Issue Paper

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Designing Airports for Security

An Analysis of Proposed Changes at LAX

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INTRODUCTION

The Los Angeles International Airport (LAX) Master Plan explores a variety of ways to meet the changing aviation needs of Southern California in coming decades. The needs include increasing the safety of passengers and airport workers. A recent proposed alternative, Alternative D—Safety and Security, includes more features for the security of airport workers and passengers.[1] Among the features of this plan are

- maintaining current gate capacity to accommodate growth to 78 million annual passengers by 2015 (from roughly 67 million in 2000), with some reconfiguration to better accommodate very large aircraft
- reconfiguring the Central Terminal Area, including removal of the U-road currently used for passenger loading and unloading, and the removal of all parking structures
- limiting Central Terminal Area vehicle traffic to emergency vehicles, mass transportation vehicles (including "FlyAway" buses to long-term parking lots), and vehicles making deliveries to tenants and concessionaires
- constructing a large Ground Transportation Center in the Manchester Square Area, approximately two miles from the Central Terminal Area; all short-term parking and passenger dropoff and pickup would occur at this facility
- constructing a mass transit system or "people mover" linking the Ground Transportation Center, the Metro Green Line, the Central Terminal Area, and a consolidated car rental facility within the Central Terminal Area.

During a series of exchanges between RAND and U.S. Congresswoman Jane Harman (D-Calif.) and her staff on topics related to national security, counterterrorism, and homeland security, involving numerous visits and joint appearances both in California and Washington, D.C., Rep. Harman asked RAND to examine the relative security merits of Alternative D. Specifically, this analysis examines how the security features of Alternative D compare with current airport configuration (also referred to as the "no action/no project alternative") in improving the security of airport workers and passengers against terrorist attacks. It follows two strands of work: (1) published and confidential RAND analyses on securing a wide range of facilities in the United States, from Los Angeles skyscrapers to the U.S. Capitol grounds; and (2) a growing body of research on improving airport and airline screening, including baggage screening, passenger profiling, use of Transportation Security Administration (TSA) employees for security screening, and enhanced aircraft safety measures (e.g., reinforced cockpit doors). This work is unique in offering one of the first explicit analyses of airport security as a function of airport design since the September 2001 terrorist attacks against the United States.

[1] See "Safety and Security Alternative Fact Sheet," available at http://www.lawa.org/news/pdf/laxmp_factsheet_7202.pdf (as of May 8, 2003).

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AN ANALYTICAL FRAMEWORK FOR AIRPORT SECURITY

Alternative D raises two general issues for consideration in improving LAX security. The first is the net effect on security of any physical change to the airport. This can be assessed by comparing the new physical features in Alternative D with existing or possible modifications of features in the current configuration and illustrates what benefits may be realized from reconfiguring the airport to include the greatest number of security features possible. The second issue is the effect of limiting airport capacity to 78 million annual passengers, which is close to the maximum capacity of the current configuration (set at 79 million). This illustrates what benefits may be realized merely by limiting air passenger traffic at LAX and ultimately redistributing it throughout Southern California. Alternatives A–C allow substantially more passengers than both Alternative D and the no action/no project alternative; Alternatives A–D call for some reconfiguration to include safety features for reducing taxiway congestion and increasing runway separation.

We begin by examining possible means of terrorist attack. The RAND–MIPT Terrorism Incident Database (known before 1998 as the RAND Chronology of Terrorism) is a database tracking terrorist activity worldwide and offers a comprehensive list of terrorist attacks against airports or aircraft since 1980. These historical data indicate both the means that have been used to attack airports as well as means of attack on other facilities that might be used against airports.

Any airport redesign for improved security can be evaluated for its effect on three security outcomes variables: (1) deterrence or detection of an attack before it occurs, (2) the number of casualties an attack would cause, and (3) the extent to which airport operations would be interrupted by an attack. For each means of likely attack, we examine how airport configuration might help in deterring or detecting such an attack as well as how it might limit the casualties and effects on operations.

