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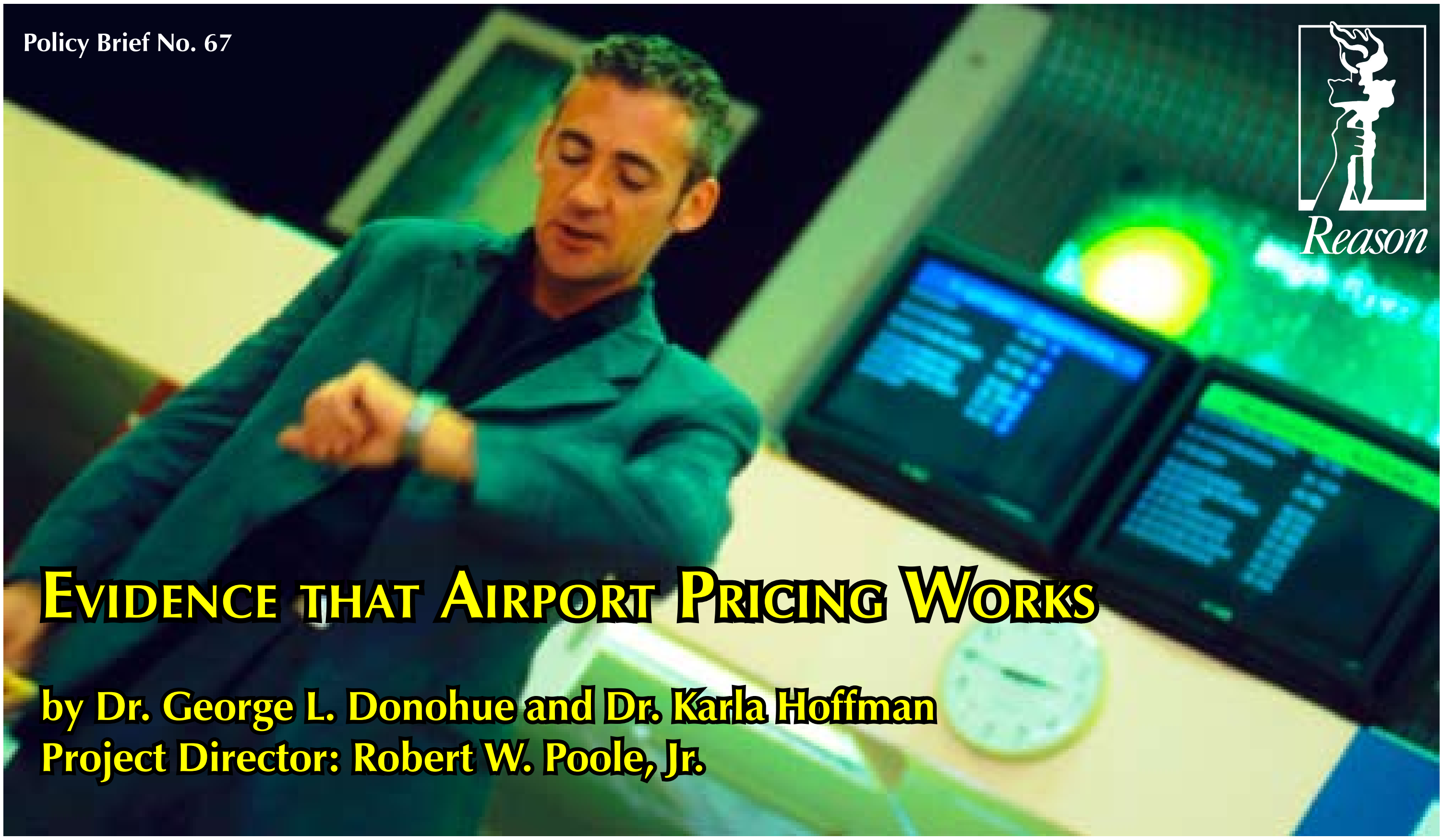

Reason

Evidence that Airport Pricing Works

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INTRODUCTION

This paper describes the results of research that analyzed mechanisms for reducing congestion and delays at LaGuardia Airport (LGA) in New York. The findings should be equally applicable to any similarly congested airport such as John F Kennedy (JFK), Newark International (EWR) or Chicago O'Hare (ORD).

