The Late, Late Show: How a Priority Flight System Can Reduce the Cost of Air Traffic Delays

CHRISTOPHER J. MAYER

Air traffic delays, although not new, have become increasingly worse in the 1980s and are now estimated to cost over $2 billion a year. A system of using flight priorities to make more predictable flight schedules is suggested, a system that could save consumers tens of millions of hours in travel time and produce millions more on-time arrivals. Such a system would allow consumers to choose among different priorities of service, such as express flights versus regular flights, with fare differences reflecting the differences in flight time. Airlines would be better able to use their planes, gates, and crews because flight schedules would be more predictable. All of this would occur without arbitrary restrictions on capacity and in a system that would encourage airlines to compete with on-time performance. A repeated auction could be used to distribute the priorities competitively and efficiently. Reducing the ticket tax by the revenue raised in this auction would leave average ticket prices unchanged. This research simulates how such a system would operate at Chicago's O'Hare Airport, using several different priority plans. With this system delays at O'Hare alone can be cut by 3.5 million hr a year. This figure is a lower bound for savings, because it does not include the savings to airlines or other related businesses and does not account for benefits such as a more predictable system. Although additional research is certainly required, a priority system seems to hold significant potential for alleviating much of the cost of air traffic congestion.

"The Late, Late Show—Airline delays are bad—and they are going to get worse," according to the *U.S. News and World Report* (*1*). A *Wall Street Journal* headline read, "Hurry Up and Wait: Airline Delays Bring Gripes—And Lots of Excuses" (2). The newspaper further reported, "Cosmetic Change: Airlines' Pledge To Reduce Delays May Be Illusory" (*3*). Although travel delays are not new, the dramatic increase in their number has attracted much media attention. In this paper a priority system is proposed that would make delays more predictable and allow consumers to choose among several probabilities of delay as they now choose between levels of service (i.e., first class, business class, or coach class). This method will also have the potential to save consumers tens of millions of travel hours, allow airlines to have better control of their schedules at a lower cost per seat, and remove significant public pressure from the FAA.

The history of the delay problem is often traced to two events: airline deregulation in the late 1970s and the strike by air traffic controllers in 1981. Deregulation removed flight routes from the government's control, allowing airlines almost complete freedom to schedule flights. The air traffic controllers strike cut back on the number of adequately trained controllers and, some claim, still affects the capacity of the air traffic control system. Responsibility for the delays that followed these two events has been hotly debated. Some blame the FAA for not rehiring the fired controllers. The FAA claims that the airlines are to blame because they bunch flights, creating unrealistic schedules that exceed capacity at many airports. The airlines often blame the public for all wanting to fly at the same time and claim that any airline that unilaterally rescheduled flights would commit competitive suicide.

Meanwhile the delay problem continues to worsen, at an increasing cost to all involved. Businessmen and frequent flyers spend more and more time traveling and less time working. The airlines' increased use of the hub-and-spoke system has caused many more missed connections and unplanned overnight stays. Delays raise the labor costs of airlines and cause them to use their capital inefficiently (e.g., for gate space and aircraft). The Air Transport Association (ATA), a trade association for the major airlines, estimated that these annual costs exceed $2 billion.

The U.S. Department of Transportation (DOT) has recently forced airlines at four major airports to amend their timetables to reduce flight delays. [By April 1, 1988, flights at the four airports must operate within 30 min of published schedules at least 75 percent of the time (*4*).] This change, as Congressman Pete DeFazio noted, makes schedules more predictable for the consumer, but has little substance (*3*). Flights do not arrive more quickly than before this ruling; airlines simply add more time to the schedules of existing flights. Without structural or procedural changes in the way the air traffic control system operates, congestion will continue and air travel will still be erratic and time-consuming.

Many people have proposed other solutions to the current problem. Some have recommended applying "classical" economics to the problem (i.e., treating the delays as excess demand for scarce resources). This reasoning led to the system of slot control that the FAA is testing at four airports—National Airport in Washington, D.C.; O'Hare in Chicago; and Kennedy and LaGuardia in New York. Slot control, however, has not managed to reduce delays greatly at these airports; they are still among the most congested in the system. (Furthermore, no one knows what the right number of slots is for any airport.) Other

Department of Economics, Massachusetts Institute of Technology, 50 Memorial Drive, Cambridge, Mass. 02139.

"market" solutions range from recommendations to raise the landing fees during congested times to the ATA recommendation to make the FAA a private organization. (The ATA proposal presumes that a private FAA would be free of bureaucratic restraints and would use market mechanisms and greater investment to create a more efficient air traffic control system.)

Others have concluded that deregulation has failed and that regulations are necessary. Currently proposed bills in Congress would require all airlines to publicize various types of service information and would fine airlines that have "unrealistic" schedules. Still others support the current DOT policy that gives airlines exemption from antitrust laws to coordinate their schedules and eliminate the bunching that accounts for many delays.

The third class of solutions would increase the capacity of the system. Congress is now releasing the funds in the Airport Trust Fund to build newer and larger airports, hire more air traffic controllers, and modernize the whole system. Some have suggested that Congress spend even more. A few believe that some current FAA safety margins are too restrictive and that changing the safety margins would increase the capacity of the air traffic control system.

When the problem of delays is considered, however, the optimal solution should address many concerns. Clearly safety should be protected with any proposal. The ideal solution should also produce socially optimal results and, if possible, benefit all parties involved. Competition must also be preserved. Of course, the solution should be politically feasible. Finally, some short-term benefit (i.e., some immediate relief from delays) is very important.

Many of the earlier solutions fell short of this ideal. The market solutions, as a group, certainly have potential for social gains, but are often politically infeasible, potentially noncompetitive, and too complicated to be realistic. (For example, an optimal landing fee to relieve congestion was proposed that would change depending on the weather.) Reregulation also has its problems. It could likely restrict competition, raise fares, and negate some of the social gains made from deregulation. Increasing capacity would certainly help to solve the delay problem, but is a long-term venture that is being held up because of budget constraints. Even without budget constraints, there is no good way to determine what the optimal investment in the air traffic control system should be. Finally, there is often local opposition to expansion and much political opposition to rehiring the fired air traffic controllers.