We make several assumptions that are important for evaluating our conclusions. First, we assume that ongoing security expenditures are equal for each alternative, or that any security personnel and equipment that would be added under Alternative D could be added to the existing configuration. Second, we assume that additional security resulting from hardening structures in the reconfigured facility could also be achieved by hardening structures in the existing structure. We evaluate only the configuration of the airport, not the actual structures, because the engineering details of the structures specified in the plan are not yet available. Third, we assume that attackers will exploit the security weaknesses of each design, and that attacks would be conducted to maximize their damage. This means terrorists will adapt to changes in security, so that improving one weakness in security will provide only minimal benefit if a more substantial weakness remains.

HISTORY OF THREATS TO AIRPORT SECURITY

The RAND–MIPT Terrorism Incident Database lists 225 attacks on civilian aircraft or airports worldwide since 1980.[2] Of these, two-thirds, or 150, were attacks on civilian aircraft and one-third, or 75, were attacks on or at airports. It is possible that the proportion of attacks on airports is slightly overstated given that a bomb detonated or detected at an airport was counted as an airport attack even if intended for an aircraft.

Attacks on aircraft have been much deadlier than those on airports. The 150 attacks on aircraft have resulted in 4,280 fatalities, compared with just 76 fatalities resulting from attacks on airports. Even if one excludes the casualties of the September 2001 attacks on and using civilian aircraft, there have still been about 1,400 fatalities resulting from attacks on civilian aircraft since 1980, or about 20 times those that have resulted from attacks on airports.

To be sure, attacks on airports have produced significant damage. Of the 75 attacks on airports

- 49 used portable explosives (mostly in luggage but also including 3 mail bombs), resulting in 58 fatalities
- 9 used vehicle bombs, resulting in 4 fatalities
- 8 used missiles, rocket-propelled grenades, or mortars, resulting in 1 fatality
- 7 used firearms, resulting in 13 fatalities.

In sum, portable explosives are the most frequent and deadly mode of terrorist attack nationwide, while attacks by firearms, though only the fourth most frequent means of attack, are the second most deadly. There have also been an unknown number of criminal, non-terrorist attacks that used firearms or other small weapons.

Attacks against airports in the United States, including LAX, have been similar to those elsewhere in the world. The RAND–MIPT Terrorism Incident Database includes data on three attacks at LAX, including a bomb attack at an Air China luggage processing facility in 1980; a 1999 plot to detonate a bomb at a security screening point which

[2] Numbers of attacks against airports and aircraft should be viewed as approximate for two reasons. First, the database is incomplete because funding was interrupted for a time, and researchers are now making the database complete for the late 1990s and early 2000s. Second, these numbers include deterred or detected attacks for which detailed preparations had been made. They include, for example, an attempted bomb attack against LAX that was foiled in late 1999 as described below.

was foiled when the perpetrator was arrested at the Canadian border upon attempting to enter the United States to execute the attack; and a firearms attack at an El Al ticket counter in July 2002 that resulted in three fatalities, the only fatalities to result from a terrorist attack at LAX.

There are two known means of terrorist attack that could plausibly be used against airports but have not been used to date. One is a very large truck bomb, such as that used against the Murrah Federal Building in Oklahoma City and the Khobar Towers in Saudi Arabia. Another is a nonconventional weapon such as anthrax, sarin, or a radiological "dirty" bomb. (An additional possibility we do not explicitly consider is simultaneous attacks using conventional means, such as those executed by al Qaeda, on multiple targets, including airports.) Such attacks may have far more severe consequences than past means of attack, so we also consider them in our analyses of the impact on security of LAX reconfiguration.

Before reviewing the effects of airport configuration on limiting possible means of terrorist attack, we remind the reader that while past data are helpful for designing means to prevent or limit the effects of future attacks, there are limits to their uses. Terrorists may change their methods, adapt to changes in security or perceived value or significance of the target, or adapt techniques that have been used successfully against other targets to attack airports.

THE IMPACT OF RECONFIGURING AIRPORT FACILITIES

In all, we consider how possible airport reconfiguration could help prior detection or deterrence and ultimate limitation of casualties and operational disruption for seven types of attacks (overall assessments are provided in Table 1), including those

(1) on aircraft
(2) with a portable bomb
(3) by gunmen
(4) with a small vehicle bomb
(5) with a large vehicle bomb
(6) with a rocket-propelled grenade or mortar, or
(7) with chemical, biological, or nuclear weapons.