Slot allocation has historically been limited at LGA by a High Density Rule (HDR) first employed in1968. Thus, airlines were provided with "slots" (rights to takeoff and land), with a use-it-or-lose it rule that returned slots to a pool for reallocation if the slots were not used 80 percent of the time. Since 1985 operators have been able to trade slots in a secondary market of sorts, but few have been sold other than during bankruptcy proceedings.

In 2004, The NEXTOR universities were requested by the Federal Aviation Administration (FAA) and the U.S. Department of Transportation (DOT) to design and conduct a series of government-industry strategic simulations ("strategic games") to help the government evaluate policy options for airport congestion management. We were directed to evaluate alternative allocation approaches for LGA, since the HDR rule was legislated to be removed by January 2007. (In fact, LGA is now operating under an interim continuation of slot controls.) George Mason University (GMU) and the University of Maryland (UMD) undertook the task of leading this research effort. UC Berkeley, MIT, Harvard, and GRA, Inc. played major roles in the design and analysis of the two games. The first took place on Nov. 3-5, 2004 and the second on Feb. 24-25, 2005. The purpose of the games was to test a range of government policy options designed to reduce the expected congestion that was likely to result from the expected expiration of the HDR on January 1, 2007. While a central issue in this research project was the replacement of the slot lottery (the "slottery") and HDR at LGA, it was recognized that the policies being tested could have potential applicability to a number of U.S. airports that are operating at or close to their maximum operating limits.

Conventional economic wisdom suggests that market-based mechanisms such as congestion pricing and auctions are efficient in allocating scarce resources. Both options charge higher fees for peak periods than for off-peak periods, discouraging low-value flights

from being scheduled in peak periods. In addition, increasing per-flight cost is expected to encourage airlines to up-gauge (substitute larger-capacity planes for some flights), and therefore increase passenger throughput.

Congestion pricing as applied to runway allocation would result in the price of an arrival or departure time slot varying by time of day and day of week, and the prices would dynamically change as the demand for operations changes over time. Congestion pricing of transport networks has been common in road traffic. Examples include traditional tolling as well as more dynamic electronic-charges to users such as those used in London [4], in Trondheim, Norway [5], Singapore [6], Toronto's Highway 407, and SR 91 and I-15 HOT lanes in California. The airlines would find congestion prices that were set at day-of-operations (as in road pricing) difficult to manage, since their schedules are announced 90 days in advance. Thus, unlike individual drivers, airlines should not be encouraged to cancel flights at the last minute due to high arrival costs. For this reason, we considered a congestion management approach whereby the prices are announced 120 days in advance, and the airlines base their schedules on these announced prices (see Daniel [7], Pels [8], Fan [9], and Schank [10], and Berardino[11] for more on runway congestion pricing).

An alternative to congestion pricing is the allocation of slots by auction for a much longer period of time. The buyer has, in essence, leased the right to a given takeoff or landing and can use or re-sell that right for any portion of the lease period. The airlines bid for the right to land and/or depart at a given time. Proposals to allocate airport time slots using market-driven mechanisms such as auctions date back to 1979 with the work of Grether, Issac, and Plot [13] and Rassenti, Smith and Bulfin [14]. European researchers, DotEcon Ltd [15] and National Economic Research Associates (NERA) [16], conducted macro-economic analysis to conclude that proper implementation of auctions will result in higher passenger volumes, higher load factors, reallocation of flights to off-peak times or to less congested airports, and lower fares on average. Ball, Donohue and Hoffman [17] put forward the need for three types of market mechanisms: an auction of long-term leases of arrival and/or departure slots, a secondary market that supports inter-airline exchange of long-term leases, and a near-real-time market that allows for the exchange of slots on a particular day of operation.