A NEW IDEA: ATTACH PRIORITIES TO FLIGHTS

In this paper a very different strategy to attack the delay problem is analyzed: attaching priorities to flights. Although this concept carries its own potential implementation problems, which will be addressed later, these problems appear to be solvable. For now, the more fundamental questions will be discussed: how might such a plan work and what are its potential gains?

A system of priorities is a market-based alternative to reregulation of the airline industry. It creates more carefully defined property rights, whereas the current system creates only ambiguous ones. A landing slot carries the right to land at an airport—a priority gives the additional right of landing before other users of lower priority. Indeed, inefficient congestion could not occur if a fully defined system of property rights existed, because market transactions would readily eliminate undesirable congestion.

How the Priority System Would Function

Currently all flights are treated equally. A fully loaded 747 is given the same probability of delay as a partly filled 737 with one-tenth the number of passengers, even though the costs of delaying the former greatly exceed the costs of delaying the latter. A system of priorities could allow airlines to separate travelers according to the value of their time, putting those with a high value of time (e.g., businessmen or other frequent fliers) on express flights and those with a lower value of time (e.g., vacationers) on regular flights. As odd as this might seem, it is similar to the structure of train service in Japan, Italy, and France, where travelers pay a premium for express service. American Airlines Chairman Robert Crandall has publicly advocated such a system.

A system of priorities allows the air traffic control system to differentiate among aircraft. This would not necessarily mean that larger aircraft would always have priority over smaller aircraft. Highest priorities should go to the most valuable users. As will be discussed later, an auction would provide an economically efficient way to distribute priorities to the most valuable users of an airport.

In addition, a system of priorities would potentially allow airlines to reduce their per-seat costs. For example, larger aircraft could be used on the express routes, so these aircraft would receive fewer delays and be used for more flights. Because express flights with larger, more expensive crews would receive fewer delays, labor costs would also fall. These gains would result in lower overall ticket prices.

How the FAA Handles Congestion: Central Flow Control

An brief explanation of how the FAA deals with air traffic congestion will also show that the priority system proposed is very compatible with current operating procedure and would not require a large-scale retraining of controllers. The FAA Central Flow Control Office in Washington, D.C., regulates congestion throughout the country. Initially, flow control was created to decrease the fuel costs of airplanes flying in lengthy holding patterns while waiting to land. Since then, safety and increased congestion have further supported the need for flow control, by which airport congestion is anticipated and demand is regulated by delaying planes from taking off until there is space for them to land.

Flow control accomplishes this by using both computers and staff. There is always a weather forecaster on site to help predict where and when the weather will constrain capacity. The controllers in flow control then discuss these forecasts with both local and regional air traffic controllers as well as with airline officials to get a good estimate of the future capacity at the target airport. This is usually done 4 hr before the expected congestion. Then the controller enters this estimate into a computer and runs a program to determine gate holds. This program looks at the intended arrival time of all scheduled service at the target airport and in an unbiased, random fashion delays the departure time of some aircraft to give an even flow of traffic into the airport. This controlled flow also ensures that plans will have minimal airborne holds before landing.

It is important to note that these programs are frequently run when airports have perfectly clear weather, because flight bunching causes everyday congestion. The flow control mechanisms are unpredictable and uncontrollable, so neither the airlines nor the public has advance warning about which flights will be delayed. Adding a system of priorities would increase the information to all involved parties. It would require only a minimal change in the software to add priority as another parameter in the flow-control program.

A priority system would only apply to aircraft before they take off. Some have suggested that the system continue while flights are in the air. This is infeasible because it would require retraining air traffic controllers at a time when there are not enough of them. Treating aircraft differently in the air could also pose a severe safety hazard.

SIMULATION OF AIRPORT WITH PRIORITY SYSTEM: 47 DAYS AT O'HARE

An important question is, How might such a system function and how would it compare with the current operating system? A computer simulation has been devised to help understand how such a system might work and to help predict any social gains that might be realized. The simulation was designed to test a priority system at a single airport using actual flight data and weather conditions. Chicago's O'Hare Airport was chosen for several important reasons. First, it is an example of a fully saturated airport that, even with slot control, has serious congestion problems and thus has potential for significant improvement. Next, very accurate weather and landing data are available that show the actual constraints on capacity by hour for 47 days during the first 6 months of 1987. Finally, O'Hare has been closely studied by FAA to determine the causes of delays there.

How the Simulation Works

The simulation does not provide minute-to-minute accuracy, because such a system would be too precise to be realistic. Instead it looks at the capacity and scheduling at O'Hare in 15-min intervals, dealing with a 14-hr "window" of flights from 7:00 a.m. to 9:00 p.m. The simulation also assumes that there are no cancellations or mechanical delays and that all flights are able to leave at their appointed times.

For example, assume that between 9:00 and 9:14 a.m. 30 flights are scheduled to arrive at O'Hare, but there is capacity for only 25 flights. Assume that these flights have the following priorities attached to them: 5 priority-one flights, 7 priority-two flights, 14 priority-three flights, and 4 priority-four flights. The simulation would clear all priority-one and -two flights to land. Priority-four flights would all be delayed 15 min and placed in the 9:15–9:29 a.m. time slot. One of the priority-three flights would be randomly chosen to be delayed with the priority-four flights; the rest would be cleared to land. The delayed flights in the new time slot would be treated as other flights of the same priority in that slot. (Later different plans will be discussed to determine whether flights should be given a higher priority after a certain amount of delay.)

