ports. Also, to our knowledge, these attacks would be relatively easy:

two radioactive bombs on the perimeter of both ports and three explosionary devices at relatively unprotected bridges. Is it desirable to make this knowledge public on the ground of “aiding the enemy?” First, this is an obvious rather than a counterintuitive finding (so there is no disclosure of important security information); the issue is not that there is an additional negative impact but rather how large it is. Second, even if potential terrorists are aware of this, the fact that U.S. counter-terrorism authorities also know it implies that the level of protection would be higher, and this in itself could be a deterrent. Third, quantifying the potential scale of the impact is very important in determining how much to spend on prevention.

A Technical Question

A recurrent problem with transportation network models is how quickly they converge. Appendix 1 shows how convergence was measured while Appendix Fig. 1 gives an example for one of our scenarios. It shows a very rapid convergence after four to five runs. Accordingly, we ran all the network scenarios for six iterations.

Qualifications

There are a few important qualifications to this current research, and we should stress the preliminary nature of the results. Perhaps the most important omission is the potential influence of the Alameda Corridor, a \$2.9 billion 20-mile grade-separated rail corridor from the ports to the marshaling yards north of downtown that opened in April 2002. Our model is currently based on the highway network. The Alameda Corridor currently takes about 13 percent of the ports’ trade, but has the capacity to take much more. By 2025, the objective is to carry 45,000 containers per day out of 90,000 (or almost 33 million per year). The Corridor is currently grossly underutilized, with 35-40 trains per day compared to a capacity of 150 per day. The primary reason is that many distributors find it more convenient to ship goods by truck to the Riverside and San Bernardino County distribution hubs, e.g. Ontario (for repackaging and distribution either by truck or rail). Only the simplest loads use the corridor. An additional 12 percent of trade (2400 containers per day) is trucked to a facility in Carson, then loaded on to the Corridor. One argument in favor of promoting the rail corridor is the alleviation of air pollution from trucks (the potential air pollution risks are in the region of 2,000 cases of cancer per million population compared with policy objectives ranging between one and 100 cases per million).

Alternatives include building one or more truckways, which are even more expensive than the rail corridor. One would run on the I-710 freeway, costing between \$4 and 10 billions (depending upon the number of truck lanes and additional car lanes); another would make SR47 a freeway from the port complex to Alameda St. (costing about \$450 million); while the third, the most expensive and most ambitious, would extend the truckway as far as Barstow, a city 120 miles away. These are unlikely to be built in the foreseeable future, given the transportation cutbacks in the California State budget.

Another idea is to run more trains from the northern terminus (near downtown) to the San Bernardino and Riverside hubs, but the tracks are already congested and it would cost \$100-200 million to

build new unloading and storage facilities at the distribution yards. Also, there are no train lines that run *directly* to the inland hubs. Furthermore, it is more expensive (by about \$100 per container) to ship by rail rather than by truck to the inland hubs. In addition, trade may triple over next 20 years, and the infrastructure to cope with this expansion is not yet there.

Of course, we could have modeled a bomb attack on the Corridor itself, but surmise that a sub-grade rail line could be repaired within a few days.

The 120-day bridge reconstruction period may be optimistic. It would be somewhat faster than the rate achieved after the 1994 Northridge earthquake. Also, if an attack on the Vincent Thomas Bridge brought it down, its rebuilding would be a multi-year rather than a multi-month project. We have not investigated in detail the bridge reconstruction costs, but based on our previous earthquake-related research the two freeway bridges would probably cost about \$50 million each. The Vincent Thomas Bridge is a different scale of magnitude and would be difficult and very expensive to replace (perhaps \$5 billion); however, a single bomb might require only a modest repair. We have not estimated the costs of mortality and radiation-related illness. An attack on this scale would have very moderate human-related costs (except for psychological costs) compared to the massive economic impacts. It is understandable why the public may be more concerned about terrorist events that threaten persons rather than property, but it would be a policy failure to pay too little attention to those events that primarily incur economic rather than human damages

A chronic problem is the expected doubling of freight traffic on the I-710 and other port access freeways by 2025. In the context of a potential terrorist attack, the rail access adds a degree of redundancy into the port-related transportation system. While it is true that an attack on Terminal Island could take down the Badger Rail Bridge, it could be replaced by a temporary structure relatively quickly (see below), while the effects of a bomb on the Alameda Corridor could be remedied even faster. However, rail access exists only to some of the terminals, and the others will not receive such access in the foreseeable future.