THE STRATEGIC GAME

The first simulation was held at GMU in November of 2004. It was principally focused on evaluating and comparing administrative measures and congestion pricing. There were six major game players consisting of teams from four airlines, the federal government and the Port Authority of New York and New Jersey (PANYNJ), which operates LGA. Other participants included representatives of other airlines and airports, the Air Transport Association, and various experts from academia, industry and government. The game projected the participants to a hypothetical setting in November 2007. The baseline scenario was an LGA schedule involving approximately 1,400 total daily operations (arrivals and departures), a number that exceeds recommended operational levels. The airline teams adjusted their schedules in response to various government policies put in place. These policies involved federal regulations, administrative restrictions, and congestion-based fees (substituting for current weight-based landing fees). For each alternative presented in these exercises, the resulting aggregated schedule was fed to two independently-developed simulation models to calculate the levels of delay and cancellations that would have resulted from an attempt to operate that schedule (see Lovell, et al. 2003 and Donohue and Le, 2004).

The airline teams were asked to make scheduling decisions under different hypothetical policy environments. The research goal was to better understand the pros and cons of alternative policy actions. The game details can be found in Ball, et.al. [19]. The game proceeded through five separate policies: Do nothing, two administrative alternatives, and two different levels of congestion pricing. Each sequence began with a baseline schedule of operations at LGA, based on the August 2004 Official Airlines Guide (OAG), with flights added to bring the level of scheduled operations to a hypothetical 1,400 operations per day, similar to the peak levels expected at the expiration of the HDR. Each airline player team was responsible for their portion of the schedule.

Included in the rules of the game was a Passenger Bill of Rights (PBR) that forced the airlines to pay passengers when their flights were delayed or cancelled. By using the PBR, we could set the metric of game flight-delay and cancelation in terms of dollars, thereby allowing a common metric for all analysis.

The simulation proceeded through three sequences consisting of a total of five moves. Each sequence began with a baseline schedule of operations at LGA. The first sequence continued by allowing the airline players to make schedule changes in response to the costs imposed on them by the PBR. The second sequence began again with the baseline, but then proceeded by instructing the government team to use whatever administrative procedures they felt were appropriate to handle the congestion resulting from the lifting of the HDR. This game included two rounds of applying alternative administrative actions with the airlines adjusting their schedules. The final sequence again started with the baseline, and implemented congestion pricing at LGA in an effort to reduce the delay costs to passengers. Two rounds of adjusting congestion prices were executed.

RESULTS OF THE GAME

Table 1 summarizes the scheduling results and delays for each game move. As noted above, one tested policy was a Passenger Bill of Rights (PBR) that

Table 1: Summary of LGA Strategic Game

Airline		Baseline	PBR	Admin Measures		Congestion Price	
			move 1	move 1	move 2	move 1	move 2
A	# arr	142	130	131	127	143	133
	arr diff	0	-12	-11	-15	1	-9
	#seats	13120	12413	12125	11977	13256	12590
	seats diff	0	-707	-995	-1143	136	-530
B	# arr	127	122	119	116	94	94
	arr diff	0	-5	-8	-11	-33	-33
	#seats	14581	14037	13671	13429	13834	13834
	seats diff	0	-544	-910	-1152	-747	-747
C	# arr	212	208	204	191	174	174
	arr diff	0	-4	-8	-21	-38	-38
	#seats	15065	15055	14282	13562	13593	13593
	seats diff	0	-10	-783	-1503	-1472	-1472
D	# arr	22	22	14	13	22	21
	arr diff	0	0	-8	-9	0	-1
	#seats	3300	3520	2228	2454	3876	4098
	seats diff	0	220	-1072	-846	576	798
E	# arr	193	183	124	129	184	186
	arr diff	0	-10	-69	-64	-9	-7
	#seats	23688	22769	15050	16166	23015	23203
	seats diff	0	-919	-8638	-7522	-673	-485
Part 135	# arr	18	28	28	28	29	29
	arr diff	0	10	10	10	11	11
	#seats	144	266	266	266	286	304
	seats diff	0	122	122	122	142	160
Total	# arr	714	693	620	604	646	637
	arr diff	0	-21	-94	-110	-68	-77
	#seats	69898	68060	57622	57,854	67860	67,622
	seats diff	0	(1,838)	(12,276)	(12,044)	(2,038)	(2,276)
Total	Cancel $	$ 784,790	$ 609,498	$ 231,195	$ 207,334	$ 390,206	$ 342,329
UMD	Delay $	$ 837,632	$ 864,716	$ 514,954	$ 461,246	$ 575,135	$ 557,354
Model	Pax $	$ 1,622,422	$ 1,474,214	$ 746,149	$ 668,580	$ 965,341	$ 899,683
	AP $	$ 392,700	$ 381,150	$ 341,000	$ 332,200	$ 866,513	$ 891,688
			$ 1,855,364				$ 1,791,371

