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BRIEFING

How Much Is Enough? Sizing the Deployment of Baggage Screening Equipment to Minimize the Cost of Flying

Executive Summary

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DB-412-RC

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PREFACE

Shortly after the terrorist attacks against the World Trade Center and the Pentagon on September 11, 2001, Congress passed a new law that mandated the screening of all baggage carried on all commercial aircraft by the end of calendar year (CY) 2002. The Transportation Security Agency (TSA), a newly formed organization that is part of the Department of Homeland Security, was given the responsibility for assuring the rapid implementation of this mandate. To the TSA's credit, sufficient equipment was acquired and installed at all U.S. commercial airports.

This research addresses airport security needs over the longer term—namely, how best to balance in the future the two principal criteria that are commonly put forward for sizing the machine deployments at individual airports. These two criteria—keeping the cost to the government of acquiring, installing, and operating the baggage scanning equipment as low as possible, and not seriously disrupting the passenger flow through the airport—are in conflict, because lowering passenger disruption requires a higher level of machines and thus more program cost. In this research we present a methodology for balancing the two criteria, and thus for answering the question in the title of this briefing, *How much (baggage scanning equipment) is enough?*

Determining how much is enough is important for keeping the *overall* cost to the flying public to a minimum while still providing the mandated level of security. Failure to have deployments that minimize the overall cost to the public will unnecessarily impose a drag on the nation's economic well-being.

This documented briefing is part of a larger study by the RAND Corporation of the implications of airport security measures on airports, airlines and, more broadly, the nation's economic well-being. RAND funded this study as a component of an even broader effort to expand our nation's understanding of the implications of terrorist threats against the United States and its allies.

The results of this study should be of interest to policymakers who are responsible for implementing the most cost-effective approach to ensuring U.S. national security, especially those concerned with air transportation. This study should also be of interest to organizations and individuals concerned with the same issues. The commerce associated with air travel is an important part of the U.S. economy. Ensuring its safety at minimum total cost to the economy is a critical policy challenge.

The breadth and depth of this study was inherently limited by time and cost, and more work in this area is warranted. Nonetheless, we believe these results provide very important insights into the best directions for policy.

This documented briefing is a product of RAND's continuing program of self-sponsored independent research. Support for such research is provided, in part, by donors and by the independent research and development provisions of RAND's contracts for the operation of its U.S. Department of Defense federally funded research and development centers.

Other documents produced as part of this study are

DB-410-RC—*How Much Is Enough: Sizing the Deployment of Baggage Screening Equipment by Considering the Economic Cost of Passenger Delays—Main Report.* Russell Shaver, Michael Kennedy, Chad Shirley, and Paul Dreyer.

DB-411-RC—*The Benefits of Positive Passenger Profiling on Baggage Screening Requirements.* Michael Kennedy and Russell Shaver.

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Charles Kelley, Joe Guzman, Frank Camm, and Mayhar Amouzegar, all from RAND, critically reviewed both the drafts of the final document and the methodology that supported it. Without exception, we obtained valuable feedback from all the reviewers; their efforts substantially improved the quality of the document. We also thank Richard Hillestad, our project leader and friend, who helped get us sufficient funding to complete the work.

Of course, the authors take full responsibility for what is in the report.

Study Background

- **Prior to the terrorist attacks of 9/11, personnel screening at airports was widely categorized as porous, and screening of checked baggage only occurred for international flights**
- **Post 9/11 the Government acted to redress these security concerns**
  - **Among other measures, Congress mandated that by NLT December 2002 all baggage checked at the airport be screened prior to it being loaded on an airplane.**
- **Using internal funds, and at the suggestion of the FAA, RAND examined the feasibility of meeting that deadline (see Reference 1)**
  - **Among the findings was that the planned (by FAA) deployments of EDS* machines would be insufficient to handle future passenger demand levels**
  - **If passenger delays at major airports were to be kept to low levels, more machines would be needed.**
  - **To handle more machines, new airport infrastructure would also be needed**
- **Missing from RAND's analysis was an objective analysis of how to properly size future EDS deployments. This study addresses that shortfall**

*** Electronic Detection System (EDS, a term used to describe a large MRI machine that can scan unopened baggage rapidly and determine whether they contain threatening material.**

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Prior to 9/11 there were repeated and widely publicized examples of contraband (e.g., guns or knives) passing through the carry-on baggage screening stations without being detected. Even though the terrorists of 9/11 did not take banned weapons onto the hijacked aircraft (box cutters were permitted at the time), the call for better screening of all baggage was an immediate reaction.

In response to the 9/11 attacks against the World Trade Center and the Pentagon, Congress mandated that all bags carried onto aircraft be inspected for various contraband (e.g., bombs). Inspection stations already existed for carry-on luggage, but baggage checked at the ticket counter was inspected only on international flights. Assessments by RAND and others indicated that even under optimistic assumptions, an inadequate number of machines would be available by December 2002 (see Reference 1). Moreover, the anticipated growth in demand for air travel over this decade would likely result in substantial passenger delays at the airports. To avoid such delays in the future, the size of the Electronic Detection System (EDS) acquisition would need to be nearly double the original estimate made immediately after 9/11. And because airports were never designed with security needs in mind, additional infrastructure would be needed to accommodate the new equipment at many airports.

Substantial delays, at least for checked baggage, have not as yet become evident, in part because the demand for air travel has not yet fully recovered from the aftermath of 9/11. This gives the government time to address two questions that up to now it did not have the time to ponder:

- Assuming that airport security and the scanning of all baggage will continue for a long time, what size deployments of EDS machines (or their equivalent) would best serve the public's interest?
- How would the answer to that question be affected by various policy options, including the establishment of a "registered traveler" program, based on positive profiling of airline passengers?

The Problem We Are Addressing Is "How Much Airport Security Equipment Is Enough?"

- **Low deployment levels of baggage scanning equipment implies:**
  - **The cost of screening all checked baggage is low, but**
  - **Long queues and excessive passenger inconvenience are the result**
- **High deployment levels of baggage scanning equipment implies:**
  - **The cost of screening all checked baggage is high, but**
  - **Passenger inconvenience and delay transiting the airport are low**
- **Passenger inconvenience and delay negatively affect demand for airline travel, and will impose a drag on the nation's economy**
- **If the cost of providing security is passed along to the passengers, this cost will also impose a drag on the nation's economy**
- **There exists an optimum, where the overall cost to the passenger is minimized. This minimum defines "how much is enough"**
  - **It is in everyone's interest for the government to size the security deployment accordingly, while still holding overall security at the high level demanded by Congress**

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It is obviously possible to have too few machines for the demand for baggage scanning. In such a situation, the baggage scanning queues would grow to substantial size during peak demand hours. The time between the acceptance of the checked bag by the curb attendant or the clerk behind the check-in counter and the arrival of the bag at the plane ready for loading could be sufficiently long that the plane would have already departed. This occurrence would negatively affect both the passenger and the airlines. The inconvenience "cost" to the passenger of not having his or her bag reach the plane in time can be substantial. To avoid that cost, most passengers would prefer to pay the lesser cost of arriving at the airport earlier than would otherwise be needed.

If, in contrast, the airport deployed an excessive number of machines so that no passenger delays occurred, the added cost of the these machines would still increase the passenger's cost of travel because the security costs would likely be added to the price of the ticket.

Thus, passengers cannot avoid paying a price for airport security. The best that they can hope for is that this security cost is held to a minimum.

Our analysis assumes that all bags are given the same degree of scrutiny; thus, security is held constant throughout. By adding the two costs mentioned above, we obtain an overall cost to the passenger as a function of the number of machines acquired. This function has a minimum. At this minimum point, the cost to the passenger is as small as it can be.

It is not only the added cost to passengers that concerns us. This added cost discourages airline commerce and therefore has a negative effect on the overall health of the nation's economy. Thus, it is in everyone's interest that the government seek nationwide deployments of the security equipment that do the least harm to the economy. In this context, we describe the EDS buy size at the minimum point as the answer to the question, "How much airport security equipment is enough?"