Airport reconfiguration is unlikely to have any substantial effect on the more common and lethal attacks: those against aircraft. Complete screening of baggage and passengers to prevent such an attack is already occurring. Airport reconfiguration can provide no additional protection against such attacks; it cannot affect terrorists' ability to fire weapons from the ground against aircraft; and it cannot boost the effectiveness of security measures, such as air marshals and cockpit barriers, that have been implemented on aircraft.

Table 1
Attack Outcomes as a Function of Threat Type and Airport Configuration

	Outcome		
	Deterrence	Casualties	Operations
Attack on aircraft	∅	∅	∅
Portable bomb	?	∅	–
Gunman	?	∅	–
Vehicle bomb (small)	?	+	+
Vehicle bomb (large)	?	?	?
RPG/Mortar	∅	∅	–
CBN	∅	∅	∅

NOTES: +, likely security advantage for new configuration; –, likely security disadvantage for new configuration; ∅, no discernible effect; ?, unknown effect; RPG, rocket-propelled grenade; CBN, chemical, biological, or nuclear attack.

Airport reconfiguration may have some effect on the most common and lethal attacks against airport facilities (rather than aircraft)—those by small (e.g., luggage) bombs and by firearms—but the full extent of this effect is unknown. Not enough is known to evaluate the effect of Alternative D on deterring or detecting such attacks. The distance between parking facilities and the new Central Terminal Area may allow some extra time to use profiling or other methods to identify potential bombers or gunmen, but would have no effect on detecting those seeking to attack the new Ground Transportation Center. There is also little evidence on the effectiveness of profiling techniques or on the ability of terrorists to "game" or otherwise elude a profiling system. Assuming any engineering or building features of Alternative D can be used in the current configuration, airport reconfiguration by itself is not likely to affect the number of casualties that result from small bombs or firearm attacks. Casualties from such attacks are determined by the density of persons waiting in unsecured areas of the airport, such as ticketing, baggage claim, security checkpoint, and transportation waiting areas. These densities are not likely to change as a result of the reconfiguration so similar casualties should be expected from such attacks in both configurations. The effect of such attacks on airport operations may be slightly more severe under reconfiguration. Reconfiguration would centralize several airport functions, such as transportation and terminal entrances that are currently distributed throughout several terminals. An attack at one centralized location may have a great effect on all airport operations during cleanup, investigation, and repair, while an attack on one terminal would affect only operations at that terminal.

Reconfiguration can improve security against small vehicle bombs, but it is difficult to determine the size of this benefit. In particular, how well reconfiguration would affect the deterrence or detection of small vehicle bomb attacks is unknown. If the proposed Ground Transportation

Center were eventually seen as "the airport," it would become the likely spot for such an attack. Cars would still be able to drive near lines of persons waiting to board the "people mover," but the greater distances that reconfiguration could incorporate between the "people mover" and passenger dropoff and pickup areas would help limit casualties from small vehicle bombs. Reconfiguration may help maintain airport operations in the event of attack by a small vehicle bomb; the new Central Terminal Area, for example, would likely continue to function, being far removed from the Ground Transportation Center.

We can draw no conclusions about the impact of reconfiguration on large vehicle bomb attacks, because the plan does not specify how large vehicles would be handled. LAX currently has about 200 restaurants, bookstores, and other businesses that require deliveries nearly every day. Reconfiguration would boost the number of these tenants. Although the Central Terminal Area will be closed to passenger dropoff and pickup, it will need to be accessible to trucks. It is possible to search these trucks before they enter the Central Terminal Area, but this would require considerable manpower. Diverting all trucks to a separate entrance may facilitate such searches and security, but such diversion does not require reconfiguration. More generally, it is not clear how airport reconfiguration should be used address the potential problem of large vehicle attacks. Airports typically make poor targets for large vehicle bombs. For example, fatalities caused by bomb attacks at tall buildings, such as those caused by bombing of the nine-story Murrah Building and the eight-story Khobar Towers, generally occur as a result of structural collapse of the upper floors onto the lower floors.[3] By contrast, airports typically have only two stories, meaning their structural collapse would have far fewer catastrophic consequences. Airports do have multistory parking structures that terrorists may seek to attack with large truck bombs, but such targets are not desirable targets for several reasons, including their minimal symbolic value, their more solid construction than residential or business buildings of comparable size, their sparse population, and their open walls that reduce energy absorbed from a blast.