forced the airlines to pay passengers when their planes were delayed or cancelled. The "Pax $" row (near the bottom) shows the PBR compensation to passengers that would have resulted in each stage of the game. This value is a proxy for the economic cost to passengers of delays and cancellations, based on data showing that, on average, a cancellation cost passengers seven hours of delays (see Wang [3]). The passenger compensation rate was set at $10 per hour for this exercise and did not include any other costs such as ticket refunds or hotel costs.

The PBR did not substantially change the delays but did exacerbate the financial vulnerability of airlines to delays caused by other operators. The penalty fees that would have been paid to passengers amounted to almost $1.5 million per day (see Table 1, PBR column, PAX$). The FAA Cost Guidelines (FAA-ASD 2004) specify that the economic cost of passenger time is $28.60 per hour, so the values shown for Cancel $, Delay $, and Pax $ can be multiplied by ($28 / $10) to derive an estimate of the full economic cost per day to passengers of congestion at LGA. In the least-delay case (Admin 2), passengers continued to suffer over $668,000 per day as calculated (or nearly $1.9 million if multiplying this number by 2.8) in addition to the $332,000 per day fees incurred by the airlines.

The "AP $" row shows the daily fees paid by airlines, either in landing fees or congestion fees. The second congestion pricing round cost the airlines $891,000 per day in congestion fees, corresponding to an average $19 per passenger (assuming a 70 percent load factor). The passengers still suffered $899,000 per day in lost time (unadjusted) or $2.52 million if adjusted. This adjusted cost translates to $53 per passenger.

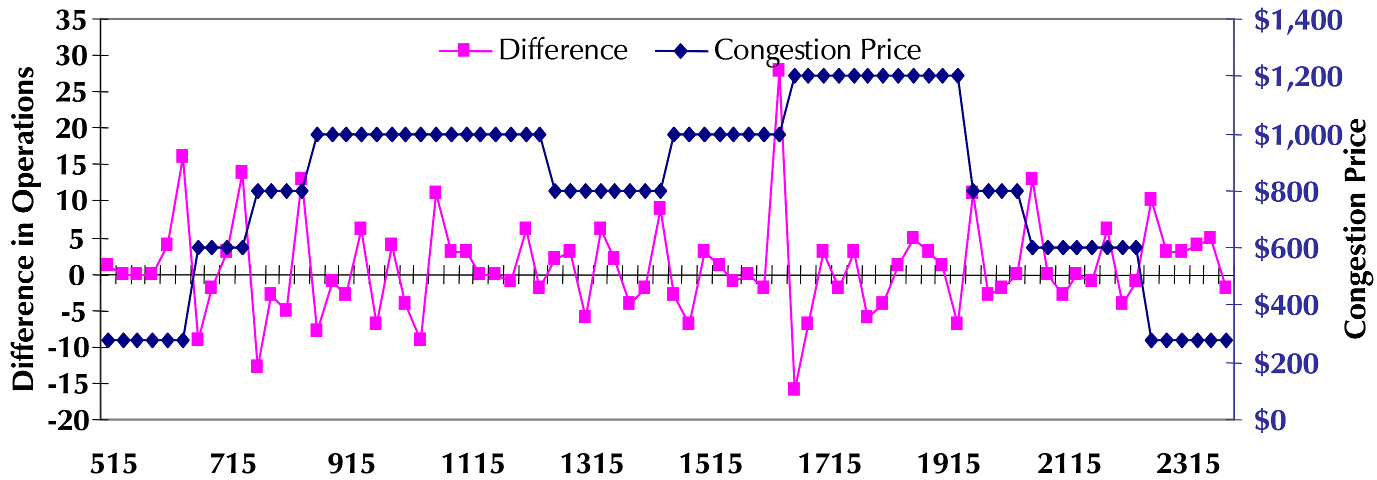
We now look more closely at each of the policy alternatives.

