

# NEXTOR Congestion Management Project: Final Report

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The NEXTOR Congestion Management Project investigated options for controlling congestion at LaGuardia Airport after December of 2006, which corresponds to the time when the current High Density Rule legislation expires. Several administrative and market mechanisms were analyzed. Project activities included two strategic simulations, one held at George Mason University in November of 2004 and one held at the University of Maryland in February of 2005. This report contains project results not included in earlier reports. A complete view of the project's conclusions are contained in this report together with the following major deliverables:

- 1) *Interim Report: Passenger Bill of Rights Game*, which describes the results of the first strategic simulation;
- 2) *NEXTOR Congestion Management Project Strategic Simulation 2: Mock Auction*, which describes the operation of the second strategic simulation; included is a tutorial and description of the auction design used in the simulation;
- 3) *NEXTOR Congestion Management Project: Interim Report*, which provides the project results as of March 2005.

Also of interest are various presentation materials used in briefings to the project sponsors.

The main body of this report contains a detailed description of the NEXTOR slot auction design. While this project involved an objective look across a broad range of congestion management options, a significant percentage of the work effort was focused on an auction design. This focus was necessitated because there is no practical experience with slot auctions and relatively little prior research addressing this topic. The body of this report together with deliverable 2) listed above provide a comprehensive view of the approach to slot auctions recommended by NEXTOR.

In April of 2005, NEXTOR was redirected to focus its attention toward developing a broad range of possible congestion management mechanisms. These were to be developed in the form of a "toolbox" so that government policy makers could choose a set of components from among the larger set and put these together in such a way to achieve appropriate policy goals. Because of the short time frame for this task, some of the mechanisms were described at a fairly high level and, also, in some cases, limited supporting analysis was performed. This "toolbox" was delivered in the form of several short memorandums as well as a presentation with supporting materials. Appendix II contains the presentation materials used to make the oral report.

The original project completion date was August 31, 2005. This report is being delivered at a time consistent with that date. However, the government has granted NEXTOR a project extension beyond this date. During the extension period several activities are being pursued:

- 1) a regulatory evaluation is being carried out by GRA;

- 2) a “fair allocation” method is being developed and tested to be applied to the problem of allocating finite-time slot leases air carriers operating at LGA airport; this method is described at a high level in Appendix II; it can be used to assign leases to carriers in a “fair” manner based on their historic slot holdings.
- 3) simulation studies are being conducted to evaluate the impact of aircraft up-gauging at LGA airport; this work will support policy actions that might induce such up-gauging;
- 4) research is continuing to define “socially optimal” air transportation service levels for LGA so that the social cost of current policies can be measured and the benefits of new policies projected.

Deliverables associated with 1) will be provided in a manner consistent with government requirements. Deliverables associated with 2), 3) and 4) will be provided at the end of the project extension period 12/31/2005.

## **1. Overview of Auction Uses and Auction Design**

The two principal uses for auctions for LGA congestion management are for the allocation of slots by the government to air carriers and for the exchange of slots between air carriers. We call the process by which the government provides slots for a specified period of time to air carriers (and possibly others) as the *primary slot market*. We call the process by which an air carrier sells its slot rights to another carrier as the *secondary slot market*. The bulk of this report describes an auction design specifically geared toward the primary market. However, this procedure can be adapted for use in the secondary market problem as well.

### **1.1 A Secondary Market for Slots Having Finite Lease Lives**

This section describes an auction design for the secondary market that allows the transfer of slots through a transparent, bidding mechanism whereby slots are put up for a given lease period, the auctioneer provides prices for each item and the bidders respond by responding with the number of slots within each time period that they are willing to procure at that price. The auction ends when the market clears, i.e. when there is no excess demand for the slots. We are proposing a *transparent secondary market*, i.e. one in which all carriers are forced to provide to the open market any slots that they wish to sell. There will be no other mechanism for the sale of such slots. Thus, sales of slot lease authorizations will be permitted only through the blind market overseen by the FAA. The restriction of sales to the slot auction will ensure that all carriers have an equal opportunity to purchase slots. No subleasing will be allowed. However, carriers are permitted one-for-one exchanges of slots so long as no additional consideration is provided. These exchanges must be publicly disclosed and can take place outside of the blind market because many of these arrangements are for operational reasons and can be accomplished only through multi-carrier trades. Such exchanges would be an effective way to deal with variations in seasonal demand. However, such slot exchanges must have received written approval of by the FAA.