There is little to distinguish Alternative D from the current configuration for boosting security against attack by rocket-propelled grenades or mortars. Reconfiguration may do little to deter, aid the detection, or limit the casualties of such attacks. It is possible that reconfiguration, by centralizing airport facilities, would aggravate the effects on airport operations of such attacks, particularly an attack that disabled the "people mover" system.

[3] National Research Council, *Protecting Buildings from Bomb Damage*, Washington, D.C.: National Academy Press, 1985.

There is also little to distinguish Alternative D from the current configuration for boosting security against attack by chemical, biological, or nuclear weapons. It is worth noting that such weapons have not been used against airports. There are several reasons for this. These weapons are relatively difficult to obtain and use effectively. If a terrorist group did obtain these weapons, it could use them against nearly any target in the United States as easily as against LAX. We do not mean to imply that such attacks would never occur at LAX, only that such attacks would be less likely, and less catastrophic, than at other locations in the region and nation.

There are two additional security considerations that affect all modes of attack we analyze and that should be considered in evaluating the security effects of reconfiguration. First, the proposed reconfiguration will increase the area to be patrolled by security personnel. This may have a negative effect on deterrence and detection if security forces are not increased for the reconfigured facility. Personnel will need to be diverted to new facilities, such as the Ground Transportation Center, at which large crowds will gather, leaving fewer to patrol the Central Terminal Area than now patrol the decentralized terminals. Second, reconfiguration may make it difficult to evacuate the terminal area in the event of an attack, particularly given reliance on the "people mover" system for moving persons to and from the terminal. Such reliance might entice terrorists to issue a bomb threat and then attack large and dense crowds waiting to board the system. Evacuation plans and equipment can help mitigate this danger, but would rely on persons leaving the terminal in a way other than which they entered. Alternatively, terrorists may seek to disable the "people mover" at any point along its two-mile route and attack trapped passengers with weapons ranging from "Molotov cocktails" to biological weapons.

THE IMPACT OF RESTRICTING GROWTH

One common characteristic of both the current configuration and Alternative D that may have a great effect on airport security is the limit on capacity (both would limit capacity to less than 80 million passengers annually). Relative to Alternatives A–C, such a limit would mean that more growth in air travel would need to be absorbed by other airports in the region. Over time, this would result in a far more evenly distributed system of air travel in which LAX would handle a smaller proportion of a growing number of Southern California air passengers.

Even without changes to airport facilities or procedures, such a limit may help deter terrorist attacks on LAX by helping reduce the value terrorists may perceive in such an attack. A capacity limit, by shifting a proportion of regional air traffic from LAX to other airports, may also help mitigate the effect of a terrorist attack on regional airport operations, because a future attack on LAX would affect a smaller proportion of regional airport operations than a present attack would. Such benefits should be viewed as highly speculative, for it is impossible to calculate their magnitude or the length of time needed to realize them. Furthermore, there may be substantial economic costs to the region resulting from restricting LAX capacity; such costs may outweigh the economic benefits of a regional air transport system better able to recover from possible terrorist attacks.

More precise calculations can be made regarding the effects of limiting capacity on potential casualties from a terrorist attack. Reconfiguration, as noted, may help improve LAX security against small vehicle bombs, but it likely would not improve security against small or portable bombs concealed in luggage, which, historically, have been about twice as lethal at airports than larger bombs. While perhaps surprising, this finding follows as a direct consequence from the physics of explosives. The force of a bomb, as well as its ability to cause casualties, is greatly reduced over distance from the bomb; more precisely, the force of a bomb decays with the cube of the distance from the bomb. Thus even small changes in distance from a bomb can result in dramatic reductions of its power (with some minor exceptions for bombs detonated in extremely rigid structures such as tunnels).[4] This also means that the density of a population being attacked can matter far more than the sheer size of the bomb. Because the density of persons can be greater in buildings or mass transit vehicles, small bombs there can be more lethal than larger bombs in more open spaces (Table 2).