Topics Covered in This Summary Briefing

- **The relationship between passenger delay and the number of EDS machines deployed at the airport**
- **Finding the minimum cost to the nation's economy of providing baggage scanning at all U.S. airports**
  - **The "simple" calculation**
  - **The "complex" calculation**
- **Comments on positive passenger profiling**
- **Conclusions and observations**

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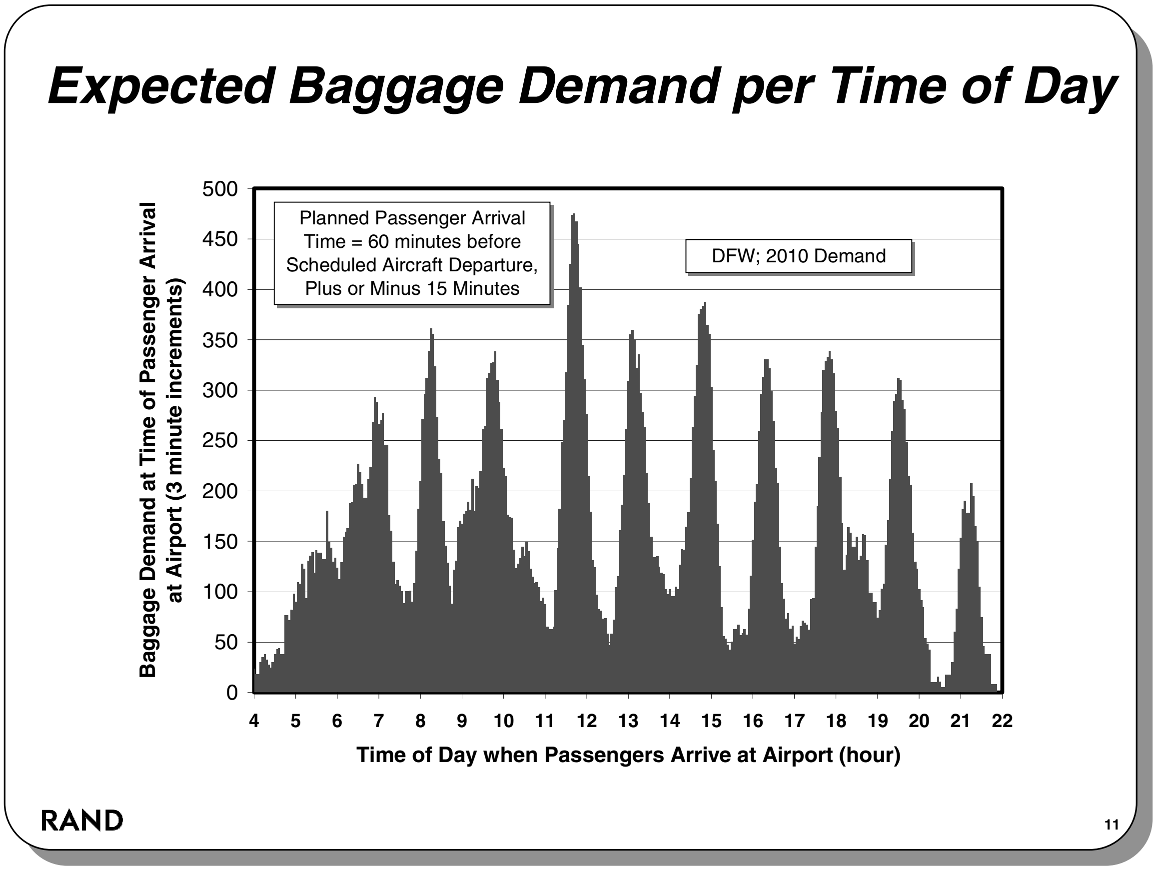
This chart describes the topics that we will cover in this briefing.

We will start with a discussion of how we calculated the size of the baggage scanning queues as a function of the expected demand per unit of time and the scanning throughput of the machines. We translate these queues into an expected predeparture arrival time for the passenger, assuming that the passenger sets that time according to a criterion related to the risk that his bag will not make the plane.

We next transform the time difference between the passenger's predeparture arrival time and the airplane's scheduled flight time into an estimate of the amount of extra time the passenger spends at the airport due solely to length of the expected baggage scanning queues. We turn this extra time into a cost to the passenger. Similarly, we calculate an estimate of the annual cost to the passenger related to the deployed scanning equipment, assuming (as is current practice) that this cost will be charged to the passengers through a security tax added to all tickets. The sum of these two costs yields a curve that has a minimum. That minimum is our desired design point.

We also perform a more complex calculation in which we substantially broaden the calculation to include the entire aviation industry. This more complex calculation better captures the effects on the nation's economy.

Finally, we will discuss briefly the implications of positive passenger profiling options on the above outcomes. Our characterization of what positive profiling means will be discussed when we get to that part of the briefing.

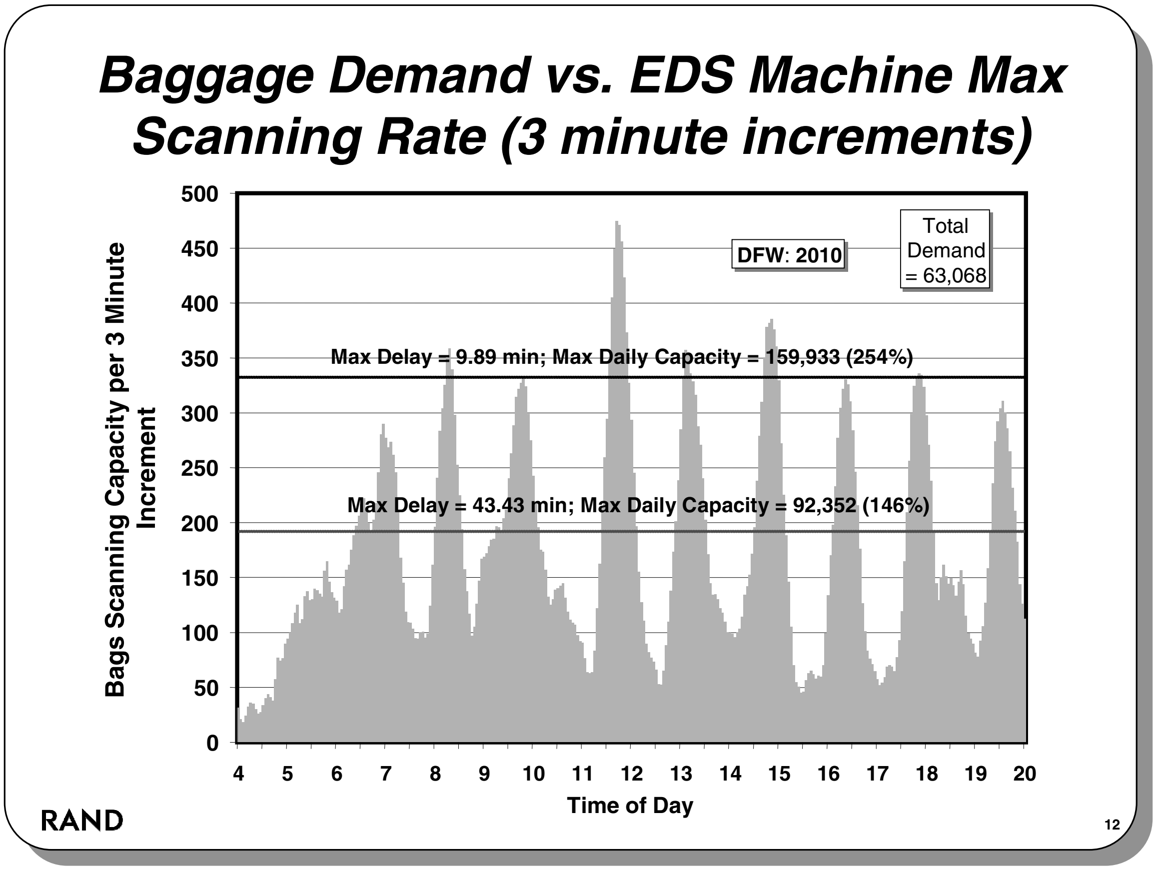


To understand the connection between deployment size and baggage scanning queues, it is important to understand the demand. This chart shows an example of a postulated future demand at a major U.S. airport (Dallas–Fort Worth). DFW is a major hub-and-spoke airport and ranks among the top three airports in the country in terms of total landings and takeoffs.

The primary character of the demand is its spikes, reflecting the hub block takeoff practices used by DFW's major airline partner, American Airlines. Although it is not obvious from this chart, the overall operations at DFW (landings and takeoffs) are not nearly this spiked because landings fill the "valleys" between the takeoffs.

The total number of bags in the demand is just over 63,000. This demand reflects only passengers originating at DFW. Transiting bags—bags that are being transferred from one aircraft to another, as is common at hubs—are not counted in this total. If these transiting bags had to be scanned, the total demand would approximately double.

The timing of the demand is tied to the scheduled departures and is assumed to be spread over a 30-minute interval (i.e., passenger predeparture arrival time at the airport varies according to the individual, and 30 minutes is our best guess as to the spread).