Although attention should be paid to the potential diversion of trade to other ports, the medium-term prospects are not promising. Trade might go to other West Coast ports such as Oakland and Seattle-Tacoma, or move through the Panama Canal to Savannah or Jacksonville, or even take an eastern route from Asia via the Suez Canal. However, the other West Coast ports have limited capacity (e.g. Oakland port has not kept up with its dredging schedule while Seattle is beginning to convert port facilities to other waterfront uses), the Panama Canal is operating close to capacity and it would take a decade or more to widen the channel to accommodate the new, larger ships, and shipping from Asia via the Suez Canal would be very expensive. Analysis of port diversion is complicated because of capacity constraints and ship sizes, but obviously diversion is a mitigating factor. However, the consensus among maritime specialists is that the potential for trade diversion, especially within a 120-day time frame, is minimal.

Another issue is whether short-term economic losses would be made up via more deliveries later. In other words, is the problem merely deferred demand rather than lost demand? Also, there may be medium-term substantial substitution possibilities, such as goods from Europe to the East Coast, goods shipped into Canada and Mexico and then via truck into the United States, or diversion to domestic suppliers (e.g.

automobile sales). All these options suggest that our estimates are upper-bound estimates. Our assessment, however, is that these palliatives would have a modest effect.

Future Research

This remains a research project in its early stage. Our economic impact model can easily measure the consequences of days of port closure and degrees of closure. The key problem from our perspective (given our limited knowledge of ports, the shipping industry and supply logistics) is how to come up with these parameters. Our future research will focus on: alternative scenarios, the degree of trade diversion, and on whether lost production and deliveries are merely delays that will be made up later. We will rely heavily on port, shipping and logistics specialists to refine our scenarios.

One scenario that we are definitely investigating is the isolation of Terminal Island, an island located between the two ports that handles approximately 55 percent of the combined port trade and has the most up-to-date loading and unloading facilities. This would be a very cost-effective attack because it would require taking out only three highway bridges and one rail bridge. A temporary trellis rail bridge to put the Alameda Corridor back in service plus restoring highway access might be built in less than 120 days (but at some cost in terms of the blockage of shipping lanes), but it would take years to rebuild the bridges (especially the wide spans of the Vincent Thomas and the Jerry Desmond Bridges). Provisional estimates of the economic losses amount to \$45 billion of output and 280,000 person-years of employment per year (because this is a linear model these numbers can be scaled up or down according to different estimates of the period that the Island cannot be used).

Mitigation and Prevention

The parameters of these impacts give some idea of the resource expenditures that might be justified to attempt to avoid these attacks. Video surveillance of the major bridges and overpasses would appear to be a very cost-effective option (and may even be in place). Attempts to improve the screening of containers in and out of the ports is currently being implemented (see Chapters x and y), but a radiological bomb attack just outside the perimeter would be almost as dangerous and almost risk-free.

Conclusions

The examples presented here illustrate a methodology for calculating the economic impacts of a plausible terrorist attack in Southern California. The examples used are a radiological bomb attack on one or both ports (Los Angeles and Long Beach), in some scenarios supplemented by the destruction of key access freeway bridges. However, the methodology is easily applicable to a wide variety of different types of terrorist attacks. The model distributes the total economic impacts of a terrorist disruption to households and businesses throughout the metropolitan economy and, indeed, to the rest of the country (but in the latter case not in any spatial detail, at least until our national model [NIEMO] is developed and integrated with SCPM). Not all post-event economic behavior is knowable, but this approach makes it possible to calculate

the economic impacts associated with a variety of scenarios, including changes in import and export chains and (potentially) transshipment modes.

The local impacts (i.e. the effects of the closure of the port on labor and other port services) of a radiological bomb attack at the two ports are modest but significant, about \$1.108 billion of lost output and 10,061 person-years of employment (about two-thirds of these impacts occurring within the region, with about 85 percent of these within Los Angeles County). However, the results of this preliminary study with respect to the disruption of international trade (both exports and imports), when the bomb attack is combined with a pinpointed disruption of transportation access to the ports, implies much more damage: up to \$34 billion worth of direct, indirect and induced costs, 212,000 person-years of employment losses, and up to \$648 million imputed time costs of transportation-related delays.