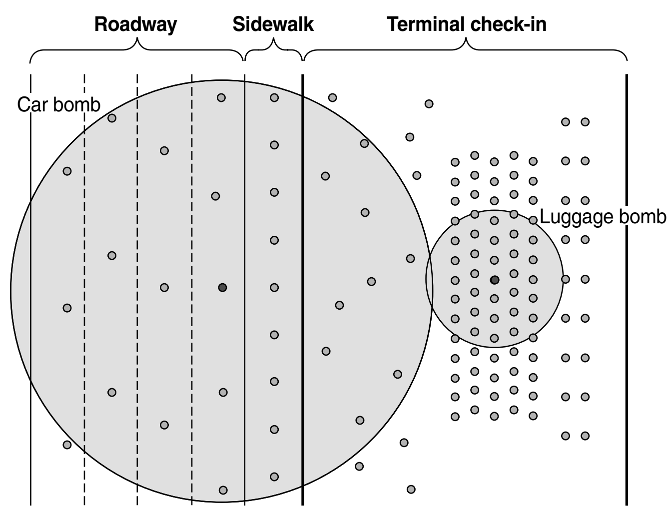
For example, the amount of explosives needed per casualty in a city bus arriving at the airport or a large aircraft filled to 80 percent capacity is about one-half, or less, that needed to kill an equal number of persons in a terminal line, while the amount of explosives needed to kill a given number of persons in an airport terminal line is about one-fifth, or less, than that needed to kill an equal number of persons in an open area, such as a sidewalk, outside the terminal. Put another way, a terrorist seeking to kill the greatest number of persons can kill more with a small bomb (e.g., luggage bomb) in a relatively dense area such as inside a terminal than with a large bomb (e.g., vehicle bomb) in a relatively open area such as a sidewalk outside a terminal (Figure 1).

Table 2
Explosives Required as a Function of Population Density in Several Airport Locations

Region of Airport	Area per Person[1] (sq ft)	Distance Between People[2] (ft)	Explosives Needed per Casualty[3,4]
Inside plane (767, econ, 80% capacity)	7	2.7	0.2
Inside city bus (80% capacity)	12	3.5	0.3
Inside airport bus w/baggage	30	5.5	1.3
Line of passenger in terminal			
High-density	16	4	0.5
Mid-density	25	5	1.0
Low-density	36	6	1.7
Open area in terminal or sidewalk			
High-density	81	9	5.8
Mid-density	144	12	14
Low-density	196	14	22
On roadway (lane next to airport bus)[5]	144	12	14
On roadway (curbside)[5]225	15	27	
On roadway (third lane from curb)[5]	625	25	125
Parking lot (1 person for every 5 cars)[5]	1,225	35	343
Parking lot (1 person for every 10 cars)[5]	2,500	50	1,000
Parking lot (1 person for every 17 cars)[5]	4,225	65	2,197

NOTES: [1]Population densities calculated within a circular area large enough to enclose 30 people. [2]Square root of density. This would be the distance between individuals if they were evenly dispersed. [3]Bomb sizes are expressed in relative units. 1 represents the power required when population density is 1 person per 25 square feet. The absolute amount of explosives will depend on the type and construction of the bomb. [4]Does not include secondary casualties from structural failures. [5]Calculations assume vehicles and building offer no protection from explosion; this will slightly overestimate the casualties from bombings in these locations.

Our calculations may overstate the casualties that would result from large vehicle bombs because of several simplifying assumptions. We assume, for example, that there is no protection whatsoever for persons within range of a given bomb, but a large number of persons within a given range of a vehicle bomb would probably be in their own vehicles, which should offer considerable protection from a blast and resulting debris. Similarly, a large number



NOTE: Dots represent people or pairs of people. 29:1 ratio in explosives will result in the same number of casualties.

Figure 1—Different Bomb Sizes Can Yield Similar Casualty Rates, Depending on Population Densities (Higher-Density Scenario)

[4] C. L. Elliot, "The Defense of Buildings Against Terrorism and Disorder: A Design Philosophy for the Construction of Ordinary Buildings and Installations to Resist Terrorism and Public Disorder," University of Southampton, unpublished M.Phil. thesis, 1986.

of persons would be inside the terminal building, which should also offer protection from the blast. While flying glass or falling debris inside a terminal building resulting from a vehicle bomb can cause fatalities, such problems may be mitigated by thorough modification to windows or reinforcement of building structures.