This simulation, although simple, is not as unrealistic as it might seem. Adding flight cancellations, for example, should not change the results much. [Even Continental Airlines, considered by some to be the most unpredictable airline, cancels about 1 percent of its flights (5).] Small departure or mechanical delays should also have little effect on accuracy because the simulation uses 15-min slots. Finally, it is recognized that scheduled arrival times refer to arrival at the gate, not the runway. However, one could simply subtract 5 or 10 min from the arrival time to account for taxiing time and not disturb the results. Certainly the simulation does not assess how the priority system would affect the operation of the whole air traffic control network instead of a single airport. It will, however, give some idea of the potential gains that could be realized systemwide.

The Current System

First, a simulation was made of the delay system that is currently in use in flow control. All flights were given the same priority and when congestion occurred, flights were randomly delayed. This resulted in a mean delay time of 9.92 min a flight. (The mean delay time is the average delay per flight. The simulation, however, only gives delays in 15-min increments. Some flights receive no delays, whereas others are delayed in 15-min increments.) Figure 1 gives the distribution of those delays; 25.7 percent of all flights received a delay of at least 15 min. Only 13 percent of the flights received a delay of more than 30 min and about 0.5 percent of the flights received a delay of more than 3 hr.

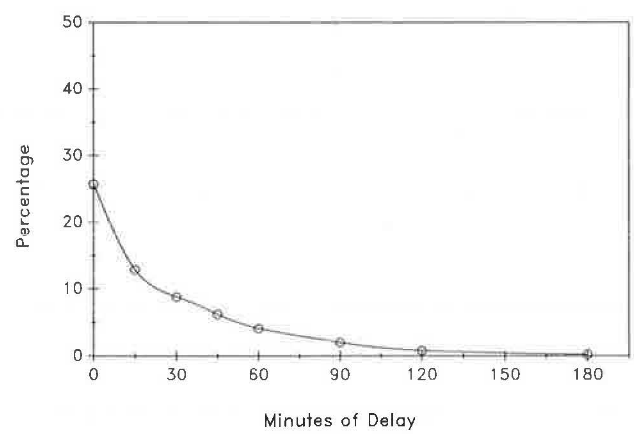

FIGURE 1 Percentage of flights with delays exceeding *X* min, current system.

FAA figures show that in 1986, flights at O'Hare were actually delayed an average of 11.34 min each. Thus the simulation seems to somewhat underestimate delays at O'Hare. This is expected because the simulation does not account for delays while the plane is taxiing, having mechanical work, and so on. Some, including ATA, argue that even FAA figures are too low because they only measure delays of 15 min or more and do not include delays caused by aircraft arriving late from their previous stop. Even with these considerations, the simulation does seem to account for most of the average delay.

The time of the simulated delays was calculated by using industrywide seating capacities for specific aircraft and individual airline load factors. This amounted to 16,264 passenger-hr a day, or almost 6 million hr a year. Assuming that travelers' time is worth $10 an hour, the total amounts to about $60 million a year. This is only a conservative estimate of lost passenger time and does not include any costs of delays to the airlines, to those waiting for late passengers, or to any other parties involved. Some might argue that $10 an hour is too low. The costs can be easily rescaled to another value of time. Using $15 an hour, the cost is almost $90 million a year.

A "Maximum Efficiency" System

Considered next was how the foregoing situation might change if some priority system were implemented. Initially the flights were divided into four classes depending on the size of the aircraft involved. (Large jets were in the first class, "stretch" 727s and MD80s were in the second class, all smaller jets were in the third class, and the rest of the planes were placed in the fourth class.) This classification scheme by no means implies that this is how it should be established administratively. Rather, it approximates what it is believed a market-based auction of priorities would produce. In the simplest terms, the bigger airplanes with more passengers should be able to demand the most prompt scheduling, and hence would likely end up with the highest priorities.

When congestion occurred in the simulation, flights were delayed by their class, rather than by random factors. That is, Class 1 flights were released before Class 2 flights, which were still in front of flights in Class 3, and so on. Within a given class, flights were treated equally. Flights were never able to change classes, no matter how long they were delayed. This is Plan A.

The results of the simulation of Plan A were quite interesting. The mean delay time of 9.92 min stayed the same because there were no changes in capacity. The distribution of delays, however, showed significant changes from the current system. Figure 2 shows that, overall, only 16 percent of the flights received delays of at least 15 min. However, these delays were longer and more concentrated. This is shown in the distribution by class in Figure 3. Class 1 flights ran virtually on time, receiving delays less than 0.1 percent of the time. Class 2 flights did almost as well, with 6 percent of the flights receiving any delay. Only 2 percent of Class 2 flights received delays of at least 30 min, and virtually no flights received delays of 45 min or longer. Classes 3 and 4 did significantly worse, with 21 and 46 percent of their flights, respectively, receiving delays of at least 15 min. Class 4 was hit the hardest, with 15 percent of its flights receiving delays of over an hour and 8 percent of its flights receiving delays of over 3 hr.

Figure 4 shows the average delay per flight by class. As might be expected, Class 1 flights were delayed, on average, for less than 0.01 min. Class 2 flights were delayed an average of 1.8 min, and Class 3 and 4 flights were delayed an average of 7.8 and 39.4 min, respectively. Rather than have small planes wait all day, airlines would have a great incentive to reschedule lower-class flights.

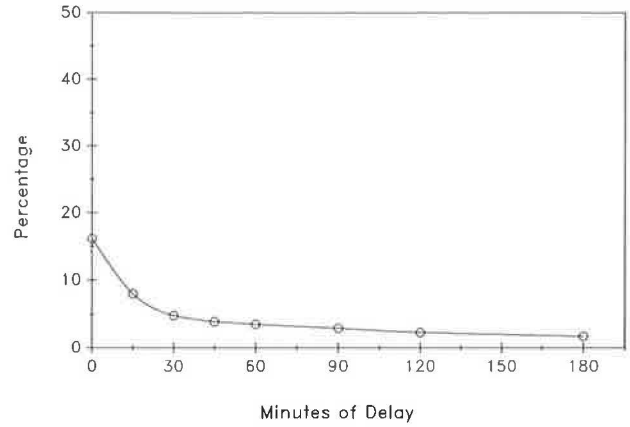

FIGURE 2 Percentage of flights with delays exceeding *X* min, Plan A.