The other implication is that a radiological bomb attack at the ports would have to be large to have a major economic rather than a primarily psychological impact. Interrupting access to the ports by bringing down key bridges would be much more damaging and, unfortunately, easier to carry out. This is merely one example among hundreds of the difficulties that the Department of Homeland Security faces in how to allocate scarce resources among competing options.

Table 1. Basic Data for the Los Angeles Metro Area, 2000

Population	Housing Units	Civilian Labor Force	Median Household Income (1999)	Total Seaborne Trade (short tons)
16,373,645	5,678,148	7,458,249	\$45,903	LA: 42,267,055 LB: 60,882,795

Table 2. Dimensions of Port Activity

	Long Beach	Los Angeles	Total
Imports (\$b.)	52.04	38.09	90.13
Exports (\$b.)	27.76	24.26	52.02
Regional Imports (\$b.)	25.67	21.13	46.80
Regional Exports (\$b.)	8.71	8.67	17.38
Port-related Jobs ('000)	265.8	235.4	501.2

Table 3. “Local” Output and Employment Losses of 15-day Port Closure, Ports of Los Angeles and Long Beach; No Bridge Damage

	GRP (\$1,000s)				Jobs			
	Direct	Indirect	Induced	Total*	Direct	Indirect	Induced	Total*
City of Los Angeles	13,965	5,262	5,068	24,295	125	48	57	230
City of Long Beach	37,058	548	521	38,127	362	5	6	373
County of Los Angeles	51,024	11,966	12,277	75,267	488	106	138	732
County of Orange	0	3,432	3,479	6,911	0	31	39	70
County of Ventura	0	763	907	1,671	0	7	10	17
County of Riverside	0	763	992	1,755	0	7	11	18
County of San Bernardino	0	1,058	1,259	2,317	0	10	15	24
Sum of Five Counties	51,024	17,983	18,915	87,921	488	161	213	861
Regional Leakages	30,286	11,194	9,052	50,529	199	95	102	396
Regional Total	81,310	29,176	27,967	138,453	687	256	315	1,258

Table 4. “Local” Output and Employment Losses of 120-day Port Closure, Ports of Los Angeles and Long Beach; No Bridge Damage

	GRP (\$1,000s)				Jobs			
	Direct	Indirect	Induced	Total*	Direct	Indirect	Induced	Total*
City of Los Angeles	111,723	42,098	40,536	194,356	1,003	381	454	1,838
City of Long Beach	296,467	4,384	4,172	305,023	2,900	37	47	2,984
County of Los Angeles	408,190	95,728	98,216	602,134	3,902	850	1,102	5,854
County of Orange	0	27,454	27,836	55,289	0	248	312	561
County of Ventura	0	6,108	7,258	13,366	0	54	82	136
County of Riverside	0	6,103	7,932	14,035	0	56	92	148
County of San Bernardino	0	8,467	10,075	18,542	0	77	116	193
Sum of Five Counties	408,190	143,860	151,317	703,367	3,902	1,285	1,704	6,891
Regional Leakages	242,290	89,552	72,419	404,229	1,593	760	816	3,170
Regional Total	650,480	233,412	223,736	1,107,596	5,495	2,045	2,520	10,061

**Table 5. Total Output and Employment Losses of 120-day Port Closure,
Ports of Los Angeles and Long Beach; Bridge Damage**

	GRP (\$1,000s)				Jobs			
	Direct	Indirect	Induced	Total*	Direct	Indirect	Induced	Total*
City of Los Angeles	2,112,863	752,657	519,864	3,385,384	9,492	5,788	5,831	21,111
City of Long Beach	553,600	93,227	53,484	700,310	4,008	640	601	5,249
County of Los Angeles	5,252,325	1,759,341	1,259,721	8,271,386	24,722	13,233	14,142	52,097
County of Orange	1,246,977	495,913	357,140	2,100,029	5,502	3,841	4,009	13,352
County of Ventura	344,904	142,855	93,101	580,860	1,459	971	1,052	3,482
County of Riverside	296,139	114,810	101,748	512,697	1,306	890	1,175	3,371
County of San Bernardino	424,042	161,191	129,281	714,515	1,842	1,218	1,487	4,548
Sum of Five Counties	7,564,387	2,674,110	1,940,991	12,179,488	34,831	20,154	21,865	76,850
Regional Leakages	14,255,919	4,116,421	3,519,554	21,891,893	64,401	31,259	39,655	135,316
Regional Total	21,820,306	6,790,530	5,460,545	34,071,381	99,232	51,413	61,520	212,165