In comparing potential fatalities from small and large bombs detonated at airports, we consider casualties from the bomb itself, rather than secondary effects of structural failure, because the detailed structural engineering required for predicting structural failure is beyond the scope of this project. Nevertheless, we note that the structural peculiarities of an airport may mean a small luggage bomb inside a terminal can cause greater structural damage than a large vehicle bomb outside it. The roadway overpass outside a terminal is designed to handle far greater loads, and has a much greater mass, than the interior floors of the terminal building. As noted earlier, structural collapse resulting from a bomb in an airport terminal of just two stories is less likely to have the catastrophic consequences that can result from large bombs used against taller buildings.

Small bombs detonated inside a terminal, in addition to being a more likely threat and more deadly for a given weight of explosives, are easier to build without detection and to deploy in an airport without suspicion and leave less forensic evidence about perpetrators. Any individual or organization that has the capability to launch an effective vehicle bomb attack outside a terminal has the materiel, skills, and motivation needed to launch several smaller and more lethal bombs inside a terminal. This is not to say that terrorists will never attack LAX with a car bomb, but instead that efforts to mitigate the damage from bomb attacks might be better focused on preventing or limiting the damage of small bombs detonated in crowded areas. Reconfiguration can offer some greater protection from some vehicle bombs, but by itself can do little to affect threats posed by small bombs. Such threats are best addressed by reducing crowded areas in the existing or reconfigured airport.

INCREASING SECURITY IN EITHER CONFIGURATION

The fact that small, portable explosives have been the most likely and most lethal means of attacks at airports suggests a number of changes can help improve security greatly either in the current configuration or in the Alternative D reconfiguration. We outline three broad areas to consider.

Expedite the Movement of Passengers into the Secure Terminal Areas

The greatest risks for casualties for most types of attacks are in the high-density areas passengers encounter before reaching the security checkpoint, particularly lines for ticketing and for passing the security checkpoint. Airport procedures and numbers of personnel, rather than configuration, determine the number of persons that must wait in these unsecured areas. Even small increases in ticketing and screening personnel may help reduce these crowded areas.

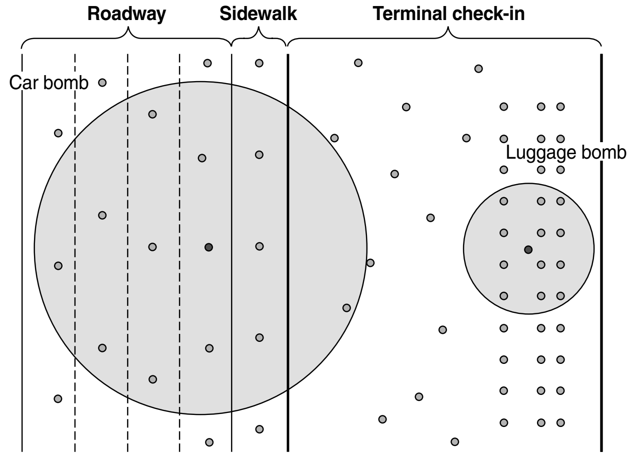
Consider, for example, that if current personnel can screen 10 passengers per minute, and 12 passengers per minute are arriving at the terminal, then a line of 60 persons will form within 30 minutes, with new arrivals facing a wait time of at least 6 minutes. Just a 20 percent increase in screening capacity would completely eliminate the line and wait time. Increased capacity at ticket counters would have similar effects. Passenger flow is extremely predictable, and airlines already make some adjustments to handle peak flight times. In fact, completely eliminating ticket counter lines may require no additional personnel, particularly as electronic kiosks are used to handle more passenger traffic.

Similarly, reducing the wait for baggage check-in from 15 minutes to 1 minute would cut the number of persons who could be killed in a bomb attack in that area by more than 50 percent (compare dot density of Figure 2 with that in Figure 1). It would also reduce the number of persons who could be killed by a curbside bomb both by reducing the number of persons waiting there for baggage or security checks and by allowing persons inside the terminal to move further from the exterior wall.