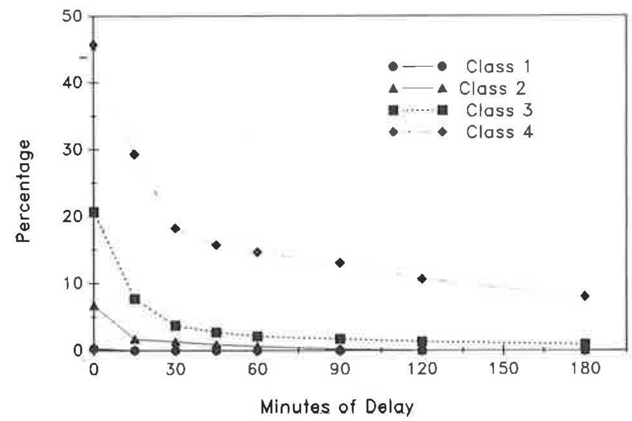

FIGURE 3 Percentage of flights with delays exceeding *X* min, Plan A, by class.

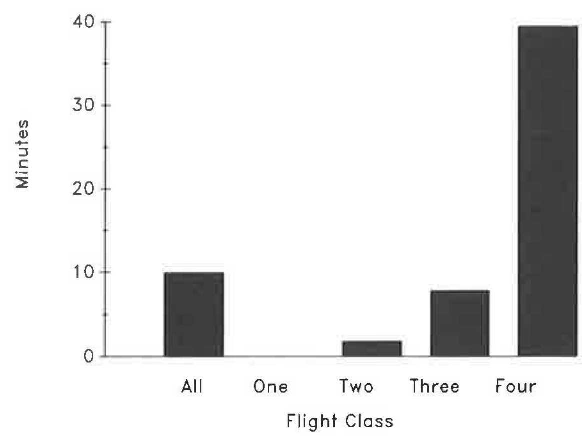

FIGURE 4 Average delay time by class, Plan A.

When the delay time of this system is calculated, however, it is 7,014 passenger-hr a day, or about $2.6 million hr annually, which is more than half of the delay under the current system. Again at $10 an hour that amounts to an annual passenger savings of $34 million. The large decline occurs because this plan concentrates delays on the smaller aircraft with fewer passengers.

Four Other Plans: Allowing Planes To Change Class

Those who live in smaller communities or travel by smaller aircraft could well argue that Plan A is not equitable and would crowd smaller planes out of the system. Although an auction might allocate some higher priorities to airlines that use smaller aircraft, in general it would be difficult for a smaller commuter airline to outbid its larger counterparts. It is possible to devise plans that afford aircraft in lower classes some protection. The trade-off is that as the lower classes get more protection, there are smaller reductions in delays.

Four such plans to provide this protection were tested. These schemes provide ways for aircraft in lower classes to automatically jump their priority, depending on the length of their delay. Plan B, the strictest of these plans, allows aircraft to increase their priority by one class every 60 min; Plan C allows this every 45 min; Plan D, every 30 min. The most lenient scheme, Plan E, allows a class upgrade every 15 min. Again, within a class, all flights are treated equally.

The results of these simulations are both straightforward and significant. The mean delay is a constant 9.92 in all the plans. The difference in delay distribution between classes, however, decreases as the plans get more lenient. In Plan B, which is described in Figures 5–7, Class 1 flights receive much the same treatment as in Plan A. In each case, Class 1 flights carry essentially a guarantee of on-time performance. However, the results change more significantly for Class 2 and 3 flights, which are much better off in Plan A than Plan B. Class 2 flights receive worse treatment, with their mean delay time almost tripling and the frequency of their delays almost doubling. Class 3 average delay and frequency of delay also increase, although not by the same magnitude as for Class 2. Flights in Class 4, however, do significantly better, with the mean delay time dropping almost one-third.

This trend continues in Plans C, D, and E. Figures 8 and 9 summarize this information, showing how the results change for each class of flights from the previous plan. A few generalizations become apparent. From Plan B to Plan E, both the mean delay time and frequency of delay for Class 1 increase almost 200 percent with each successive plan (i.e., Class 1 service becomes less guaranteed). Class 2 flights suffer smaller percentage losses between successive plans, so that by Plan E, they are similar to Class 1 flights. Class 3 flights show

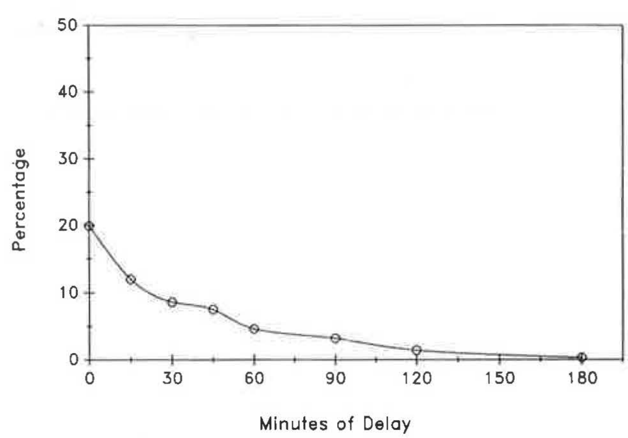

FIGURE 5 Percentage of flights with delays exceeding X min, Plan B.