Carriers having arrival or departure rights at LaGuardia may place such rights up for sale in the quarterly auction. Those purchasing these lease rights will be under the same congestion pricing rules and other fees as those imposed upon the seller. When a carrier puts a lease up for sale, the carrier agrees to work closely with the NY/NJ Port Authority to provide access to gates and other ground facilities. A buyer of slots must put up an advance deposit to ensure that such bidders are capable of paying for the slots won. Such upfront deposits are typically 5-10% of the largest price bid on any package within the auction.

The FAA will collect such offers to sell and alter the lease life of such offers so that each lease up for sale will have a ten-year life. The auction will provide a *transparent secondary market* allowing any and all carriers to compete for such slots. The seller and the FAA will share the amount received from the sale of the slot proportional to the time each had ownership of that lease. The only consideration permitted for transactions in the auction is cash. Use of real property such as gates, non-monetary assets or other services in lieu of cash is not permitted.

Any carrier may participate in the secondary market as a buyer. However, a seller selling an arrival lease (departure lease) at a given period cannot buy an equivalent arrival (departure) lease in the same period. The seller has the right to specify a reserve price and the lease will not be sold unless a buyer is willing to procure the lease at a price equal to or greater than the reserve price.

If a seller finds that there are no buyers for a slot he wishes to sell, then the seller can – at any time – relinquish ownership of the slot and the slot will revert to the FAA.

## **1.2 Overview of the Package Bidding Auction Design**

The auction design we propose is an *ascending clock auction with package bidding*, in which a bidder submits bids for any package of the slots. A slot is defined to be an arrival or a departure during a given time period. The auction design proposed is capable of handling many related items. The approach combines the simple and transparent price discovery of the clock auction (an ascending auction where multiple items are sold simultaneously) with the efficiency of combinatorial auctions. Air carriers with service at LGA were invited to participate in a mock auction in February 2005 using this auction design.

The auction design we propose blends features from the “Clock-Proxy Auction” (Ausubel, Cramton and Milgrom 2005<sup>1</sup>), and allows an optional final proxy round based on ideas from Parkes and Ungar (2000) and Ausubel and Milgrom (2002).

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<sup>1</sup> Ausubel, Lawrence M. and Peter Cramton (2004), “Auctioning Many Divisible Goods,” *Journal of the European Economic Association*, 2, 480-493, April-May.

The *clock auction* is a simple iterative auction procedure where the bidders specify the number of arrival and/or departure slots they desire in each time period at the prices announced by the auctioneer. The design allows bidders to specify a collection of slots (i.e. a business plan) and know that they will win the entire package or none of that package. Enabling bids on *packages of slots* protects a bidder against the risk of winning only a portion of the slots needed for its business plan. The prices provided in each round allow bidders to understand the cost of competition and limit their evaluation to packages that they consider most profitable and/or essential to their business.

This design has been used commercially in a number of other industries in recent years. It generalizes the eBay-style online auction to accommodate multiple items, and it utilizes an “activity rule” that prevents last minute “bid sniping”<sup>2</sup>. The auction proceeds in rounds whereby no item is “won” until the end of the auction. Since more than one slot will be auctioned in a given time period, a bidder specifies the *number* of slots desired in each time period at the specified price.

This auction design includes a feature known as *Intra-round* bidding – the ability for bidders to provide information about slot demand between the last round and current round bid prices – is used to accelerate the auction process. This feature allows the auctioneer to specify larger price increments between rounds without jumping past the maximum price that bidders are willing to pay for slots. Thus, if a bidder who desired a given package at the last round prices finds that the package is no longer profitable/desirable at the current prices, the bidder has the opportunity to specify a price point in between the last round and the current round prices for which this package would remain of interest. This bid would indicate that the bidder is willing to purchase this package at any price up to the intra-round bid price. A bidder can supply up to a fixed number (specified by the auctioneer prior to the start of the auction) of intra-round package bids, thereby providing the price points at which a bidder wishes to substitute one package for another package.