We have added two lines to the previous chart, one representing a "low" EDS deployment and the other a "high" deployment. The low deployment (about 27 EDS machines in a two-tier configuration) approximates the FAA's planning number for DFW in December 2001. The high deployment (about 48 EDS machines) was sized to produce maximum delays no greater than 10 minutes (we will give a graphical example of what we mean by maximum delays on the next chart). The scanning capacity in bags per 3-minute increment is shown on the left.

The figure shows that the baggage scanning capability for both deployments could easily accommodate all the bags that arrive over the day (e.g., the low deployment option can scan over 92,000 bags in 24 hours, or 146 percent more than the total baggage scanning demand).* However, both deployment options will experience periods when the number of arriving bags significantly exceeds the inspection system throughput. In such circumstances, the "excess" bags will be forced into a queue, waiting for machines to become available.

This study assumes that all checked bags are scanned after check-in, in an area not visible to the public. This is somewhat counter to what travelers experience today, but

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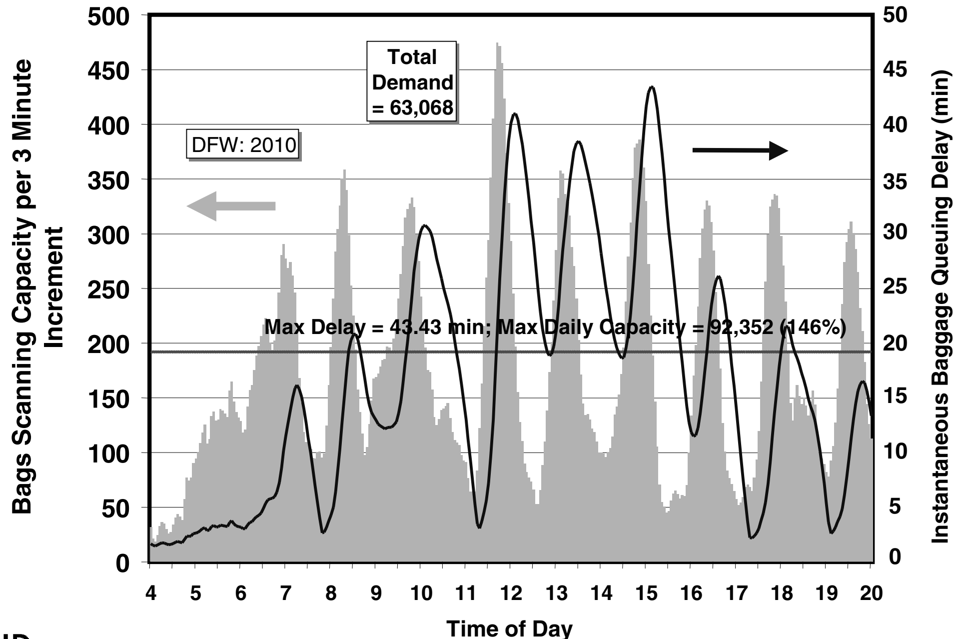
* Even if we assumed only a 16-hour workday, the demand and the capacity would be about equal in the "low" deployment case.

is the end state that most airlines desire. Under this assumption, baggage queuing delays are only relevant in terms of whether the checked bag actually makes it onto the airplane. The passenger can directly influence the outcome by altering his arrival time at the airport. The earlier he or she arrives, the higher the probability that the bag makes the plane. As already noted, arriving early entails a "cost" to the passenger because he or she is forced into spending "unproductive" time at the airport. This cost is an important factor in deciding how many EDS machines should be deployed, as we will shortly show.

Relating Queuing Delays and Baggage Demand (Scanning Rates ~ 65 Bags per Minute)



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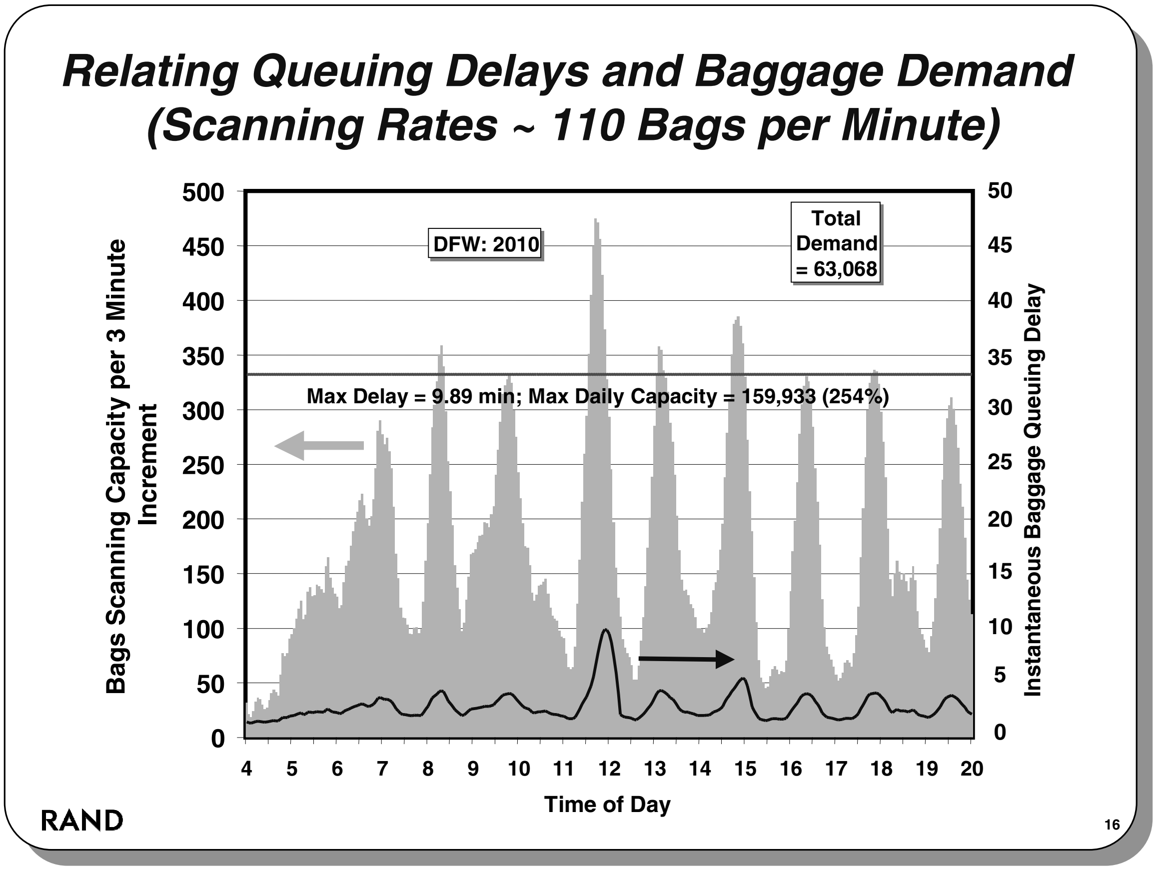
We have added to the prior chart the time-history of baggage queuing delays associated with the low deployment. The dark wavy line on the chart shows the time history of the size of the queues over the course of the day (the abscissa for this curve is shown on the right-hand side of the chart). We define *delay* as the amount of time a bag is in the queue before being scanned. As the chart shows, these waiting times vary over the day. For the assumed (low) deployment, the delays reach a maximum of about 43.5 minutes around 3:30 PM and have three additional peaks of over 30 minutes.

A quick inspection of the chart shows that whenever the demand exceeds the EDS throughput, delays rise. And when demands are less, delays fall. Thus, the peaks of the delays do not coincide with the peak demand but “slip” somewhat to the right. Moreover, the maximum delay does not necessarily correspond with the peak demand period.

For a number of reasons, the magnitude of the peak delay is important. Neither the passenger nor the airline wants to have a checked bag fail to be loaded onto the same plane as the passenger. It angers the passenger and creates ill will for the airlines. Moreover, the airline does not want to delay a flight departure to accommodate a bag stuck in some queue. It is common for airlines to advise their passengers to arrive at the airport an hour or more before the scheduled departure time, in part to ensure sufficient time to get all the checked baggage to the correct airplane prior to departure.

System performance is also related to the "average" delay. We define *average delay* as the sum over the day of all delays in each time increment, weighted by the number of bags in that increment. Although not shown on this chart, the average delay per bag for this deployment is approximately 20 minutes. Average delays are a good measure of how much additional time an *average* passenger will need to add to his planned predeparture arrival time. Of course, some passengers will have to add more time, and some less, depending on the time of day they fly.

Passengers will learn about delays through experience and will modify their behavior accordingly. For purposes of our analyses, we have assumed that the passenger will "hedge" and arrive earlier than "just in time," knowing that random factors could work against him. We have thus assigned a 15-minute hedge to take these random factors into account.