Table 6. Comparison of Network Performance in Peak Hours, Multiple Impact Scenarios: Freight and Personal Trips with Time Costs Measured in PCE-Minutes

	Freight Trips	Personal Trips	Total Trips	% of Freight Trips	Freight Travel Cost	Personal Travel Cost	Total Travel Cost	% of Freight Travel Cost
Baseline	120,011	5,249,246	5,369,257	2.2352%	17,338,612	221,730,845	239,069,458	7.2525%
Scenario 1	118,268	5,249,246	5,367,515	2.2034%	17,306,258	223,911,512	241,217,770	7.1745%
Scenario 2	118,268	5,249,246	5,367,515	2.2034%	17,283,293	223,554,346	240,837,639	7.1763%
Scenario 3	117,791	5,249,246	5,367,037	2.1947%	17,154,239	221,457,684	238,611,924	7.1892%
Scenario 4	117,791	5,249,246	5,367,037	2.1947%	17,220,699	223,830,140	241,050,839	7.1440%
Scenario 5	116,050	5,249,246	5,365,296	2.1630%	17,115,162	223,324,249	240,439,410	7.1183%
Scenario 6	116,050	5,249,246	5,365,296	2.1630%	17,241,634	225,822,085	243,063,719	7.0935%

Table 7: Comparison of Network Performance over 120 days, Multiple Impact Scenarios: \$million

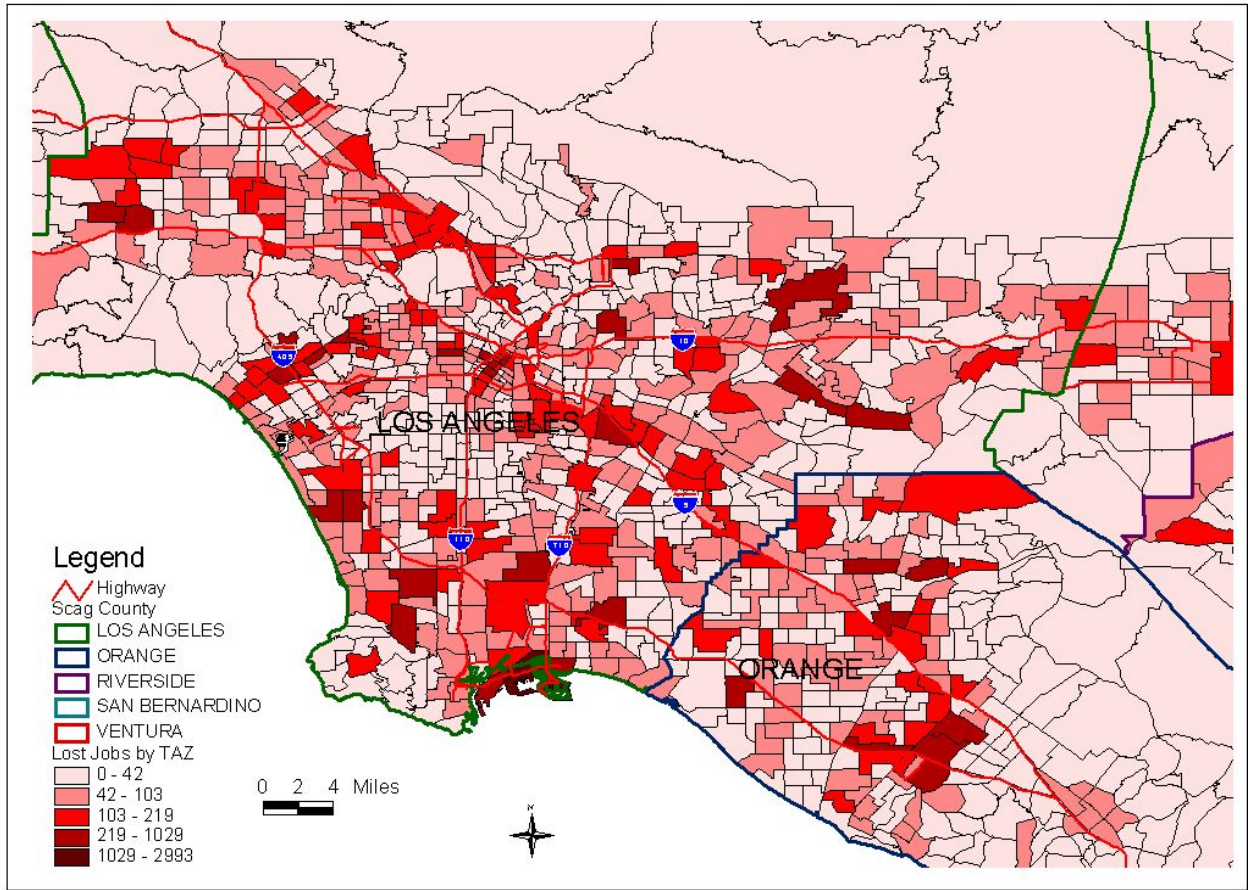
	Freight Travel Costs ¹	Personal Travel Costs ²	Total Costs	% of Freight Travel Costs	Freight Travel Cost ¹	Personal Travel Cost ³	Total Costs	% of Freight Travel Costs
Baseline	7,896.43	18,753.73	26,650.16	29.6299%	7,896.43	37,507.46	45,403.89	17.3915%
Scenario 1	-14.73	184.44	169.70	-0.2424%	-14.73	368.88	354.14	-0.1668%
Scenario 2	-25.19	154.23	129.04	-0.2369%	-25.19	308.46	283.27	-0.1630%
Scenario 3	-83.97	-23.10	-107.07	-0.1968%	-83.97	-46.21	-130.18	-0.1355%
Scenario 4	-53.70	177.56	123.86	-0.3376%	-53.70	355.11	301.41	-0.2322%
Scenario 5	-101.76	134.77	33.00	-0.4180%	-101.76	269.54	167.77	-0.2873%
Scenario 6	-44.17	346.03	301.87	-0.4957%	-44.17	692.06	647.90	-0.3406%