Passenger Bill of Rights: Congestion was not significantly reduced by imposing a Passenger Bill of Rights. A possible reason that it had such a small effect on reducing delays may have been the reluctance of any one airline to be the first to make significant reductions in their schedule and loose market share. In game theory, this is known as the "Prisoner's Dilemma."

Administrative Decisions: The administrative decisions did lead to a controlled level of congestion but the delay was still relatively high, and passenger throughput was significantly reduced. Had the government chosen an alternative capacity setting each time period, the delay would have been reduced further. But the government's slot-controlled approach is likely to maintain the relatively inefficient use of LGA's runway, gate, and aircraft resources. Specifically, the Port Authority would like LGA to operate at a 30 million annual passengers (MAP) enplanement capacity (i.e., approximately 68,000 seats per day), a number in line with the estimated land-side capacity of the airport. Under current slot controls and a capacity constraint similar to that imposed by the FAA during the game, the airport is operating at less than 27 MAP (i.e. approximately 58,000 seats per day).

Congestion Pricing: Under congestion pricing, the airlines chose schedules that led to a larger average aircraft size (gauge) when compared to the airline response under the administrative measures. Since under congestion pricing, any airline can use the runway for the stated fee, there is no incentive for an airline to pay for slots and then either not use them or use them inefficiently. In this setting, certain carriers with historically large numbers of slots and operations reduced their operations. At the same time carriers with historically smaller footprints at LGA increased their levels of operations. The increase in average gauge provides some evidence that these changes led to a more efficient use of the slot resources. Congestion pricing increased the passenger capacity of LGA by nine percent, compared with administrative measures, achieving the PANYNJ goal of nearly 68,000 daily

Figure 1: LGA Flight Schedule Changes with Congestion Pricing



seats. Figure 1 shows how the schedule was modified from an administratively dictated schedule (e.g. a schedule very similar to the LGA summer of 2004 schedule). The left axis shows the difference in scheduled flights in 15 minute aggregated time bins. The right axis shows the operational price for each period, set to encourage efficient use of the landing opportunities and to reduce congestion back to 2005 levels. One thing the game highlighted is that the schedules were very sensitive to the times when prices either increased or decreased substantially, i.e. the airlines concentrated flights just prior to price increases or following price decreases. Further pricing changes could mitigate these steep step increases.

Figure 2 shows the effect of congestion pricing on aggregate airline gauge choice throughout the 24-hour schedule. Overall gauge is increased significantly at almost all times of the day. Figures 3 and 4 show how the schedule was modified by flight distance, aircraft gauge and schedule frequency. Notice that the congestion pricing options produced a complex response by both flight distance and aircraft gauge.

We note that the game invented a hypothetical Pricing Board with authority to set prices dynamically based on schedules submitted (in principle) every 90 to 120 days. The process would work as follows: The airlines submit schedules based on initial announced prices. The Board evaluates the schedules provided, and returns prices to reduce demand in oversubscribed times; the airlines provide new schedules, and the process continues until the capacities and schedules are in balance. This process of determining the congestion prices before schedules are announced to the public results in a pricing approach that is, in essence, a short-term ascending auction for rights to announce schedules at LGA.

More generally the results of this strategic game support economic arguments that market-based allocation mechanisms, e.g. congestion pricing or slot auctions, are likely to lead to better use of the scarce airport resources than the present administrative measures.