This chart shows delays associated with the "high" deployment. Note that, as advertised, the maximum delay is less than 10 minutes, with all other peaks less than 5 minutes. Moreover, the location of the maximum delay is tied to the maximum demand, allowing passengers to anticipate when the delays will be the largest.

Before leaving this chart, we should note that the calculation shown here assumes that the equipment deployed can produce the scan rates shown. Once reliability considerations and other relevant uncertainties are factored into the equation, the notion of an expected scan rate becomes important. That expectation depends on the configuration of the scanning equipment. In this study we assumed a two-tier scanning system in which a set of high-speed EDS machines inspects all bags and passes along to a second tier only those bags that are flagged as worth additional higher-resolution scanning in a slower machine. In such a configuration, it would be sensible to balance the machines so that neither tier is the bottleneck. When reliability is taken into account, it will often be the case that one tier or the other will be the dominant factor in causing baggage scanning queues. Nevertheless, the simple approximation of reducing the overall scanning rate by the reliability gives reasonable, if somewhat optimistic, estimates of overall throughput performance.

Important Factors in Our Analysis

- **Expanding demand to include two major airports**
  - **Capture differences in demand characteristics**
- **Expected Maximum and Average Delays vs. Buy Size**
- **The Cost of Passenger Delay**
  - **Interaction between ticket price and cost of delay**
- **Positive Passenger Profiling for Demand Management**
  - **The potential of responsive profiling to minimize number of bags not scanned.**

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Our prior analysis, reported in Reference 1, focused almost entirely on baggage scanning needs at a single airport (Dallas–Fort Worth International). In our judgment, the use of a single large airport risked biasing the results. To compensate, we extended this analysis to include Chicago's O'Hare airport (ORD). O'Hare is also a major hub, but the demand is not as spiked because it has two major carriers (United and American). Both carriers run a hub-and-spoke system out of O'Hare, but they try to avoid arrivals and departures that conflict with the other. The following analysis combines the equipment needed at the two airports, determining buy sizes by holding delays (peak or average) constant.

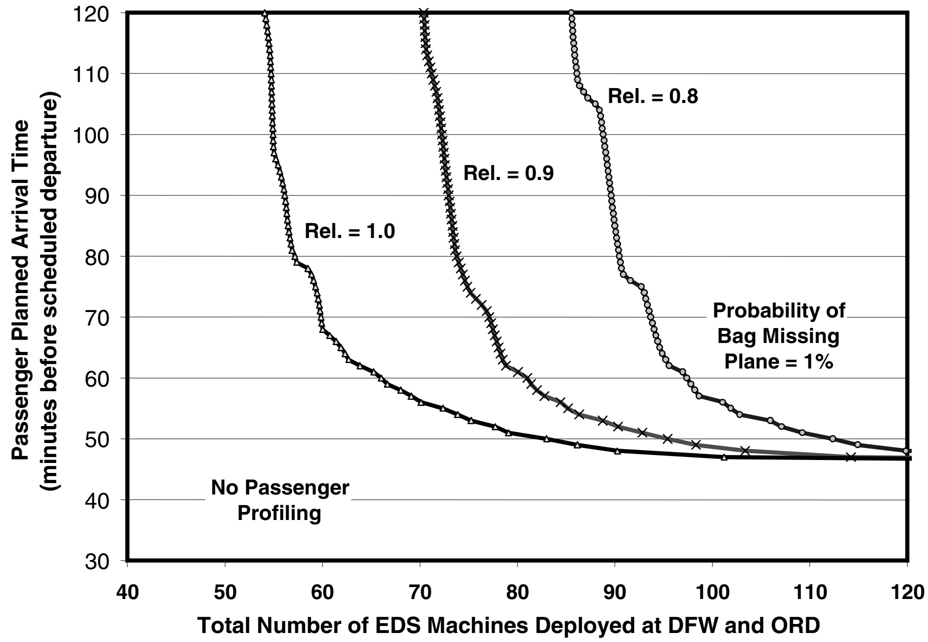
The following results are shown in terms of number of EDS machines needed. To turn this number into an equivalent scan rate, multiply the number of machines by approximately 7.

The subsequent analysis looked at both peak and average delays. The numbers shown in the next few charts, however, will be in terms of average delays. Our analysis showed that equipment reliability is the dominant uncertainty. The results include a range of reliabilities, running from a high of 1.0 to a low of 0.8.

As noted earlier, we undertook two separate approaches to estimating the overall costs of security associated with the baggage scanning system. One simply adds the cost of acquiring, operating, and maintaining the equipment to the cost to the passenger of having to endure additional (excess) time at the airports because of baggage queues. The second uses a classic *consumer surplus* approach, in which passenger price elasticities are used to determine the impact on future air transportation activity, with all that this implies for the aviation industry and the health of the U.S. economy. We will show results for both.

Finally, we considered the potential of positive passenger profiling to lower demand and ultimately lower the total cost of security to the nation.

Passenger Arrival Time vs. Machine Buy Size (Scaled for Joint DFW/ORD Deployment)



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We have constructed this chart by combining the maximum expected delay curves for ORD and DFW to come up with a combined machine buy (see Reference 2 for individual airport delay curves). These two airports support approximately 6 percent of all departures from commercial airports in the United States. They are two of the top four airports in total operations and passengers served (Atlanta Hertzfield International and Los Angeles International are the other two). Time and money did not allow us to extend the analysis past these two, but we believe that these two should be sufficient to reach some general observations and conclusions.

This chart plots the required passenger planned predeparture arrival time that corresponds with a passenger having his or her bag miss the plane with no more than a 1 percent probability. The shape and location of the curves are sensitive to a number of parameters, including machine reliability, the machine's false alarm rate, and the passenger's tolerance of risk. This chart shows the sensitivity to machine reliability.

Note that all three curves asymptote to a value near 45 minutes as the machine buy size exceeds 120. This occurs because we are assuming that 30 minutes is the minimum time needed to check baggage at the counter, have the airline scan it (with no queue), and deliver it to the plane.* An additional 15 minutes is added to the passenger's planned arrival time to deal with his or her uncertain arrival time at the airport. With a smaller number of machines, baggage scanning queues will appear, increasing the 30 minutes of baggage handling transit time. To still get his or her bags on the plane, the passenger must arrive earlier. As the chart shows, the sensitivity to the total number of machines grows as the number of machines declines. As we will demonstrate shortly, this suggests that when planning for a total deployment it is important to hedge on the high side.

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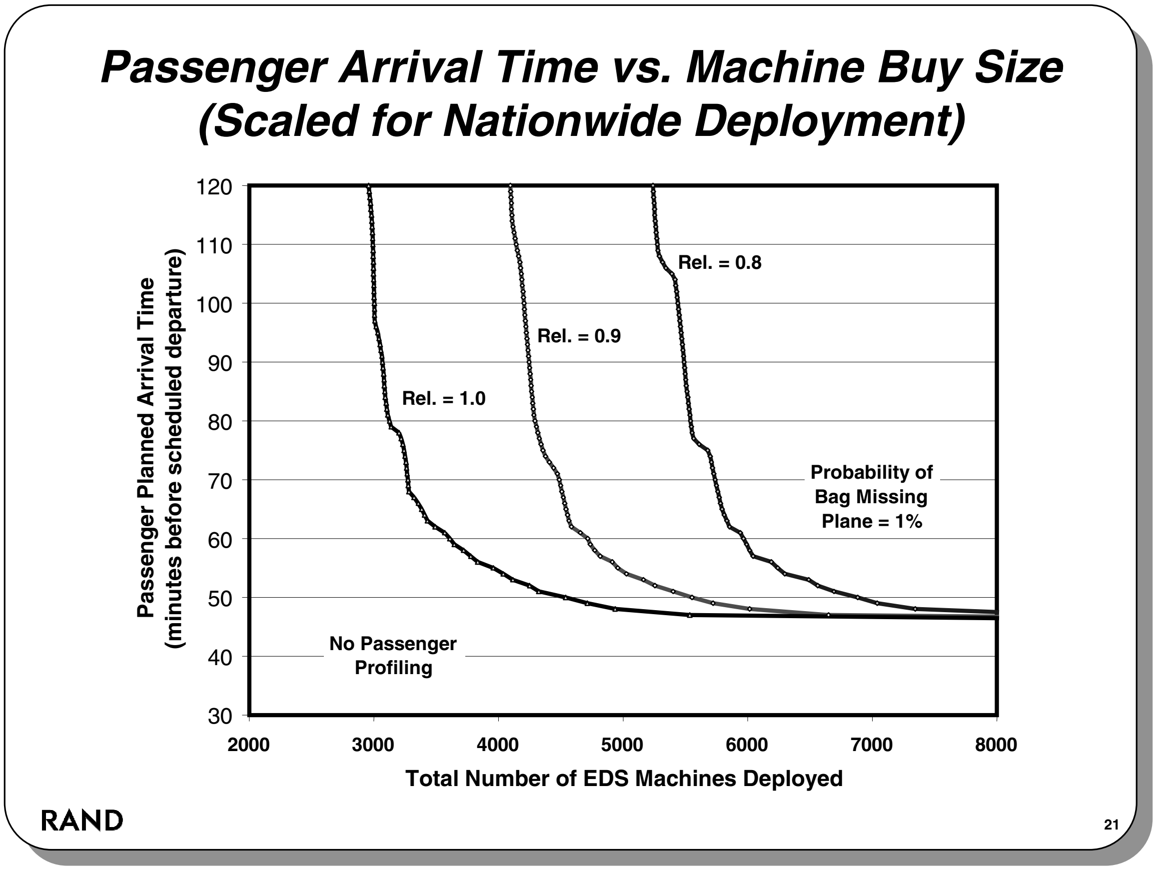
* In reality, the bag needs to be placed on the plane well before the plane departs, so the actual transit time must be somewhat less than 30 minutes. This does not change our calculation because the last few minutes are needed to prepare the airplane for departure.