Note: 1. Freight trip cost is assumed as \$35.00 per PCE per hour

2. Personal trip cost is assumed as \$6.50 per PCE per hour

3. Personal trip cost is assumed as \$13.00 per PCE per hour

Source: Authors' calculation by dividing by peak-hour ratio (0.1537028) and translating the time period to 120 days.



Map 1. Spatial Distribution of Job Losses by 120-Day Port Closure, Port of Long Beach and Port of Los Angeles, Bridge Damage (Scenario 6)

Appendix 1: Convergence

The objective function of the assignment follows the formula developed by Sheffi (1985) for Wardrop (1952)'s first principle to minimize travel costs as follows:

$$\text{Min} \sum_a \int_0^{x_a} C_a(x) dx \quad (1)$$

$$\text{subject to } x_a = \sum_o \sum_d \sum_p \delta_{a,p}^{od} h_p^{od} \quad \forall a \quad (2)$$

$$\sum_p h_p^{od} = T_{od} \quad \forall o, d \quad (3)$$

$$h_p^{od} \geq 0 \quad \forall p, o, d \quad (4)$$

where x_a is the total flow on link a, including both personal and freight trips.

$C_a(t)$ is the cost-flow function to calculate average travel cost on link a,

$\delta_{a,p}^{od}$ is a link-path incidence variable; equal to one if link a belongs to path p connecting OD pair o and d ,

h_p^{od} is the flow on path p connecting OD pair o and d ,

T_{od} represents total trips between origin node o and destination node d , and

p is a network path, with o and d being the two end nodes on the network.