Unfortunately, the TSA is setting funding and personnel at each airport to levels that could result in security checkpoint wait times of up to 10 minutes.[5] This will have more detrimental effects at larger airports, such as LAX, because a 10-minute wait for a terminal that must handle 15 passengers per minute will result in a crowd of 150 persons at each security checkpoint, while such a wait at a terminal that must handle 5 passengers per minute would result in a crowd of only 50 persons.

The economic costs of such delays should be considered in efforts to improve security. These occur because the value of air travel is in the savings of time it offers relative to other modes of transportation. Anything that adds time to a trip by air reduces its value and hence its demand relative to other modes. A recent RAND analysis concluded that the costs of increased equipment and personnel needed to eliminate security delays would be more than offset by the resulting increased value passengers

[5] The TSA recently announced it was reducing its number of screeners by about 6,000, including more than 150 at LAX. See http://www.tsa.gov/interweb/assetlibrary/ScreenerReductionFactSheet.doc (as of May 8, 2003).



NOTE: Dots represent people or pairs of people. Scenario assumes reduced density in check-in and sidewalk areas, but the same density in the roadway area; thus 18:1 ratio in explosives will result in the same number of casualties.

Figure 2—Different Bomb Sizes Can Yield Similar Casualty Rates, Depending on Population Densities (Lower-Density Scenario)

would perceive, and pay, for air travel.[6] In other words, most passengers would pay the minimal increase in cost required to eliminate waiting in lines in unsecured areas of the terminal.

Eliminating lines in unsecured areas for passengers departing LAX would shift the most vulnerable location in the airport to the baggage claim area. Crowd density in this area is lower than that for ticketing counters or security checkpoints, but it is still significant. Unfortunately, eliminating these crowds is not simply a matter of increasing personnel or capacity. Nevertheless, some changes are possible to increase the security of this area. Restricting baggage claim access to those persons disembarking planes would increase the security of this area, but would possibly be seen as an inconvenience to persons meeting passengers. Alternatively, security personnel could prohibit non-passengers entering the baggage claim area from bringing any bags or backpacks into it.

Harden High-Value Structures

Potential casualties from a bomb attack could be greatly reduced through structural modifications. A high priority should be preventing damage from flying glass through use of shatterproof glazing, decreasing the size of window panels, or using stronger window frames. Other structural changes that may also be cost-effective include reinforcing walls in high-risk areas or adding support columns.[7] Such changes may help reduce the damage and casualties from earthquakes in the region; these secondary benefits should be considered in any cost-benefit analysis.

Use Physical Barriers

Physical barriers can help increase the separation between vehicles and buildings or crowds. These barriers would reduce the population density of an area a vehicle bomb could affect, and they could reduce the secondary damage from structural failures. Truck use of the road underneath the upper (departures) deck could be limited by placing height restrictions on vehicles there and through other means to prevent the passage of heavy vehicles.[8] Because buses picking up passengers currently use the lanes that are not under the upper deck, this would not restrict current traffic flow. Barriers such as planters or bollards could also increase the distance between cars and the terminal building and between cars and pedestrians. It may be less expensive, however, to move passengers inside the terminal further from exterior walls.

CONCLUSIONS

While there have been past terrorist attacks on LAX and future attacks cannot be ruled out, airports have been very safe places in recent decades, and the threat of terrorism at an airport should be viewed in the context of other safety and security threats facing air travelers. An airplane collision at LAX, for example, could result in more casualties than any terrorist attack not using a nuclear weapon. An earthquake could also result in more damage and a significantly longer shutdown of the airport. Any terrorist attack can result in tragedy, but the threat of terrorism should not dominate discussions of airport planning at the expense of solutions to more common problems. Any reconfiguration of LAX should be judged primarily on how efficiently the airport will function and on the effects reconfiguration will have on the transportation and economy of Southern California. There is enormous economic value to be realized in getting passengers from their homes to their destinations quickly and safely. The economic costs incurred by an inefficient airport operation could therefore outweigh the economic benefits of some of the more expensive security aspects in reconfiguration.