This chart extends the results of the prior chart to equivalent EDS machine deployment levels appropriate for supporting baggage scanning requirements at all U.S. commercial airports.

To scale up from the combined number of EDS machines at DFW and ORD, we took into account the following factors:

- *Extrapolating machine demand at DFW and ORD to all commercial airports in the United States:* Past studies by the FAA on nationwide needs for baggage scanning equipment broke the needs into individual airports. Although the estimates for machine needs in those earlier studies were significantly smaller than those derived in this study (mostly because the criteria for sizing these deployments were less demanding), the relative needs among airports is, in our judgment, satisfactory for our needs. The resulting scaling factor is 43.75.

- *Airport baggage scanning inefficiencies:* Until now, we have assumed that baggage scanning at DFW and ORD was done in a central facility (this was also true in the FAA studies). This practice maximizes the use of the machines but overstates what is possible at most airports. The airlines prefer to keep all the checked bags under their control. Combining this with airport layouts, which tend to segregate the larger airlines into individual terminals, we developed the following scale factors:

– 25 percent increase in number of machines for reliability of 1.0

– 33 percent increase for reliability of 0.9.

– 40 percent increase for reliability of 0.8.*

We use the demands shown on this chart as inputs to the cost tradeoffs that we will now discuss.

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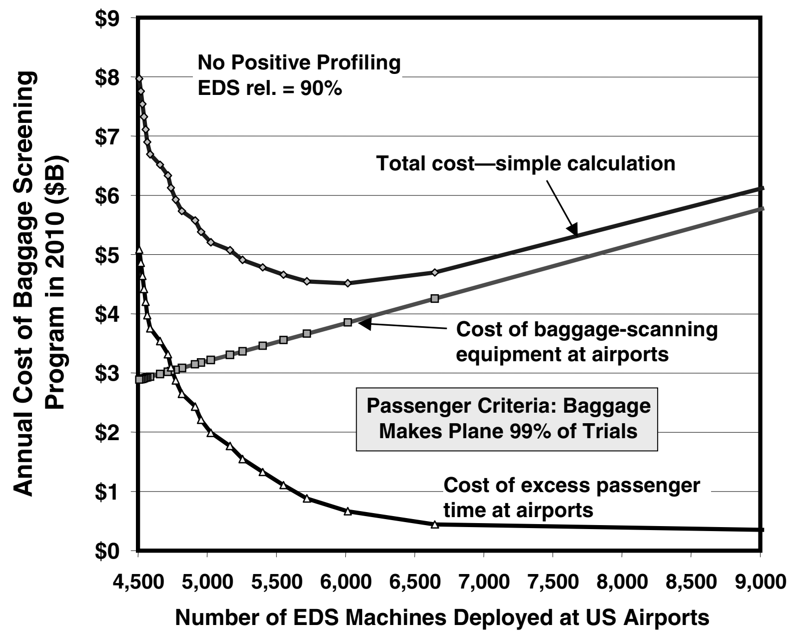
* See Reference 2.

How Much Equipment Is Enough? Minimizing Total Costs to the Flying Public



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An important objective of this study was to identify the optimum size of the acquisition of EDS machines at all U.S. airports. To make that evaluation, we undertook the approach of balancing two competing costs associated with baggage scanning. One is the actual cost of baggage scanning itself, including the acquisition of the equipment, the modification costs to the terminal to house the equipment, the personnel costs of operating and maintaining the equipment, the cost of spare parts, and overhead costs associated with management.* The other is the cost to the passenger incurred when the passenger must spend more time at the airport than would be necessary if baggage screening could be done without causing the passenger any delay. This chart shows the components of both. The equivalent annual cost of baggage scanning is shown as almost a linear function of the total number of machines acquired. It is roughly $650,000 per machine. The cost associated with the extra time the passenger spends at the airport is assumed in this chart to be a linear function of that time, calculated at approximately $32 per hour.**

The curve at the top is the simple sum of the two curves below. As expected, it starts out high (because of excess passenger time spent at the airport), ends up high (because

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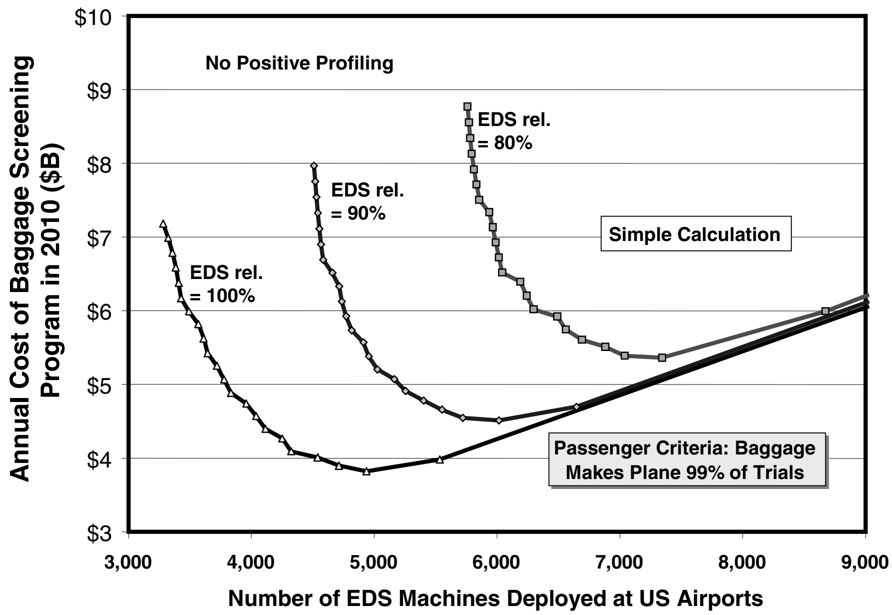
* All costs are annual present value, amortized over ten years.

** This figure was taken from the FAA's web site, and is the government's official cost per hour to be used in this kind of calculation.

of the growing cost of the equipment and its operation), and passes through a minimum somewhere in the middle. For the assumptions on this chart (e.g., EDS reliability = 0.9), the minimum occurs in the neighborhood of 6,000 machines. Thus, a nationwide operational deployment of around 6,000 machines (optimally allocated to airports, of course) would minimize the overall cost to the flying public, presuming that the equipment costs are passed along to the passengers as part of the ticket price (e.g., as a security tax).

It can be argued that minimizing this cost to the flying public should be the target for TSA sizing the buy. After all, with security held constant, the lower the cost to the passenger, the higher will be the passenger's interest in flying and the greater will be the commerce that flying enables and reinforces. However, other economic factors come into play that could move this optimum. We will discuss these additional factors shortly.