The concept behind intra-round bidding is to allow a larger price increment between rounds without jumping past the maximum price that bidders will pay for slots. The auctioneer announces lower and upper bound on round prices and the bidders can provide up to five different price points that are linear combinations between the beginning and ending prices at which they can provide a package. For instance, assume that the beginning price for a given time period is \$10 and the ending price is \$20. Between \$10 and \$13.99, the bidder wants 4 slots. Between \$14.00 and \$16.50, it wants 3. And any price between \$16.51 and \$20.00, it will accept 2 slots. This bidder would then provide three bids: one at the beginning price, one at \$14.00 and one at \$16.51. If there is more

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<sup>2</sup> Bid sniping occurs at the last minute of an auction with a fixed-time ending. The purpose of sniping is to give other bidders no chance to respond to an offer to buy. Similar actions occur when a bidder prefers to not disclose the value that it places on a bid. This bidder acquires price information from other bidders but does not reciprocate since throughout most of the auction, the bidder is silent. Such bidders are often referred to as “snakes in the grass” since they do not participate throughout the auction, but “snipe” or “attack” at the end of the auction.

demand for this item than supply at the \$20.00 price, then the starting price in the next round is \$20.00 and the ending price is somewhere above \$20.00, determined by the auctioneer. If, on the other hand, not all items sell at \$20.00, then the auctioneer determines at what price all items clear and announces that price at the starting price of the next round.

At the end of each round of the auction, new bid prices for the next round are computed. These prices will increase on arrival and departure slots where aggregate demand exceeds the supply, and the bidders will again specify desired slot quantities at the new prices. Prices increase as a function of the amount of excess demand for the individual slots. The price of a package is then determined by summing the unit prices for each of the slots that make up that package. Prices on packages are defined as the sum of the prices of all slots within a package. The auctioneer announces the total number of bids (aggregate demand) for all slots within each time period and the new prices of the slots. This process is repeated until either the auction closes naturally when there is no excess demand for slots in any time period or can be stopped by the auctioneer when total auction revenue increases by less than a target figure (to be announced prior to the auction) in two successive rounds, at which point a “last and best round” is declared. If the auctioneer declares a *last and best round*, these bids must comply with the activity rule but unlike bids earlier in the auction, the bidders can provide final bid prices that exceed current end prices. The auction will close with the final allocation that maximizes revenue given these final bids and all bids in previous rounds. However, rather than forcing bidders to pay the price bid, a procedure is employed (called a “proxy auction mechanism”) that assures that the winner bidders pay only the minimum required to overcome the non-winning coalitions of bidders. Thus, as in an eBay auction, the winning bidder pays the lowest price that prevents another bidder from winning, rather than paying its maximum bid amount. As a result, the identity of the winning bidders remains the same; only the prices that they pay are affected. For a complete description of the underlying economic properties of the proxy auction, see Ausubel and Milgrom (2002).

At the end of the auction, winners will be announced. All winners will be required to provide payment of the total bid price within 30 days of the end of the auction. A bidder who defaults on payment will be assessed a default penalty equal to 2% of the bid price or the difference between the bid price and the bid of the highest losing bid on that slot, whichever is higher. The default penalty will be recovered from the up-front payments. If the bid of the highest losing bidder exceeds the reserve price, then the slot will go to that bidder. Otherwise, the slot will revert back to the seller.

A well-functioning slot auction needs rules that discourage last-minute bidding. In familiar on-line auctions such as eBay, a bidder has an incentive to place bids in the final minutes or seconds of the auction, to conceal the bidder’s intentions (sniping). In order to avoid this problem, the clock auction phase utilizes an *activity rule* that requires bidders to bid for minimum quantities of slots at the beginning of the auction in order to continue to be eligible to bid for equivalent quantities at the end of the auction. Thus, the activity rule is designed to penalize bidders that misrepresent their demand in early

rounds. This is important for a well-functioning auction, because useful price-discovery requires sincere and early bidding by all parties.

This auction design has a number of positive features. The auction is similar to the simultaneous multi-round auctions used by the Federal Communications Commission (FCC) for spectrum licenses. Although these auctions have been quite successful and have been adapted to many other applications, the present auction design makes a number of improvements over the previous non-package design:

1. Enabling bids on packages of slots protects bidders against the risk of winning only a portion of the slots needed for its business.
2. The auction groups functionally equivalent slots into fungible classes, thereby expediting the auction – in this case, all arrival slots in a given time period are considered fungible;
3. The auction design limits the amount of non-essential information provided to the bidders, thereby reducing potential problems of collusion and retaliatory bidding. Price and demand information are provided to the bidders after each round, but information about the specific behavior of particular bidders is not provided;
4. Bidders have the ability to specify packages at prices in-between the last round and the current round informing the auctioneer that they are willing to pay up to some price that is less than the price announced by the auctioneer. The process of providing such package-price points is labeled *intra-round* bidding.
5. There is an activity rule labeled the *revealed-preference rule* that forces bidders to bid for everything that they desire early in the auction in order to be able to win these items.
6. Bidders will be responsible for paying for these slots at the conclusion of the auction and, if a bidder defaults, there will be a penalty assessed for such actions. Thus, bidders must be sincere in their offers throughout the auction process.