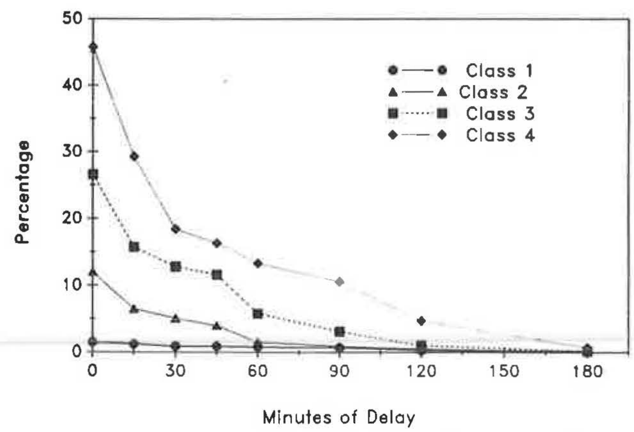

FIGURE 6 Percentage of flights with delays exceeding X min, Plan B, by class.

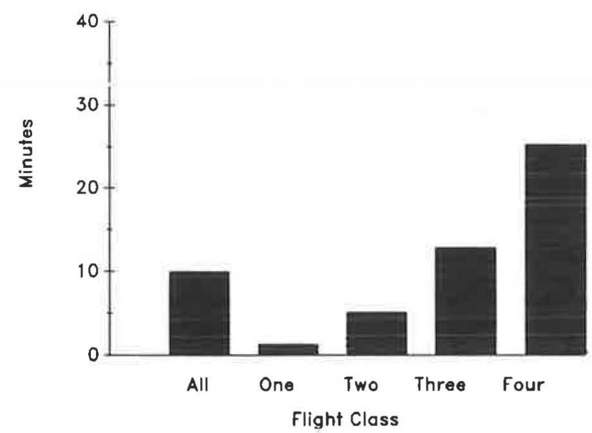

FIGURE 7 Average delay time by class, Plan B.

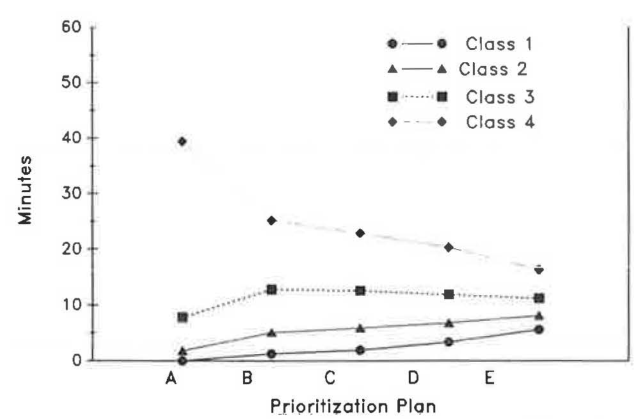

FIGURE 8 Average delay per flight.

very little change between plans. Their mean delay time shows a slight decrease, but they are delayed more frequently. Class 4 flights show significant gains in mean delay time with each successive plan, but are still delayed with the same frequency. Most of these gains are at the expense of Class 1 and 2 flights.

Delays Versus Costs: What Is the Optimal Protection for Lower Classes?

As might be expected, the more lenient the plan, the greater its annual cost of delays. (The annual delay costs for all plans and

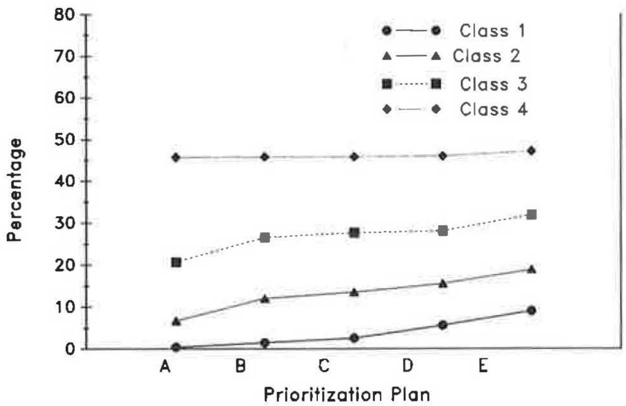

FIGURE 9 Percentage of flights delayed 15 min or more, by class.

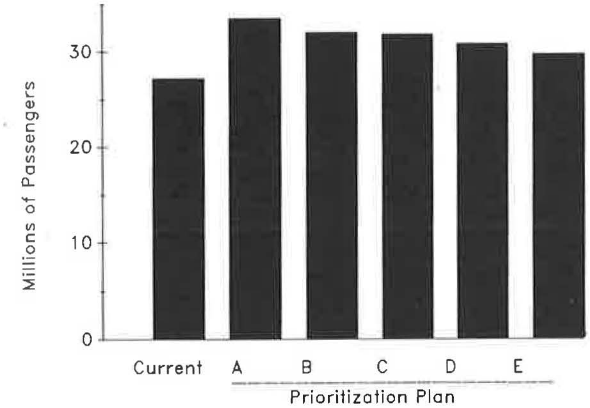

FIGURE 11 Annual number of on-time arrivals at O'Hare International Airport by plan.

for the current system are shown in Figure 10. To determine hours of delay, divide by 10.) Figure 10 raises the interesting question of how much society might be willing to give up (in delays) to have a more "equitable" system. That question will not be addressed here, although it may be noted that even the most lenient scheme (Plan E) provides for annual savings at a single airport of about $8 million or a decrease amounting to 15 percent of the cost of delays. The stricter plans do much better; Plan B cuts the annual cost of delays by 35 percent, or $20 million. The greatest savings is achieved by Plan A, which cuts costs over 55 percent, or over $34 million.

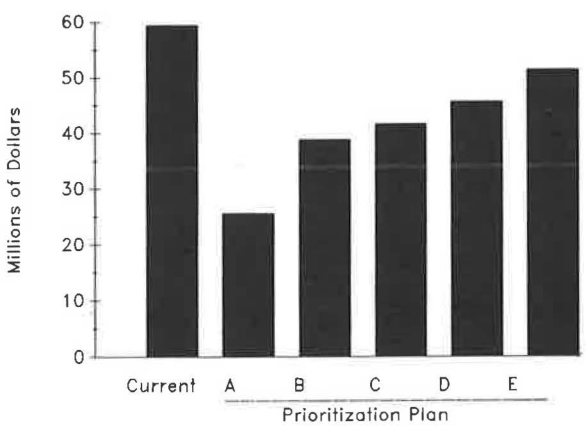

FIGURE 10 Annual passenger delay costs at O'Hare International Airport by plan.