We note that the administrative actions could have led to more significant reduction in delays had the administration been willing to set the capacity at a lower level. Thus, one important component to managing delay is the determination of a proper capacity limit. The planned capacity (operations rate) is the most influential control available to determine the level of delays contributed to the NAS by each airport, and the game revealed that there is little policy or consensus providing guidance for trading off delay/unpredictability against unused capacity. The level of schedule predictability is a major public policy issue. Recent over-scheduling at ORD (2005) and JFK (2007) have demonstrated that significant delays at one airport propagate throughout the network. Thus, mis-specification of capacity can lead to significant

Figure 2: Schedule Average Gauge in Admin1 & CP2

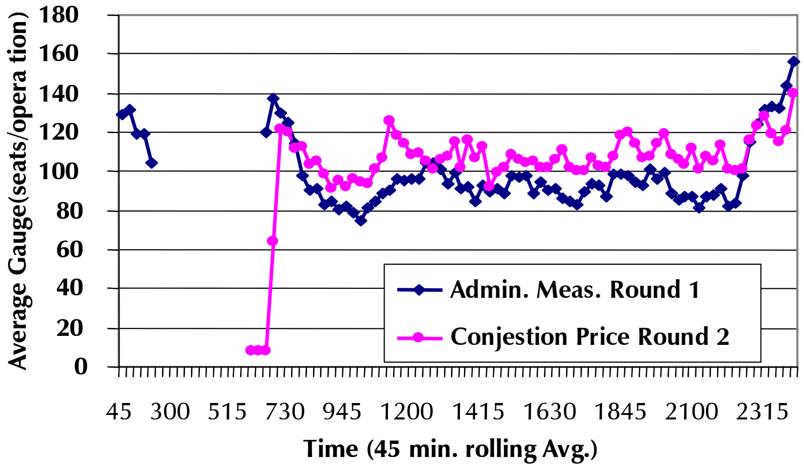


Figure 3: Percent Change in Number of Operations by Flight Distance

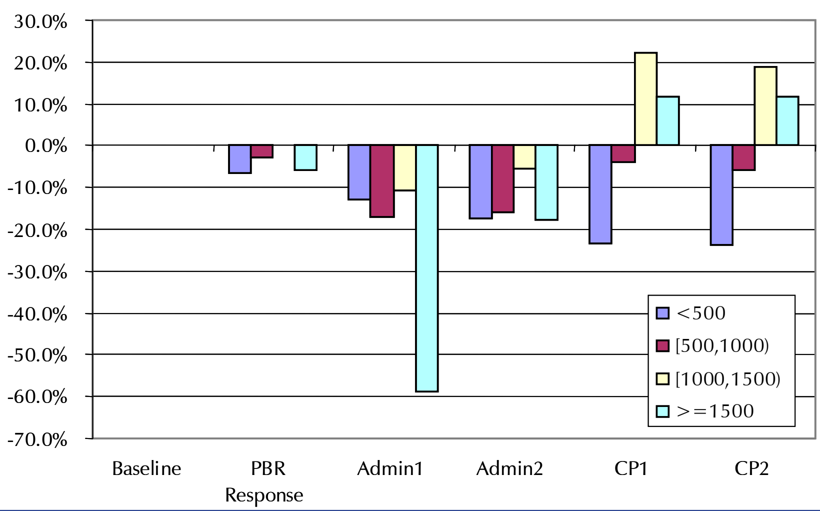
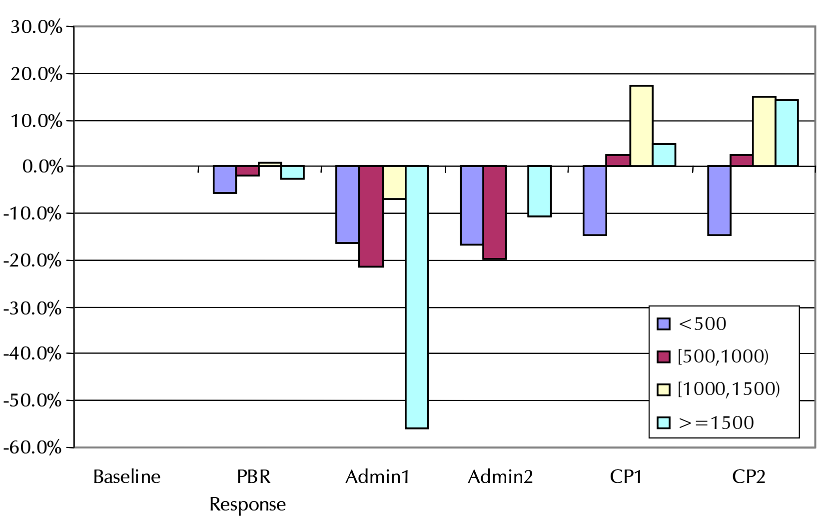