### **1.3 Relationship of Primary Market to Secondary Market**

The secondary auction will take place every three months. The slots available during any auction will be those that have been placed into the auction by current leaseholders and by the FAA. If the slots are submitted by a leaseholder, then the FAA will augment the lease period so that the buyer will have use of the slot for the standard period (ten years). Thus, the secondary auction and the primary auction (new slots offered by the FAA or slots that have reverted to the FAA) will be intermingled with the slots offered by sellers. During the first few years, most slots submitted for auction are expected to be those offered by sellers. In the early years, the funds received by the FAA based on the extension of leases to the standard 10-year period, may be refunded through a procedure

similar to that used by the revenue-neutral congestion pricing approach or may be returned to the industry to subsidize the use of technologies that allow greater throughput (capacity) at LGA.

**Advantages of an initial allocation, a secondary market for exchanges and a future primary market:**

- Use of slots insures congestion is controlled.
- Initial allocation based on incumbency provides easy transition.
- Limited slot lifetimes and use of market mechanism for allocation insures slot turnover and efficient use of slots.
- Secondary market will encourage early mechanism for slot turnover and transition phase to primary market.
- The secondary market creates a transparent market in which multiple parties can participate and compete for available slots and promotes competition by making trades anonymous.
- There is little additional financial burden placed on airlines.
- The auction design has been tested by other government agencies and there is software available that can be adapted easily for this use. There are other government agencies and/or private companies that can administer the auction for the FAA.
- The secondary market is likely to be used cautiously at first, thereby allowing a transition period in which to evaluate the auction design and make any changes to either the design or the software based on feedback from users.

**Disadvantages:**

- The secondary market may not be sufficiently active to allow new entrants the access to LGA that they wish.
- The ten-year time fixed lifetime of a lease may be too long. The industry may want staggered or shorter lease lives.
- There is no authorization currently for the FAA to receive funds and not redistribute to the industry. Thus, any funds obtained by extending leases must be reallocated and a reallocation plan is not yet finalized.

**2. Complete Specification of the Clock Package Bidding Design with Optional Final Round**

**2.1 Package Creation**

*2.1.1 Clock Phase*

Bidders can create packages each round by specifying the total quantity desired of each item at the current prices. A bidder can create a package of items of its choosing with the exception that a bidder who has introduced slots to sell into the auction cannot bid on slots in that time period.

### *2.1.2 Last Round*

The bidder is given one opportunity prior to the final round (proxy phase) to submit all packages for consideration during this phase. For each package, the bidder provides a package name, package structure (the quantity of each item making up that package), and the package value. Again, bidders can create any collection of items as a package with the single restriction that sellers cannot bid on slots in a time period where they have submitted slots for sale. In addition to the new package bids submitted, the final round will include *all* bids made in prior rounds at their bid prices. Since the final round is a combinatorial auction design (a proxy mechanism) bids from prior rounds might “win” since they “fit well” with other package bids. Thus, during the entire auction, bidders should be aware that all bids submitted will be “live” until the auction ends.

## **2.2 Minimum Acceptable Bid (MAB) and Bid Increment**

### *2.2.1 Clock Phase*

The clock prices for all items are initialized to starting prices. A seller may set a reserve price higher than the minimum opening price or may, instead, set the minimum opening price at the minimum at which the seller will sell the item. The clock prices of items with excess demand are incremented by a percentage of the prior price to set the minimum acceptable bid prices for the next round. The price of a package is the sum of the prices of the quantity-items that make up the package. If the seller specifies a reserve price, then the auctioneer will inform the bidders when the price exceeds the (undisclosed) reserve price.

The bid increment percentage for each item is updated based on the history of excess demand using exponential smoothing and constrained to lie between a lower and upper bound specified by the auctioneer. However, the increment is always 0% whenever there is no excess demand in the prior round (demand is less than or equal to supply). For the exact calculation of the bid increment see Appendix I-A-1.