Selecting Total EDS Machine Deployments to Minimize Overall Costs to Travelers



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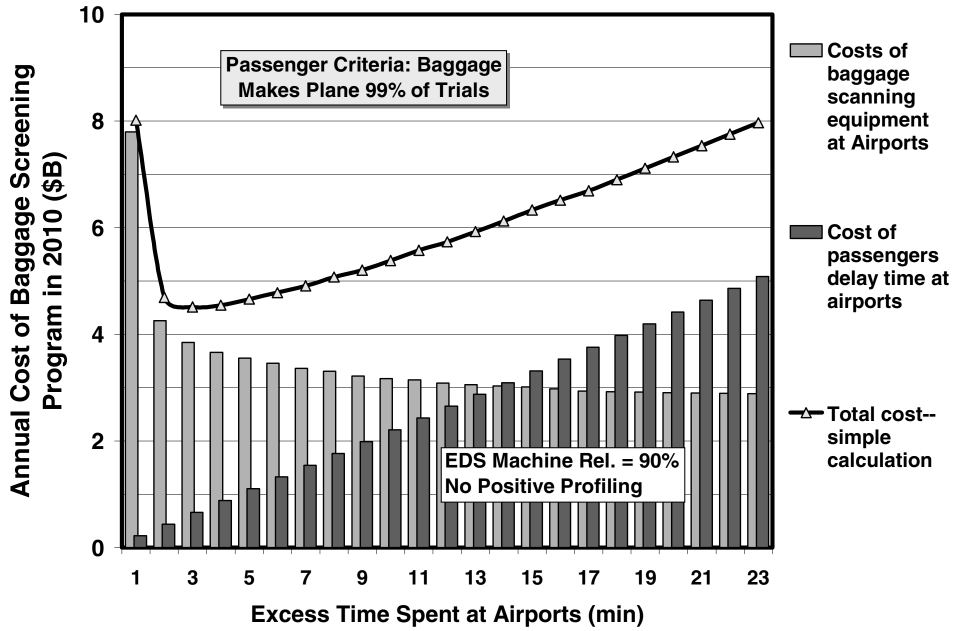
This curve shows how machine reliability alters both the cost and the location of the cost minimum vis-à-vis the total number of machines operationally deployed. Several obvious points can be made.

- A lowering of reliability pushes the optimum machine buy higher, resulting in a higher cost to the flying public. Note that we did not assume that the change in reliability alters the cost of the individual machines or their maintenance. We are assuming that lower reliability will force higher machine deployments to achieve the same level of baggage scanning throughput. This is the principal reason for the higher cost.
- Even with perfect reliability, the optimum buy is around 5,000 EDS machines, a number that substantially exceeds the original estimate put together by the FAA in December 2001.
- The curves are flatter to the right of the minimum point than to the left. Given the inherent uncertainty of the actual reliability that will be maintained over the lifetime of the machines, it is better to hedge toward a buy that exceeds the optimum point.
- The overall cost to the flying public is in the few billions, so long as the buy is reasonably sized. This equates to a few percent of actual ticket revenues

that the airlines obtain from tickets. A few percent may seem small, but it is a relatively large fraction of the airlines' profits.

Passengers are price sensitive. Thus, an increase in the cost of a ticket could alter the overall demand for airline travel. These effects and others will be discussed shortly when we describe a more complex economic calculation that could replace the simple addition shown above.

Total Cost as a Function of Delay Times



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This chart is a simple replot of the chart on page 23, where the variable on the ordinate has been changed to the expected average delay associated with the machine buy size. With this change, the passenger delay costs rise linearly with excess time, and the costs of the EDS deployments fall because fewer machines are needed as more delay is allowed. The curve at the top is again the sum of the two costs (shown as bars below).

The minimum total cost of around $4.5 billion occurs when average passenger delays are about three minutes. At first glance, this result seems remarkable, given the relatively insensitivity that most passengers appear to have regarding their exact arrival time at the airport. But people do make choices on whether or when to fly based on price. That price includes perceptions of inconvenience. And the many hundreds of million passengers a year turn these relatively small individual costs of wasted time into numbers that quickly exceed the total cost of the security system.

The policy implications of this chart are obvious. First and foremost, passenger convenience is a very important factor in judging how much is enough. And potential delays due to the screening of checked baggage play a role. Admittedly, most passengers are primarily concerned about passenger screening stations (all passengers experience those delays). Baggage screening delays are often disguised by long lines waiting to check in at the counter. These lines effectively meter the arrival of people and their baggage at the counter at a rate that makes baggage scanning no longer one of the "long poles of the tent."

Second, these results apply more generally to airport flow. While we have not analyzed other flows (especially those through passenger screening stations), it is self-evident that a similar study of these stations would yield a similar result. The two cost structures are essentially the same—even though the magnitude of the screening costs may be substantially different.* It is passenger delays that dictate the outcome! And passenger delays at the carry-on screening stations are every bit as important as those associated with baggage.**

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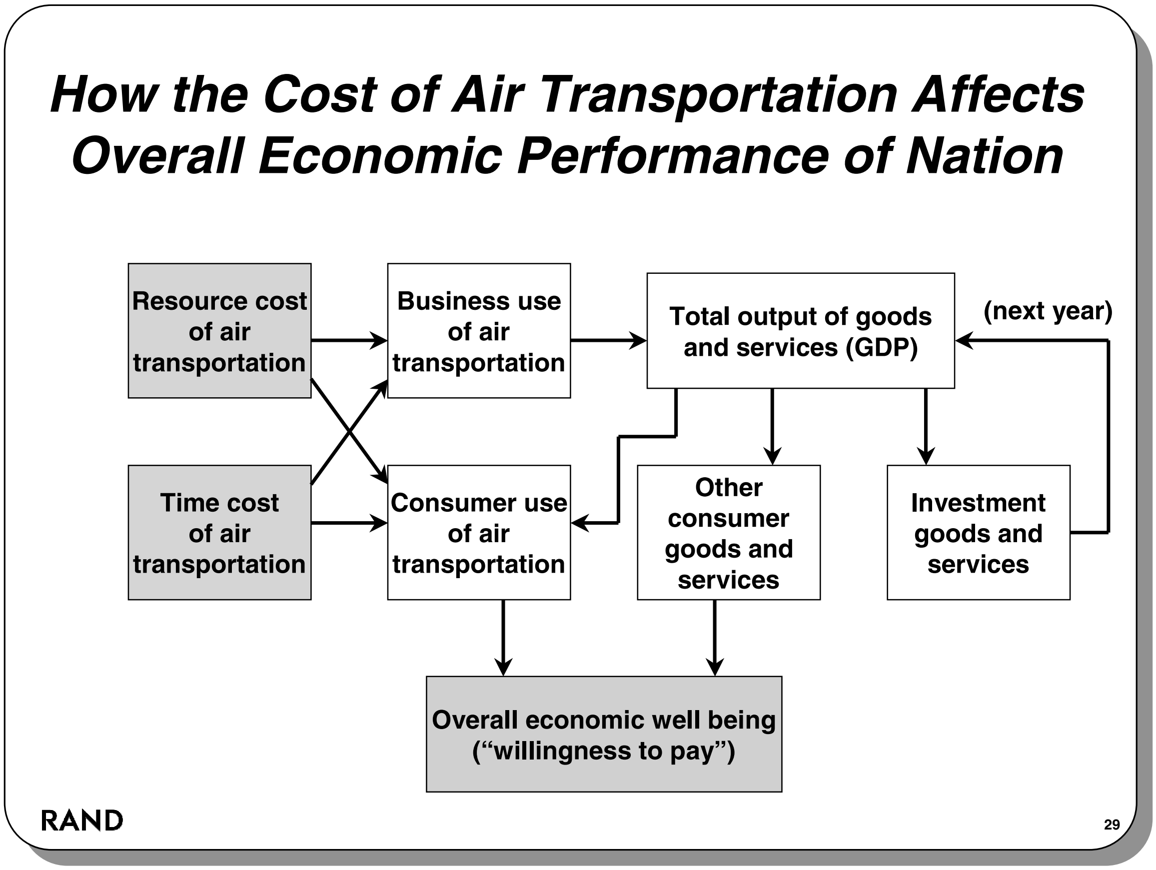
* See Reference 2, Appendix B, for a discussion of how passenger screening delays might affect the results of this study.