Terrorism is dynamic and terrorists adapt their methods to suit changes in weaponry and defense tactics. Terrorism prevention and security therefore also needs to be dynamic. Buildings are essentially static. This makes it extremely difficult, and expensive, to design airport facilities that will be as secure against attack 20 years from now as

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[6] Russell D. Shaver III, Michael Kennedy, Chad Shirley, Richard Hillestad, and Brian Rosen, *How Much Is Enough? Sizing the Deployment of Baggage Screening Equipment by Considering the Economic Cost of Passenger Delays*, Santa Monica, Calif.: RAND DB-412-RC, forthcoming.

[7] National Research Council, *Protecting Buildings from Bomb Damage*, Washington, D.C.: National Academy Press, 1985.

[8] Bruce Hoffman and Peter Chalk, with Timothy E. Liston and David W. Brannan, *Security in the Nation's Capital and the Closure of Pennsylvania Avenue: An Assessment*, Santa Monica, Calif.: RAND MR-1293-1-FCCDC, 2002.

they may be today. While in the past ten years there have been a number of notorious terrorist attacks using vehicle bombs, which airport reconfiguration might help mitigate, future terrorists may use rocket-propelled grenades for their attacks.[9] This could diminish some of the short-term improvements in safety and security that Alternative D could effect.

Our analysis helps indicate the priorities for considering security in airport planning. Top priority should be given to securing aircraft, the most likely—and lethal—target of terrorist attacks on air transportation. This should include screening of all baggage and passengers, adequate security procedures and equipment on aircraft, and restricted access to aircraft on the ground.

The next priority should be given to securing airport facilities against portable bombs, the most commonly used weapons in terrorist attacks against airports. Such weapons are easy to build and the perpetrators of such attacks are hard to catch. Detonation of these bombs in crowded areas of the airport makes them more lethal, per pound of explosive, than any other means of attack.

Restricting passenger capacity as proposed in Alternative D, or as would result from the no action/no project option, could reduce the overall vulnerability of LAX in particular and Southern California aviation more generally. Restricting LAX capacity would make it a less prominent target for terrorist attack, while distributing air traffic more evenly throughout the region would help its air traffic system continue functioning in the event of an attack on one of its parts. Such restrictions may have detrimental economic effects beyond the scope of this work.

Other features of Alternative D appear less likely to improve security. The proposed reconfiguration could help limit damage caused by a vehicle bomb, but would not help limit damage caused by small bombs, and it could increase the time the airport is shut down by such attacks. Reconfiguration could also result in two security problems that will need to be addressed in future versions of the plan. First, the present plan would substantially increase the area that would need to be secured against possible terrorist attack. This will be difficult to do with the present number of security personnel. Second, the present plan would consolidate transportation to the Central Terminal Area on a "people mover" that could become a tempting target for terrorists and that may impede evacuation of the terminal in the event of an attack, a fire, or a natural disaster.

Regardless of configuration, several improvements in airport processes could be made to improve security against terrorist attacks at LAX. The most important of these is expediting the movement of passengers into secure terminal areas. This is the best defense against small bombs and firearms—the most common, and deadly, types of terrorist attacks. Building structural improvements, including the replacement of conventional glass with shatterproof materials and changes to the terminal facade and structural supports, can also mitigate the effects of terrorist attacks. Physical barriers to increase separation between vehicles and persons, as well as the prohibition of tall or heavy vehicles underneath the upper (departures) deck, can also limit potential casualties from larger bombs.

If it is assumed that some reconfiguration of LAX (in the form of Alternative A–D) is likely, Alternative D would likely have a slightly positive effect on improving LAX security. This positive effect would be due to only one portion of the plan—restricting passenger capacity—and not those parts that are more expensive, such as reconfiguring the terminal, parking, and ground transportation at the airport. The current configuration would allow airport managers to realize the most likely security benefits of Alternative D and to add others as well. Airport planners need to consider the security benefits of restricting passenger capacity with the economic effects of doing so, as well as economic or safety reasons, such as runway separation or taxiway improvements, favoring Alternative D that were beyond the scope of this analysis.

[9] There are recent reports of rocket-propelled grenades selling for as little as $150 in the European black market. See Nicholas Rufford, "Prime Suspect: Who Masterminded the Rocket Attack on MO6 Headquarters?" *Sunday Times* (London), September 24, 2000.

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