### *2.2.2 Last Round*

We present two alternatives for setting the minimum acceptable values for the last round:

1. The clock phase of the auction can end because there is no excess demand. In this case, the auction may end with excess supply in which case the final prices and assignments from the clock phase may not be good starting prices. In this case, we propose solving for the revenue maximizing assignment based on all the bids made during the clock phase. The associated linear price estimates would

then serve as lower bounds on values for new package bids in the proxy phase by standing high bidders. See Appendix I-A-4 for a complete description of how linear prices are calculated.

2. Alternatively, the auctioneer may end the clock phase when the revenue improvements are less than  $x$  percent for two consecutive rounds. In this case, there may be excess demand on some of the items and the end prices can serve as good lower bounds on values for new package bids in the proxy phase by standing high bidders.

## 2.3 Bidding

### 2.3.1 Clock Phase

Bidders submit a single package bid that provides the total quantity demanded for each item desired at the current prices. Bidders can also provide intra-round bids in every round, whereby they express their demand for an item at various price levels along the line segment from the prior round price vector to the current round price vector. This intra-round bidding allows the bid increment to be kept relatively large without increasing the likelihood of losing efficiency. A pre-defined time limit is set during which new bids are accepted at the start of each clock round. All bids submitted should satisfy the activity rule specified in Section 7.

Intra-round bidding works as follows. A bidder can specify up to ‘ $w$ ’ price points (the number is specified by the auctioneer) at which it expresses a new quantity vector. The 0.0 price point corresponds to start-of-round (previous round MAB) price vector. The 1.0 price point corresponds to the end-of-round (current round MAB) price vector. A bid in the round is the collection of price point and quantity vector pairs. Each bid specifies the quantity of each item that the bidder desires at various price points between the start-of-round price vector and end-of-round price vector for the round.

Consider the bid of a particular bidder. Let  $MAB^t = (MAB_1^t, \dots, MAB_{|I|}^t)$  denotes round  $t$  price vector, and let  $(P^k, Q_j)^t$  denote the  $k^{th}$  pair of price point and quantity demanded of each item of package  $Q_j$ , where  $k$  is the index of the price point. The price point is a fractional value or  $0 < P^k < 1$  and its corresponding price vector is:

$$\left( MAB_1^{t-1} + P^k * (MAB_1^t - MAB_1^{t-1}), \dots, MAB_{|I|}^{t-1} + P^k * (MAB_{|I|}^t - MAB_{|I|}^{t-1}) \right).$$

Thus the bid amount of package  $Q_j$  at price point  $P^k$  of round  $t$  is

$$b^t(P^k, Q_j) = \sum_{i \in I} q_{ij} * \left[ MAB_i^{t-1} + P^k * (MAB_i^t - MAB_i^{t-1}) \right].$$

With intra-round bids, bidders express their quantity demands in each auction round at all price vectors along the line segment from the start-of-round prices to the proposed end-of-round prices. Each bid constitutes a binding commitment to enter into a contract for the implied number of items at any price between the start-of-round price vector and end-of-round price vector for the round. All intra-round bids must satisfy RPAR at the price points chosen by the bidders. The bids must be consistent with a downward sloping demand curve. That is, for a package comprising of a set of items, a bidder may not specify larger quantities of each item at a higher price point than at a lower price point.

**Example:**

Consider a numerical example with two products, as shown in Table 1. The start-of-round prices are (90, 180) and end-of-round prices are (100, 200). The bidder decides to reduce quantity at two price points (0.40 and 0.60) between the start-of-round and end-of-round prices.

Price Point	Item 1		Item 2	
	Price	Quantity	Price	Quantity
0.00	90	8	180	4
0.40	94	5	188	4
0.60	96	5	192	2
1.00	100	5	200	2

**Table 1: Intra-round package bids**

2.3.2 Last Round

In the last round, bidders submit their *maximum bid amounts* (maximum willingness to pay) on multiple packages that satisfy the relaxed activity rule (revealed preference rule). Each bidder can win at most one package at the end of the proxy phase. The prices paid by winning bidders will be no higher than is necessary to overcome the bids of non-winning bidders.

**2.4 Eligibility – Bid Deposit**

Bidder eligibility to bid on a package is limited by a financial constraint based on the bidder’s deposit and the deposit factor  $F$  set by the auctioneer. Thus, a bidder cannot bid an amount for a package that is more than  $F$  times the bidder’s deposit.