As Sheffi (1985) stated, this objective function is the sum of the integrals of the link cost-flow or link performance functions. The cost-flow function in this simulation model (SCPM 2) follows the one published by Bureau of Public Roads (BPR, 1964), and is applied to represent the relationships between link flow and travel time, shown as follows:

$$C_a = C_a(0) \left[1 + \alpha \left(\frac{x_a}{D_a} \right)^\beta \right] \quad (5)$$

where $C_a(t)$ is the cost-flow function to calculate average travel cost on link a, and

$C_a(0)$ is the free-flow travel cost on link a,

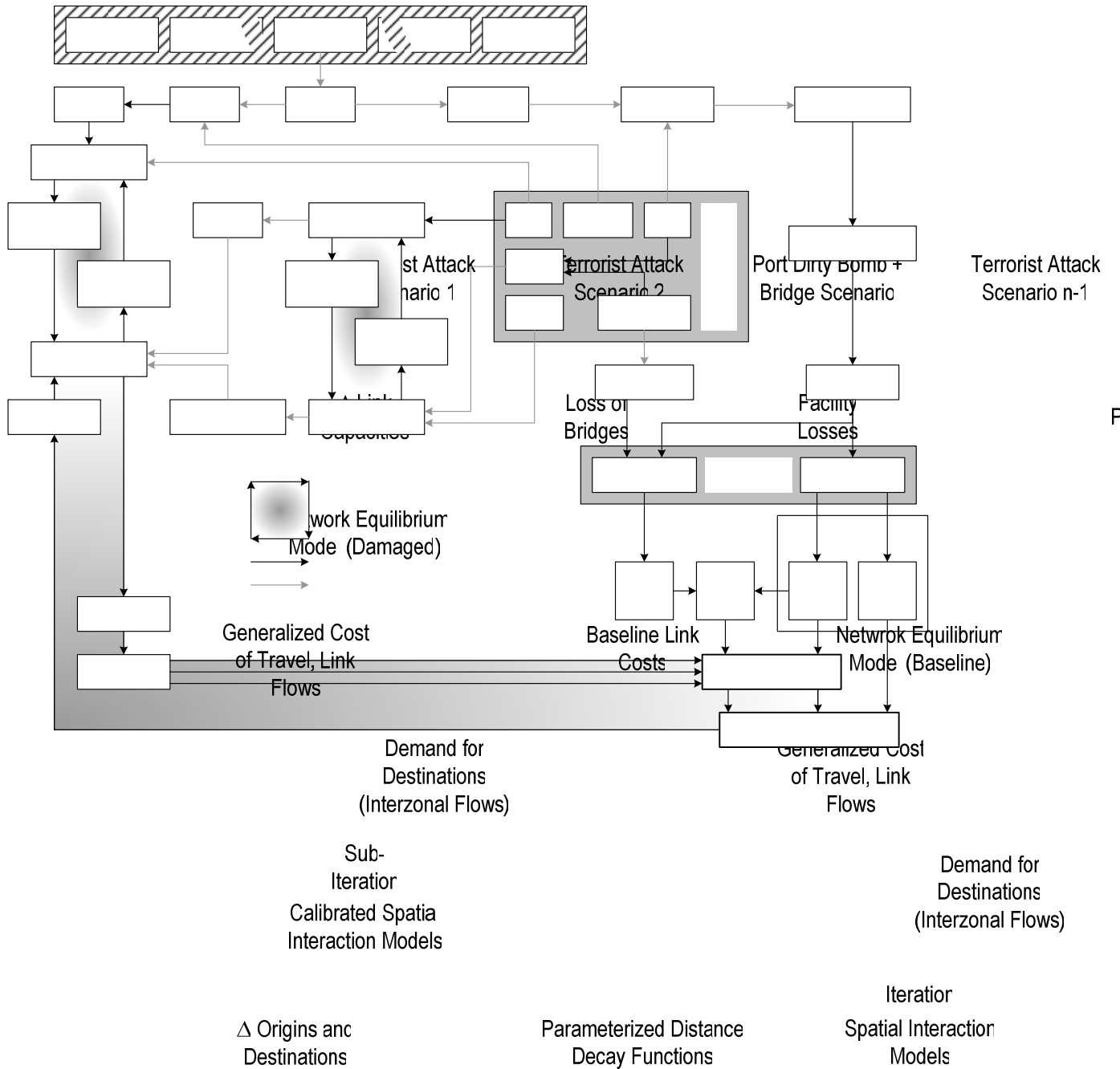
x_a is the total flow on link a, including both personal and freight trips,

D_a is the capacity of link a, and

α and β are parameters, while $1 + \alpha$ is the ratio of travel time per unit distance at practical capacity D_a to that at free flow. Both α and β are estimated from empirical data. In this study, α is assigned a value of 0.15 and β is assigned a value of 4.