Another way to measure the gains by a priority scheme is to look at how many passengers arrive on time (see Figure 11). With the current system, the simulation predicts about 27 million on-time arrivals. With Plan A, that number increases 23 percent to about 34 million. Even Plan E results in 3 million more on-time arrivals than the current system.

It may be pointed out that it is important to have at least one class of flights run virtually delay free. Presumably, there is a significant number of people whose time, especially while on business travel, is much more valuable than $10 an hour. Even if less stringent plans are considered, safeguards should be built in to ensure that Class 1 service is always extremely reliable. These safeguards might protect Class 1 by limiting its size or how fast flights can be moved up to Class 1. This brings up the possibility of combining some of these plans to achieve an optimal one. For example, Plans A and E could be merged so that flights might be allowed to move one class every 15 min, but never into Class 1. Other similar combinations are possible to determine a system that fits in with the overall policy goals of the FAA.

The Long-Run: What Is Missing?

On further thought, it may be suggested that this simulation significantly underestimates the gains from adopting one of these plans. The simulation does not address the potential savings to airlines. A priority scheme that makes delays more predictable would significantly improve planning, leading to more efficient uses of capital and labor. Better information would also allow airlines to get more use out of gates, ground personnel, and equipment, which are often scarce resources. They would be able to use their larger and more valuable aircraft with greater frequency, handling more passengers and cargo. They could potentially match their highest-rated cockpit crews with their best-instrumented planes, creating flights that would be even less susceptible to weather delays. Because planes with larger crews would receive fewer delays, crews could fly more flights a month. Costs per available seat should fall. Most important, it would give airlines much greater control over their timeliness.

This could permanently change the way airlines do business. They would realize that under Plan D, for example, Class 1 flights have a 98.5 percent chance of running on time and the average delay is only 1.3 min. If the airlines were able to do their part to reduce delays (e.g., by creating more realistic schedules and reducing mechanical problems), they would be able to compete on timeliness in addition to service and price.

Airlines could advertise these different classes of flights and their differing abilities to be on time, giving consumers a greater variety of flying options. (Eastern Airlines already advertises the on-time performance of its Boston–New York–Washington, D.C., shuttle. Imagine how many more shuttles, express flights, and so on, might develop if airlines had better control of scheduling.) Predictable timeliness and more accurate flight times would relieve much public dissatisfaction with the system, taking pressure away from the FAA and Congress.

The FAA would be able to concentrate more on safety and increasing capacity and less on policing the airlines.

A priority system would have varying effects on airports. There are essentially two types of airports—those with one hub airline and those with either two hub airlines or none. At an airport dominated by one airline, delays often result because that airline attempts to have all its flights arrive at one time and leave half an hour later. A priority system would force that airline to recognize that this is impossible. Instead, the airline would have the incentive to write a more realistic schedule and could enforce a priority system among its flights during bad weather. Other airlines at that airport would be able to compete with the dominant carrier by bidding for priorities in an anonymous auction.

At airports without one dominant airline, the priority system gets around the "overscheduling externality." Often airlines schedule flights at congested times for competitive reasons, knowing that these flights will be delayed. A system of priorities reduces this problem, giving airlines a better idea of how to schedule at these airports.

The simulation does not account for the secondary changes that would occur if a priority system were implemented because it does not differentiate between aircraft of the same size. To assume that all aircraft have the same load factors and a single type of passenger is to understate the potential for gain. It is likely that the optimal use of a priority system is to serve markets with a variety of different classes of service. Currently, passengers on the same aircraft are mixed as to the value of their time. If an airline were able to have express service for passengers with a high value of time and regular service for other passengers, it could price these services according to the various passengers' willingness to pay. The airlines would make more profits, and consumers would have greater choice of service at varying prices.

A look at the breakdown of flights at O'Hare shows that this segregation is possible, but very hard to predict. There is a great discrepancy in costs, even between Plan B and the optimal Plan A ($38.8 million versus $25.6 million), because of the large number of flights in Class 2. (See Figure 12 for a breakdown of the number of flights in each class.) The difference between the two plans is that the average delay for Class 2 roughly triples from Plan A to Plan B. A decrease in costs could be realized by dividing Class 2 into different groups depending on the value of individual flights in that group. These gains would be increased further by increasing the number of classes.

How Many Classes?

These simulations, however, do not determine the optimal number of priorities. The use of four priority classes was arbitrary based on a natural split of the types of aircraft used at O'Hare. The choice of how many priority classes to use and how large each should be will have a profound impact on the gains realized by each priority scheme. The problem here is a trade-off between economic gain and complexity. Presumably the largest gain would occur if each flight were given a priority based on its value of time, meaning that the number of classes would equal the number of flights. This, however, would be very hard to implement. To fully utilize an airport, a constant

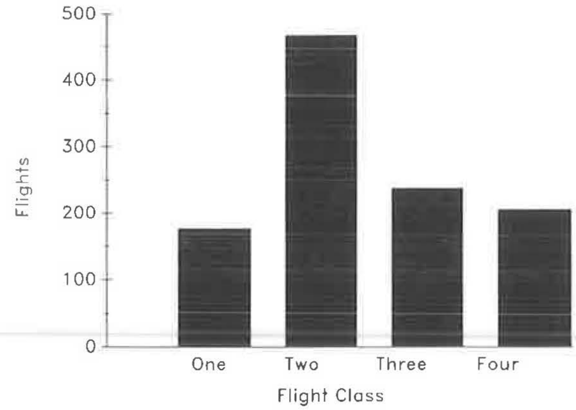

FIGURE 12 Number of flights per class.

flow of traffic is essential. Specifically, the more precise a priority system gets, the harder it is to ensure a steady flow of traffic. Because of this, a system with a relatively small number of classes (e.g., four) using moderate time blocks (e.g., 15 min) may be feasible. No attempt is made here to determine the optimal number of classes and increments of time. It is suggested, however, that it could be possible to find a feasible system that had even larger gains than those that have been shown.