2.4.1 Clock Phase

A bidder can continue bidding during the clock phase as long as it increases its deposit amount to conform to the financial qualification constraints imposed by the auctioneer in the auction.

2.4.2 Last Round

In the proxy phase, the bidder can express values that are higher than the deposit allowed during the clock phase. However, based on the payments required of winning bidders determined by the proxy calculations, a winning bidder must raise its deposit amount to conform to the deposit factor within two business days of the auction. If any bidder is unable to provide the sufficient deposit, the last round (proxy) is rerun with the valuations on all packages reduced to at most the deposit multiplied by the bid factor for that winning bidder in the initial proxy run. Bidders will be penalized 2% of the shortfall in the bidder's deposit if they are unable to increase the deposit as required. Any new winners in the new run have the same two-day window to raise their deposits to satisfy the deposit constraint. If any bidder fails to increase its deposit, the proxy round is again rerun with appropriate value reductions for these new winners. This process is repeated until there are no new winning bidders that fail to increase their bid deposits so that winning payment over deposit is at least the deposit factor for every winning bidder. This process can last at most  $2n$  business days (where ' $n$ ' is the number of bidders in the auction). More typically, the process would end immediately with all bidders providing sufficient deposits.

Since bidders cannot adjust their proxy bids in any way during this process, there is no opportunity for "gaming" in the proxy round.

## **2.5 Bid Removal and Withdrawal**

No bids can be withdrawn during either phase of the auction. However, the valuations of a bidder can be reduced by the auctioneer, in the proxy phase, if the bidder fails to increase its deposit to meet the financial qualification as described above.

## **2.6 Demand**

### *2.6.1 Clock Phase*

Demand for an item is defined as the total quantity bid by all bidders at the current price. If demand for an item is greater than its supply, then the price of the item is increased by an amount proportional to the excess demand. See Appendix I-A-1 for further detail.

### *2.6.2 Last Round*

The last round does not require any calculation of demand. The winner determination problem determines the quantity of items sold based on the collection of packages that maximizes revenue to the seller. Starting prices (or reserve prices) are considered as auctioneer's valuation. Hence, unsold items are credited an amount equal to this value, when solving the winner determination problem.

## **2.7 Activity**

### *2.7.1 Clock Phase*

A *Revealed Preference Activity Rule* (RPAR) is proposed in this design. This rule depends on the history of both prices and quantities and is derived from standard consumer theory<sup>2</sup>. For the case of a single item this is equivalent to the condition that as price goes up quantity cannot increase, i.e. bids must be consistent with a weakly downward-sloping demand curve. The extension to a multi-item case would be that if a bidder chose to bid on package  $Q_r$  over package  $Q_s$  based on the prices in round  $t$ , then it would be inconsistent or untruthful for that bidder to bid on package  $Q_s$  in a later round ( $t + k$ ) (where  $k$  is an integer number of rounds), unless the price increase for package  $Q_r$  was greater than or equal to the price increase for package  $Q_s$  in the intermediate period. There is also an equivalent expression for multi-item auctions involving multiple units of the same item. The RPAR is a mathematical constraint that enforces consistency in bidding. RPAR can be summarized by a color code for each package, with green indicating that a package satisfies the RPAR constraint, and red indicating that the package violates RPAR, at any particular price point. See Appendix I-A-5 for further detail.

A bidder that is bidding on some package at the end of the clock phase is referred to as a *standing* high bidder. Any bidder that does not submit a package bid at the minimum acceptable prices (100% price point) in a clock round is considered to have *dropped out*.

### 2.7.2 Last Round

To promote price discovery in the clock phase, the proxy agent's allowable bids must be constrained by the bidder's bids in the clock phase. One cannot, however, impose the exact RPAR used in the clock phase, since linear pricing provides incentives for bidders to reduce demand below their true demand during this phase of the auction. Bidders should have the opportunity to expand their demands in the proxy phase. A relaxed RPAR rule is applied during the proxy phase of the auction with respect to bids in the clock phase. The degree of relaxation  $\alpha_p$  is determined by the auctioneer.

Every bidder that dropped out prior to the end of the clock phase may submit any of their existing packages along with new package bids that all satisfy relaxed RPAR rule. by the auctioneer.