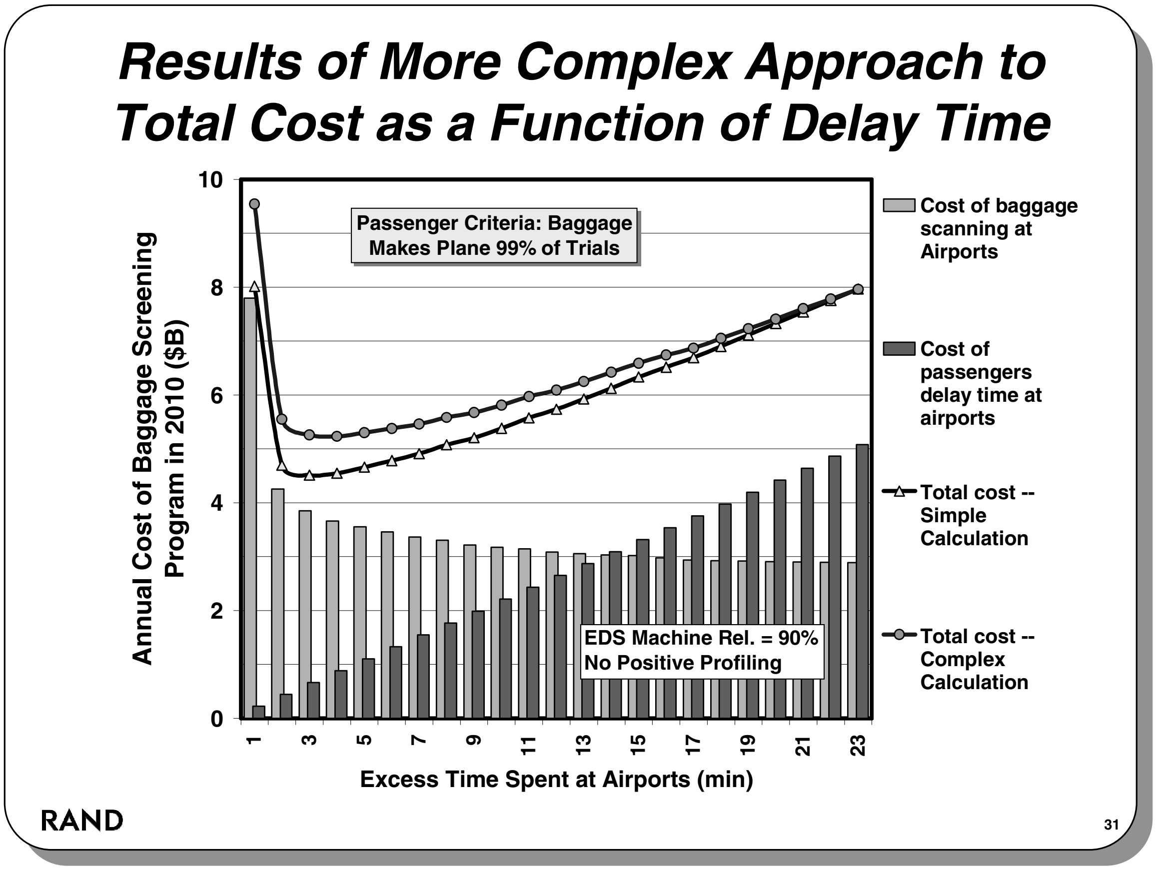
** The delays associated with passenger screening stations need to be included in any robust treatment of overall airport security and how the costs of providing the overall security at the airport can best be minimized. However, this study ignored these delays for reasons already mentioned at the start of this briefing.



This flow chart illustrates the second methodology by which we calculate the overall economic cost of any level of baggage scanning equipment and its associated delay. The methodology is a model of the entire U.S. economy and the role of air transportation in determining overall GDP and consumer well-being. (A complete mathematical statement of the methodology is given in Reference 2, Appendix A.) For this calculation, we consider how the level of air travel depends on both its dollar or resource cost and the time it takes. For each level of delay, we calculate the average cost per revenue passenger mile (RPM), and in the economic model we add this to the cost of air travel, in effect assuming that the cost will be passed on to air passengers in proportion to their RPM flown. We also assume that the level of machines required to achieve the given level of delay is proportional to the volume of air travel, as measured by RPM.

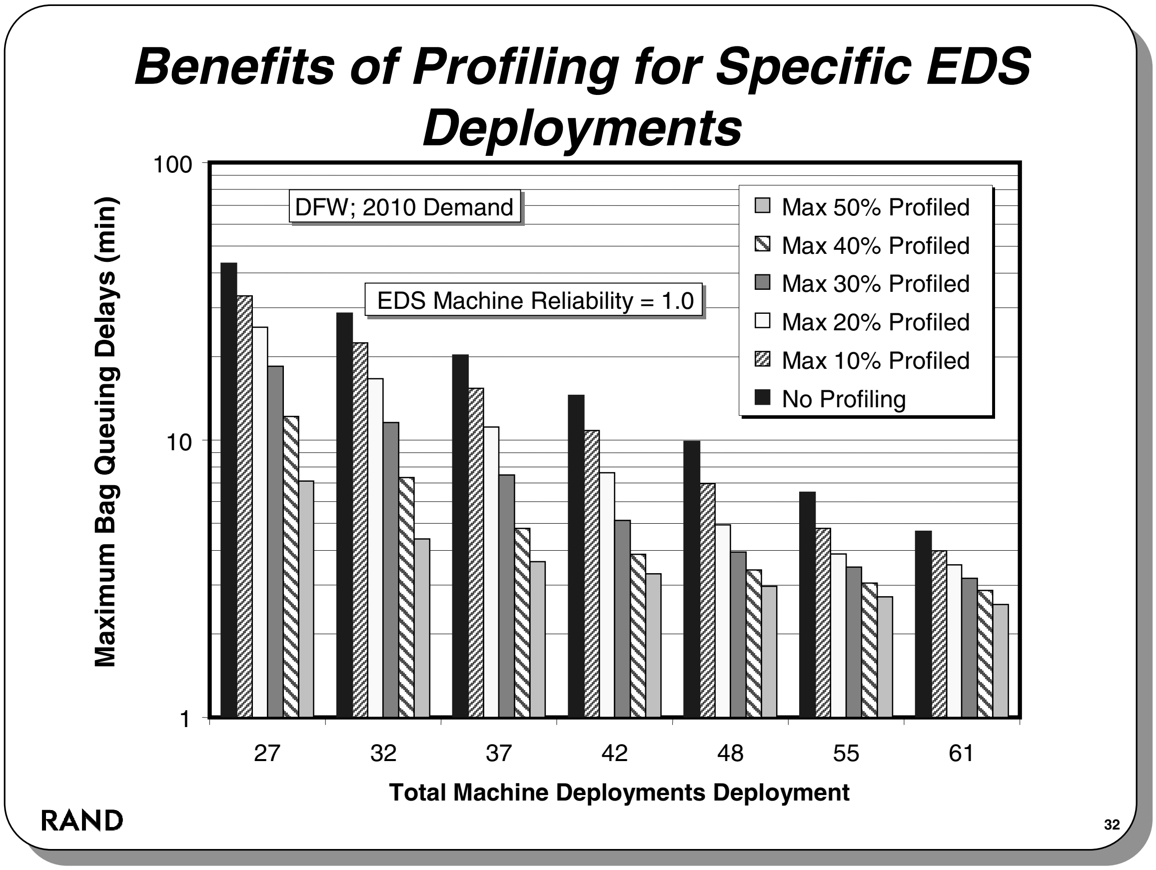
Thus, as the flow chart shows, we begin each calculation with the delay level ("time cost of air transportation") and the increase in the cost of air travel ("resource cost of air transportation"). Changes in these variables have two primary effects. First, air travel is an input to the production process in the economy as a whole. Increases in either its resource cost or time cost will lower the overall level of output, or GDP, and will result in a decrease in air travel for business. GDP determines consumer income. Decreases in GDP and increases in either the resource or time cost of air transportation will lower consumer economic well-being, as well as decrease consumer use of air transportation. It is the decrease in the economic well-being of consumers that we use as the measure of economic cost in these calculations. This measure is precisely defined as the amount consumers would be willing to pay to avoid the changes in resource and time cost, called *consumer willingness to pay*.

A further effect captured in the model is that investment in any year depends on GDP, and a decrease in GDP will lead to a decrease in investment. The decrease in investment will in turn lead to a decrease in GDP in future years from what it would have been, thus affecting consumer well-being in future years as well. Our calculations capture this effect on consumer well-being over time.



This chart overlays the results of the more complex approach on the results of the simple approach shown in the chart on page 27. The results are very close. Thus we conclude that including consideration of the impact of price and delay time on the level of air travel, and on the level of business productivity and the resulting rate of economic growth, does not change the basic finding of the simple approach: Sufficient machines should be procured to reduce delay times to very low levels.

Because the results of the more complex approach are mediated through the various elasticity parameters, a direct comparison possible with the more simple approach is not possible. For example, because in the more complex approach air travel falls with increases in price and delay, the economic cost is mitigated to some degree. On the other hand because in the more complex approach any change in costs leads to lower GDP—which, through its effect on investment, lowers future years' GDP—the effect is magnified. This chart shows that on balance the magnifying effects are calculated to be higher. We offer one plausible explanation of why this magnification falls as delay levels increase. It may be due to economic growth effects—all the machine usage costs feed into investment and lower future GDP, while some of the time cost is borne every year but does not compound.



An alternative to reducing the passenger delays for specific EDS deployments and thus reducing the economic costs is to change the screening process related to certain classes of passengers. Positive passenger profiling, sometimes called "trusted traveler" or "registered traveler" programs, offer real opportunities for reducing the baggage check-in demand at busy airports. References 2 and 3 describe the approach to such a program in more detail. This chart shows how specific EDS deployments can lower the maximum queuing delays as a function of the fraction of profiling employed. Holding delays constant, a 50 percent reduction in demand yields an almost 50 percent reduction in number of machines. Holding machine buy size constant, a 50 percent reduction in demand yields an 80-plus-percent reduction in delays.