IMPLEMENTATION ISSUES

The priority system is completely compatible with any enhancements to the current air traffic control system. If the system capacity were increased in some way (by hiring more controllers, building more runways or airports, using updated technology, etc.), a priority system would use the additional capacity in the most efficient way.

Use of Competition To Stop the Bunching of Flights

A priority system might also restructure the way airlines use resources such as runways and others. Currently there is a "Catch 22" in which airlines see that bunching flights causes delays, but are competitively unable to stop the bunching, especially while using a hub-and-spoke system. A priority system would solve this dilemma because it orders the importance of flights at any given time. An airline might be hesitant to schedule a Class 4 flight at a time when many Class 1 and 2 flights are scheduled, knowing that the Class 4 flight would always be released last. This is a competitive method for encouraging the smoothing out of the schedule of flights without relying on relaxed antitrust standards, the current approach. It does not arbitrarily set the number of slots at an airport either, but instead allows the market to decide.

Earlier in the paper the political problems associated with many of the proposed solutions for air traffic congestion were noted. The priority system has the potential to benefit all parties involved and thus would be politically feasible. However, some further elaboration might be needed, especially how the priorities might be distributed.

Efficient and Equitable Allocation of Priorities

No matter which plan is chosen, the priorities involved have great value. The same problem came up when the FAA introduced slot control at four airports. There was debate as to who should own the slots and the duration of any property rights that were given. The FAA decided to divide the slots into different groups: commercial service, commuter service, and "essential" service, including international flights, private users, and so forth. Slots were numbered and the owners were given lifetime property rights, provided that the slots were regularly used and were not transferred between groups (e.g., commuter slots were not to be used for larger commercial service). The slots could be revoked by the FAA either for nonuse or in a random, predetermined order if the FAA needed them for another purpose. In a highly controversial move, the FAA gave slots to their current users rather than auctioning them to the highest bidder. This allowed the airlines, not the public or the airports, to generate the "scarcity rents" at slot-controlled airports (*6*).

The distribution of priorities also involves many of the same issues. Any system of distribution must ensure that new carriers have the means to obtain priorities and that no user is able to monopolize them, either in a given market or on a single route. It is also important that the priorities end up in the hands of the carriers that would use them most efficiently. The priorities must have a long enough duration to allow their owners to establish a profitable and consistent business strategy. Finally, the public should receive the revenue from the sale of these priorities.

A Repeated Auction

It is recommended that the FAA distribute the priorities using a revised "Clarke tax," also referred to as a "repeated auction" (*7*). The repeated auction is a multistage process that is not finished until each bidder is satisfied with the results. The first stage of the auction involves soliciting a list of bids from the various players for each of the priorities (or classes) available. This could be done simultaneously for each of the airports in question. Then the commissioner of the auction gathers all bids and awards the priorities to the highest bidders at the price of the highest losing bid. That is, if there were 25 Priority 1 slots available at O'Hare at 9:00 a.m., they would be awarded to the 25 highest bidders at the price of the 26th-highest bid. If there are fewer bidders than priorities for a given time, all bidders receive those priorities at no cost. Limits could be set up to ensure that no one is able monopolize any subset of the priorities.

The commissioner then publishes an anonymous list of bids and gives each player a list of his winning bids. The players would have a specified period of time to evaluate their positions and change any of their bids. If there are no changes, the commissioner declares the bidding closed and the awards are final. Otherwise, the commissioner would take the revised bids and, using the same method as he did in Stage 1, hand out the results of Stage 2. This process would continue until there were no changes or the commissioner declared that there were no major changes and closed the auction.

This scheme would get around the complicated "system" problem of the simultaneous distribution of priorities at more than one airport. Airlines need to know the priorities they would use in all their markets in order to set up a system of flights that conforms to a consistent business strategy. That is, to set up a Class 1 flight line, airlines need Class 1 priorities at all the airports on the line in order to preserve the full benefits of Class 1 operation.

Each round of bidding would increase the information available to the airlines and give each an opportunity to set up a business strategy based on market constraints. Some carriers might not be willing to bid much for high-priority slots, whereas other carriers would be willing to pay more for priorities, depending on their business strategy and their perceived value of that priority. No carriers could gain by overbidding or underbidding, because they might be forced to pay too high a price for a priority or they might not receive a priority at a price they found profitable.

This bidding system was tested by the FAA when they were considering its use in allocating slots (*8*). They simulated its use in the "Airline Management Game," with five airlines having varying marketing strategies and somewhat overlapping routes. They found that a competitive, efficient equilibrium was reached quickly and the market players received overall higher profits after the auction than before its use.

One of the reasons the repeated auction was not used to distribute slots was probably pressure from the airlines, which argued that being forced to buy slots that they previously received at no cost would result in higher ticket prices to the consumer. However, priorities cannot be given away to current holders, because they do not exist. They are created entities that have great value, but only if allocated to the most efficient users. [There is some debate whether an auction would guarantee the most efficient use of priorities (*6, 9*).] The priorities could, of course, be randomly allocated among current users on a weighted basis and the owners given property rights. That might eventually lead to their purchase from the current owners by the most efficient users, but that is not assured.

There is a solution to this dilemma that could satisfy both the airlines and the consumers. Congress could lower the current 8 percent tax on ticket sales by an amount corresponding to the revenue raised by a repeated auction. Although the average ticket prices should remain the same (or possibly be lower because of increased airline efficiency), the distribution of ticket prices would reflect the more efficient market. Prices would be more closely tied to congestion; that is, the more congested the time of day and the airport, the higher the ticket price would be. Discount fares would be lower for those willing to travel at off-peak times or to wait longer.