Figure 4: Percent Change in Number of Seats by Flight Distance



delays at airports other than the one whose capacity was set incorrectly.

THE SECOND GAME

A second strategic exercise took place on February 24-25, 2005 at The University of Maryland. At the end of the first game, the industry indicated that they did not understand auctions and believed them to be too complex. The exercise in February had the industry use combinatorial clock auction software where only price and aggregate demand information was provided to the industry in each round of the auction. Given prices based on time of day, the industry was asked to provide schedules. The industry learned that the auction was not dissimilar from the congestion pricing exercise.

Since the purpose of the game was to illustrate how auctions would work, we only had the industry participate in a few rounds. Therefore, we do not provide any results from this game other than to say that the auction resulted in frequencies and up-gauging similar to those seen in the first game.

CONCLUSIONS OF THE STRATEGIC EXERCISES

We are not suggesting that the charts and tables provided reflect the final prices or schedules that would occur if these policies were implemented. In each case, only a few rounds were employed. And, as prices got higher, the airlines indicated that they needed more time and their sophisticated scheduling technology to determine their next moves. In addition, they worried that their responses might provide strategic decisions that they were not at liberty to reveal.

One result that we do believe is true: the airlines will be influenced by both the fees they are assessed and by the capacity limitations that the FAA might impose. As the fees increase, the airlines are likely to put slots to their most efficient use, resulting in both up-gauging and frequency reduction. Due to the up-gauging, LGA is likely to find that they handle the same or a greater number of passengers with less congestion of their runways and gate facilities.

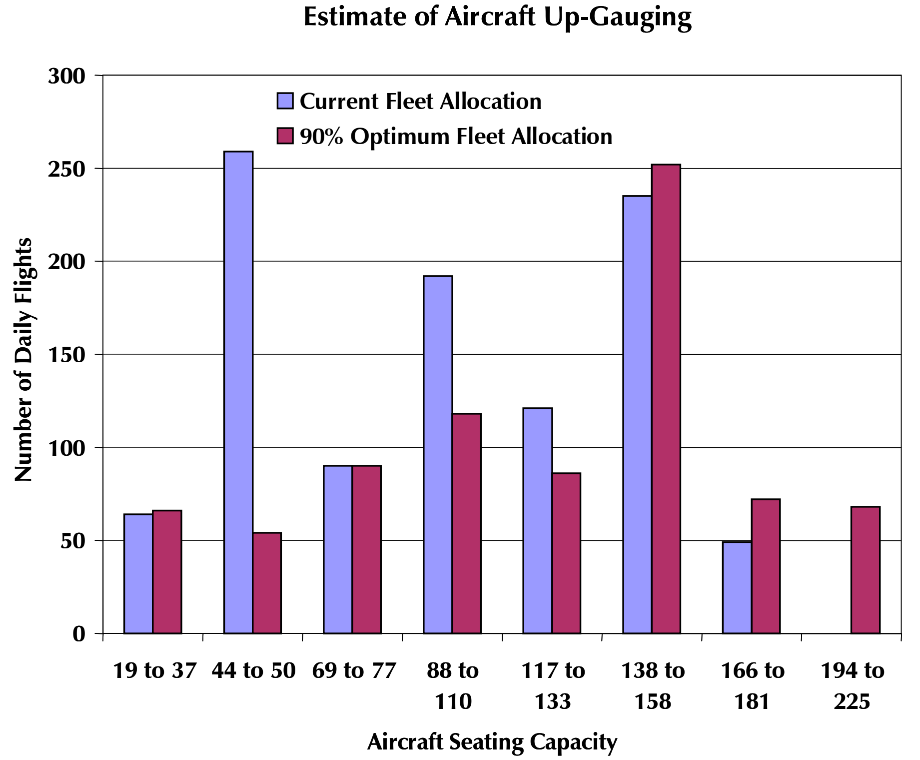
It is not clear to us whether a shorter term auction (i.e. congestion pricing as described above) or a longer auction is best for the industry. Shorter term pricing mechanisms require less financing and more ability to move in and out of markets. Longer term auctions provide more stability and thereby more ability to market new locations and services and to invest in infrastructure.