The implications for cost reduction are obvious and significant.

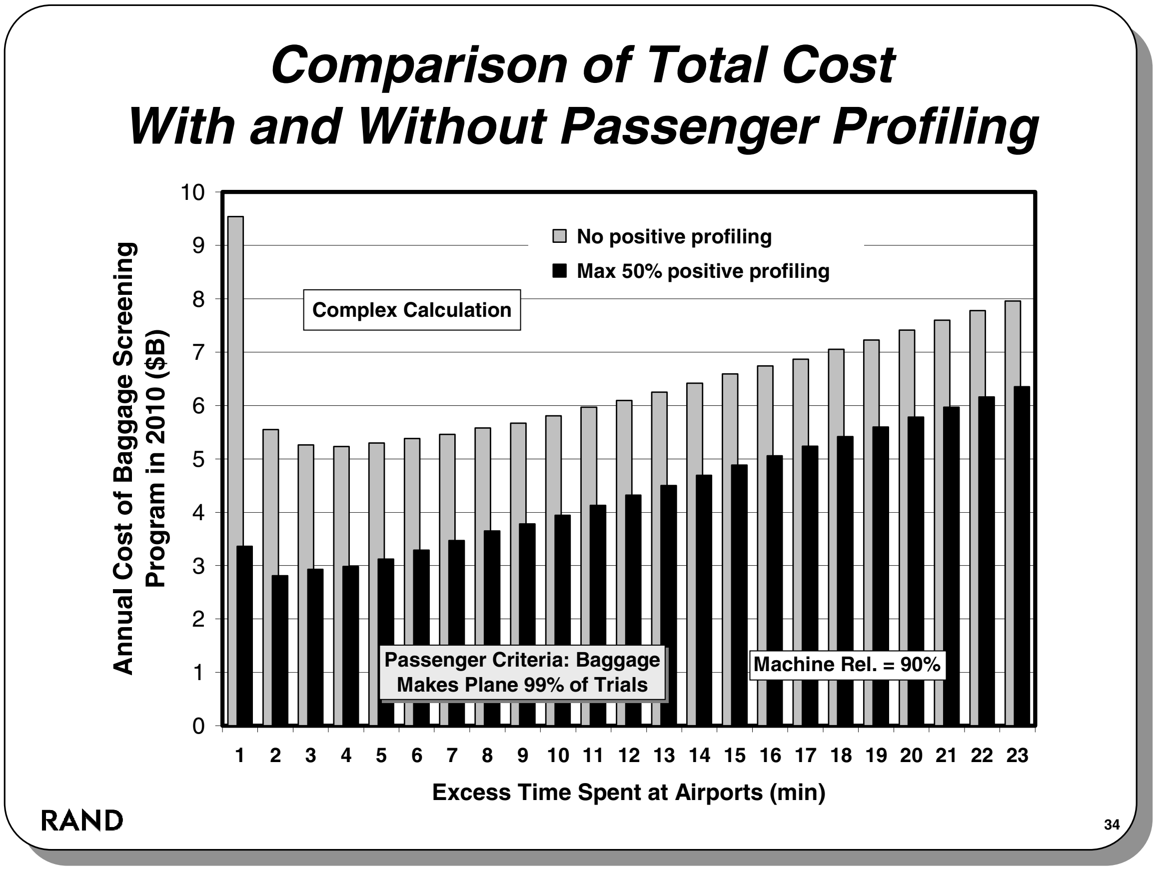
However, many oppose positive passenger profiling, for several reasons:

- *Issue 1:* It requires the government (or some private entity) to build an extensive (and potentially intrusive) database on all would-be registered travelers, raising civil liberty issues.

- *Issue 2:* It requires a virtually 100-percent reliable identification system; otherwise it could be "spoofed"—increasing the danger to civil aviation. Even if this were achievable, there is a danger that a "trusted" passenger could be "turned," perhaps through coercion.

- *Issue 3:* It segregates passengers into at least two classes, suggesting discrimination against a class of travelers who do not have the requisite background clearances.

Reference 3 discusses these issues in more detail. We merely note here that positive profiling could have a dramatically beneficial effect in the economic cost of screening.



This chart compares the annual costs of baggage scanning with and without positive passenger profiling. For this example, we have selected a maximum profiling of 50 percent. As might be expected, the annual savings are substantial at the lower delay times, corresponding to the savings associated with the fewer machines that need to be acquired and deployed at the airports. The optimum (i.e., minimum cost) point along the ordinate is around 2 minutes.

Observations on Positive *Passenger Profiling*

- **Positive passenger profiling can benefit airline passengers, the airlines, and the nation's economy in several ways**
  - **Lower delays for the passengers**
  - **Higher assurance of baggage delivery to intended planes**
  - **Lower ticket prices if security costs taxed against passengers**
  - **Lower overall cost to nation by approximately 45% if 50% of the travelers can be positively profiled**
- **Adaptive strategies can play an important role**
- **But valid concerns about positive profiling remain and need to be resolved**

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Positive profiling is complementary to negative profiling and arguably more likely to be successful. It is much harder to find a "terrorist" in a group of people than it is to find someone who matches the positive profile. The criteria for finding "terrorists" are classified because they could be used by the terrorists to avoid being profiled and thus gain normal access. The criteria for positive profiling are openly stated: they must be impossible for terrorists to meet, or else positive profiling would not work.

The benefits of positive profiling are listed in the chart. We note without further discussion that adaptive strategies could lessen concerns about positive profiling and retain most of the gains (see Reference 3 for further discussion of adaptive strategies).

We do not know how many people might be eligible for the kind of positive profiling identified here. We suspect that upward of 50 percent of daily travelers would qualify, but the actual number would depend on the criteria selected.

There is substantial opposition to positive profiling in various quarters. Good arguments can be made pro and con. However, there is one concern that has not gotten as much attention but appears serious—namely, the use of coercion against a registered traveler in order to get that traveler to act in concert with the terrorists.

We support both negative and positive profiling as potentially useful approaches but would withhold endorsement of positive profiling until more is known about how many people would qualify and what criteria would be used.

Summary

- **Congress mandated that all bags be scanned by the end of 2002**
  - TSA, the airlines and the airports have been in a rush to meet the mandate (a few airports couldn't meet the deadline and were given a reprieve)
- **Overlooked in this rush is the question of what size deployment would best serve the nation's interest**
- **Employing queuing analysis and a specially constructed economic analysis model we have arrived at several important conclusions**
  - To minimize the economic impact of bag security screening to the country (and the airlines) enough screening equipment should be deployed to reduce average delays to less than 5 minutes
  - At this level of deployment the economic cost to the country is about $4.5B per year but with inadequate amounts of equipment deployed the cost could be easily $10B or more per year
  - Positive passenger profiling may provide a promising method of reducing this economic cost, but several issues remain unresolved
- **In general, this implies that the government should over time acquire and operate substantially more machines than originally planned**

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Meeting the congressionally mandated deadline was not easy and forced TSA to accept some compromises (including the wide use of available ETD* machines rather than the preferred EDS machines). With only a few exceptions, the mandate was met at the airports, to the credit of TSA and all the airports involved.

At the time of this writing (March 2003) it is not clear whether the current deployments will result in substantial delays any time soon. Our analysis looked into the future (CY2010) and used future demand for baggage screening. If our estimate of demand is off by a year or two, then our results would shift to that year. Moreover, the core of our conclusions—the criterion that appears most apropos to answering *how much is enough*—is not particularly sensitive to the magnitude of demand.

Our analysis shows that the cost of passenger delays is a dominant factor. This leads directly to the conclusion that sufficient baggage inspection equipment should be deployed to drive the average delay to under five minutes. It also argues for hedging in the direction of even larger deployments, given the sensitivity to machine reliability and false positive alarm rates. Based on our analysis, the minimum annual cost to the nation

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*Electronic Trace Detection.

of the scan-every-bag mandate is about $4.5 billion. Nonoptimal baggage deployments would increase that cost.

A mitigating option—employing positive passenger profiling, often associated with the "registered traveler" label—could lower the total cost to about $2.5 billion if 50 percent of passengers were eligible, but it would not materially alter the conclusion about the optimum delay point.

Our analysis holds the level of security constant for all options. Thus, whatever the benefits or costs of security, they do not figure in the analysis.

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3. Shaver, Russell, and Michael Kennedy. *The Benefits of Positive Passenger Profiling on Baggage Screening Requirements.* Santa Monica, CA: RAND Corporation, DB-411-RC, 2004.