Unrestricted access to markets, one of the keystones of deregulation, and efficient use of priorities could also be ensured by holding the repeated auction every 6 months. Between auctions the owners could be free to buy and sell their priorities or the commissioner could anonymously accept offers to buy and sell unwanted priorities. Excess priorities would be distributed on a first-come, first-served basis. In addition, airlines could still be free to add more flights to a city, but these flights would be at the lowest priority level. This would give a crude approximation of the optimal amount of congestion in a given airport. When entering at the lowest priority, the added entrant receives a much greater share of the delay cost that his entry imposes on other users. Finally, the results of this auction would provide financial information that would allow the FAA to determine the optimal investment in additional capacity.

Commuter Flights: Where Do They Fit In?

If commuters were given a separate category of priorities and shielded from competition with other users, the gains from this plan would be significantly cut, if not permanently erased. Large jets would still be delayed, and small planes would operate on time. However, in a competitive environment, users with larger aircraft would inevitably bid up the price of most priorities above affordable levels for many commuter airlines. To compensate, these airlines might find it economical in all but the smallest cities to have a mix of service that would include at least one higher-priority flight. It would be hard to imagine that priorities would be bid for strictly in terms of the size of aircraft using the priority.

Even assuming that commuters would mostly fly on Class 4 flights, they would still receive some benefits from a strict priority scheme. Most important, if commuter airlines do not buy high-priced priorities, ticket prices should fall. Also, most of those commuters who fly into large airports intend to catch connecting flights to other destinations. Currently, connecting at a major hub is an extremely unpredictable affair. More accurate timetables under a priority system would make connections easier.

Commuter airlines would probably reschedule some of their flights to avoid major delays at many airports. Although impossible to simulate, such a change could significantly reduce the average delays for lower-priority service. Flyers would be better able to make decisions about how long to allow for making connecting flights. This benefit would extend not only to commuter passengers, but to all who travel by air.

What About Other Users?

Finally there is a concern about how to deal with other airport users, including those originating in foreign countries, not scheduled, and in essential service. International flights could be given automatic priority and be required to pay a prorated fee to operate at certain times or even required to purchase Class 1 service. Even though international flights are not charged, they still represent only a small proportion of flights at congested airports and often use aircraft large enough to require some priority for efficient operation. Unscheduled users, although representing a small percentage of flights at congested airports, could be treated like other users. When unscheduled flights file their flight plans, they could be required to choose a level of priority, pay a prorated fee for that priority, and be treated as any other user with the same priority. This would give them the same choices as others, also ensuring that they face the full cost of flying at a given time. Service that the FAA deems "essential" would travel at any priority to which it is assigned.

CONCLUSION

The Future

The potential gains from an administrative change to a priority system appear substantial compared with the costs involved in implementing the system, which seem relatively minor. This simulation found passenger time savings of over 55 percent, or $34 million a year, at a single airport. These savings have a perpetuity value of $680 million, a figure that would increase greatly if it included gains at all the airports in the system. On-time arrivals could increase by about 23 percent, meaning that 6 million more passengers would arrive as scheduled. Furthermore, these calculations appear to underestimate the savings, not taking into account savings to airlines, secondary shifts in passenger and airline behavior, and benefits from greater predictability. A priority system seems to have the potential to revolutionize the organization of the air traffic control system, benefiting all who fly. It could even reduce the average delay time by reducing the bunching of flights.

Additional Research

Additional research needs to be done, however, to get a better idea of the feasibility and potential gains from a priority system. A more detailed computer simulation would be required to determine the specifics about feasibility and the effects on current and future market participants. Further analysis should explain how the scheme might fit into an entire system as opposed to a single airport. It is also necessary to have some idea of what business strategies might be possible and profitable with a priority scheme, including how commuter airlines would operate. This analysis should include the effects on service for different-sized communities. Research might also determine the possibility of a spot market, in which airlines would be permitted to trade priorities between specific flights on a daily basis.

After all, as the *New York Times* noted in an editorial (*10*), "Even under the best of circumstances . . . it will take years for capacity to catch up with traffic. That is why it is essential to find market-based ways to make the existing system more efficient. . . . [The airline industry's] potential ought not be undermined by a Government that simply can't keep the planes moving."

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REFERENCES

1. W. Chaze and W. Cook. The Late, Late Show. *U.S. News and World Report*, Dec. 27, 1986, p. 14.
2. E. Bean, B. Morris, and T. Smith. Hurry Up And Wait: Airline Delays Bring Gripes—And Lots of Excuses. *Wall Street Journal*, April 28, 1987, p. 37.
3. J. Koten and J. Valente. Cosmetic Change: Airlines' Pledge To Reduce Delays May Be Illusory. *Wall Street Journal*, Sept. 3, 1987, p. 21.
4. C. May. Six Airlines Agree To Reduce Delays At 4 Big Airports. *New York Times*, Aug. 29, 1987, p. 1.
5. J. Dahl and T. Petzinger. Numbers Game: Continental Air Opens Data War. *Wall Street Journal*, Oct. 6, 1987, p. 31.
6. S. Kreager. Airline Deregulation and Airport Regulation. *Yale Law Journal*, Vol. 93, 1983, pp. 319–339.
7. T. N. Tideman and G. Tullock. A New and Superior Process for Making Social Choices. *Journal of Political Economy*, Vol. 84, No. 6, 1986, pp. 1145–1159.
8. M. L. Balinski and F. M. Sand. *The Allocation of Runway Slots by Auction*. Report FAA-AVP-80-3. Office of Aviation Policy, FAA, U.S. Department of Transportation, 1980.
9. S. Borenstein. On the Efficiency of Competitive Markets for Operating Licenses. *Quarterly Journal of Economics*, 1988.
10. Waiting, Waiting in the Flight Line. *New York Times*, Dec. 22, 1986, p. A22.