RESEARCH TO PREDICT SCHEDULE CHANGES IF REDUCED CAPACITY WERE IMPOSED

A question that came out of these exercises was whether schedules exist that could accommodate actual 2006 passenger throughput at LGA if capacity limits were set at the lower level called for during inclement meteorological conditions (IMC)--a figure determined by the FAA based on the capacity of the runway(s) when instrument landings are required. A second question was: What prices could one expect with such a schedule, given that the congestion price schedules would be at the lowest prices consistent with the airlines maintaining profitability?

In an attempt to determine if such schedules exist, we modeled how a benevolent monopolist airline, representing the best interests of both the PANYNJ and the passengers, might schedule its flights under restricted IMC capacity. The study was undertaken by Dr. Loan Le as part of her doctoral studies at GMU. This research project used the same analytical models that the airlines use to generate schedules, determining fleet size based on price elasticities of demand. Two main features characterize the methodology: (a) we model a single benevolent airline instead of individual airlines, and (b) we explicitly account for the inherent demand-supply relation through price. Thus, prices are based on the elasticity of the market based on the competitive environment observed in 2005. In the dissertation [20], Le analyzes multiple scenarios that relax our single benevolent airline concept. The results show that at IMC operating rates, the airline's profit-maximizing responses found scheduling solutions that offer a 70 percent decrease in flight delays and a 20 percent reduction in the number of flights--but with almost no loss of the markets served or of passenger throughput. The profitability of the schedule was obtained at prices consistent with the competitive market existing at LGA today. Table

Figure 5: Estimated Up-Gauging for Priced IMC Operations at LGA



2 shows the change from the 2005 schedule in terms of aircraft gauge, price, delay, markets served and number of flights. Figure 5 shows the type of up-gauging that is projected to take place. We find it interesting that the smallest planes remain in the schedule, i.e. those routes are profitable at that size. Where we see the greatest up-gauging is at the 44-50 seat size, and we see the up-gauging taking place at origin-destination pairs that have significant frequency (five or more arrivals per day).

Table 2: Impact of Simulated Pricing for IMC Operations at LGA

Metrics	Baseline	Flight Schedule at 90% Maximum Profit
Number of Markets	67	64 (-4%)
Number of Flights	1024	808 (-21%)
Number of Seats	96,997	98,100 (+1%)
Average Aircraft Size	95 seats/AC	121seats/AC (+27%)
Average Fare	$139	$134
Average Flight Delay	19 minutes	5 minutes (-72%)

CONCLUSIONS

LaGuardia will always be a popular airport with limited capacity. LGA, however, is not the only airport facing congestion caused by scheduling that exceeds runway capacity. There are at least 10 U.S. airports with current schedules greater than their runway capacity, and the number is likely to grow given the costs, long lead-time, and politics involved in airport expansions.

To overcome current and future delays, one must address two issues: (a) How should one set the capacity restriction? (b) How should one allocate that capacity? We believe that DOT should consider policy decisions that treat all congested airports uniformly. A workable solution to this problem is to set capacity at each airport to its IMC rate and to use market-clearing mechanisms (congestion pricing or auctions) to allocate the capacity. By so doing, one would provide passengers with predictable travel, reduce airline fuel and repositioning costs, improve the overall safety of the airspace, and improve U.S. economic productivity.

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