The regional impact simulation model was run over multiple iterations to reach an optimal point minimizing travel costs, as described in formula (1). Scenario 4 (the closure of Port of Long Beach and the bridges) is used as an illustrative case to test how quickly the model converges. Figure 1 shows that the objective value of the sum of freight and personal trips approaches a convergence point after 4 or 5 iterations. Given this evidence, we ran 6 iterations of the simulation model for each scenario.

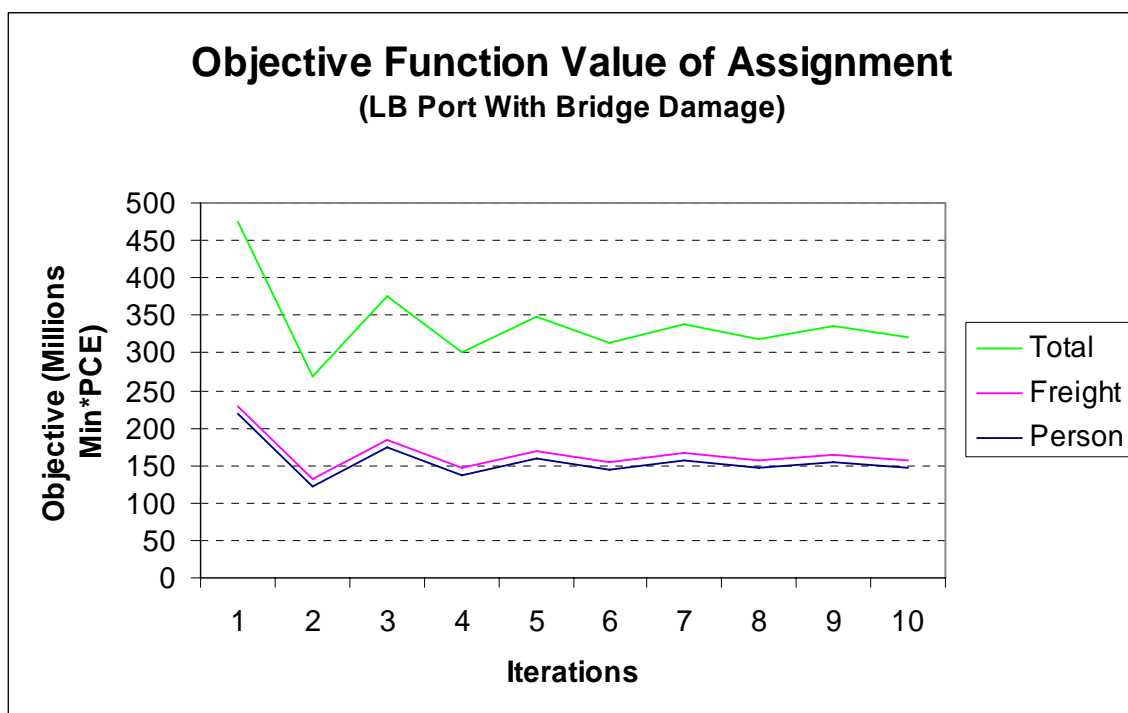
Figure 1. SCPM Data Flow



Numerical Iteration Cycles Used to Compute Simultaneous Economic Equilibria

Computation Data

Appendix Figure 1. The Rate of Convergence



References

Bureau of Public Roads (BPR) (1964) *Traffic Assignment Manuals*, U.S.Department of Commerce, Urban Planning Division, Washington.

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.

Peter Gordon, James E. Moore, II, Harry Richardson, Masanobu Shinozuka, Donghwan An, and Sungbin Cho, "Earthquake Disaster Mitigation for Urban Transportation Systems: An Integrated Methodology that Builds on the Kobe and Northridge Experiences," *Spatial and Economic Impacts of Natural Disasters*. Edited by Yasuhide Okuyama and Stephanie E. Chang. Springer Verlag: New York (2004): 205-232.

Gordon, Peter, Harry W. Richardson, and Bill Davis. 1998. "TransportRelated Impacts of the Northridge Earthquake". *Journal of Transportation and Statistics*, 1(2), 21-36.

Sheffi, Y. (1985) *Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods*. New Jersey: Prentice Hall.

Wardrop, J. G. (1952) "Some theoretical aspects of road traffic research," *Proceedings of the Institution of Civil Engineers*, Part II, Vol 1, 325-62.