## 2.8 Stopping Rules

### 2.8.1 Clock Phase

We present two alternative rules for ending the clock phase of the auction. The clock phase could be declared over when:

- (1) There is no more excess demand on any of the items in the auction, or
- (2) The revenue improvement for two consecutive rounds is below 'x' percent.

The second alternative is proposed because there may be excess demand on some of the items and the end prices can serve as good lower bounds on values for new package bids

in the last round by standing high bidders. A reasonable value of  $x$  is  $\frac{1}{2}$  to 2 percent but will be determined by the auctioneer.

### 2.8.2 *Last Round*

Once all bids are provided, an ascending proxy auction design is used to determine the winning bidders and the prices that these winning bidders pay. The ascending proxy auction mechanism is implemented using the most efficient method of determining a bidder Pareto-optimal point in the core. Please refer to Hoffman et al. (2004) and Day and Raghavan (2004) for practical approaches to implementing the ascending auction proxy mechanism.

## 2.9 Round Results

### 2.9.1 *Clock Phase*

The only feedback available to the bidders during the clock phase is the list of prices and demands on each item. At no time during this phase will bidders receive information regarding the identities of other bidders, the content of other packages, or the valuations of other bidders. Bidder-specific demand and intra-round bidding information is not revealed. However, in any given round, the auctioneer announces how many bidders have used the waiver option and the maximum degree of violation of RPAR.

### 2.9.2 *Last Round*

At the end of the clock phase bidders receive feedback on the minimum acceptable prices for items. In addition, for auctions with a large number of items and sufficient competition, all package bids placed throughout the clock phase, without their associated bidder identities, will be revealed to all bidders. This is to help bidders focus on the subset of packages that have the greatest chance of forming a coalition with other bidders, since they may not be able to submit all combinations of packages due to restrictions by the auctioneer on the maximum number of packages allowed per bidder.

They may submit valuations on these packages at or above the minimum acceptable prices provided they satisfy the relaxed RPAR.

## 2.10 End of Auction

At the end of the auction, winners will be announced. All winners will be required to provide payment of the total bid price within 30 days of the end of the auction. A bidder who defaults on payment will be assessed a default penalty equal to 2% of the bid price or the difference between the bid price and the bid of the highest losing bid on that slot, whichever is higher. The default penalty will be recovered from the up-front payments. If the bid of the highest losing bidder exceeds the reserve price, then the slot will go to that bidder. Otherwise, the slot will revert back to the seller.

If a proxy last round is used to determine the winning bids then individual prices are not apparent since the proxy auction mechanism determines package prices. Assuming that there are multiple sellers who have contributed to items that make up such a package, one must determine how to allocate the overall package price to the individual sellers. We propose to solve an optimization problem similar to that used for obtaining item prices at the beginning of the proxy stage to determine the allocation of the package price back to the sellers.

### **3. References**

1. Ausubel, Lawrence M., Peter Cramton and Paul Milgrom, "The Clock-Proxy Auction: A Practical Combinatorial Auction Design," September 2004.
2. Day, Robert W. and S. Raghavan, "Generation and Selection of Core Outcomes in Sealed-Bid Combinatorial Auctions," Working Paper, University of Maryland, 2004.
3. Hoffman, Karla, Dinesh Menon, Susara van den Heever and Thomas Wilson, "Observations and Near-Direct Implementations of the Ascending Proxy Auction", Chapter 17, Combinatorial Auctions, MIT Press, 2005.
4. Hoffman, Karla and David C. Parkes, "An Ascending-Clock Auction for LaGuardia Airport", Draft Version, December 21, 2004.
5. Porter, David, Stephen Rassenti, Anil Roopnarine and Vernon Smith, "Combinatorial Auction Design," PNAS Early Edition, 2003.

# Appendix I: Mathematical Formulas Related to Auction Design

## A-1. Minimum Acceptable Bid (MAB) Calculation in Clock Phase

### a. Minimum Acceptable Bid Percentage Increment for an Item

- Let  $y_{mab\_ceiling}$  be the lower bound percentage, set by the FCC,  
 $y_{mab\_floor}$  be the upper bound percentage, set by the FCC,  
 $\omega_{mab\_weight}$  be the exponential smoothing weight,  $0 < \omega_{mab\_weight} < 1$  and set by the FCC,  
 $a_i^t$  be the activity index for item  $i$  in round  $t$ ,  
 $d_i^t$  be the sum of demand quantities for item  $i$  in round  $t$  (see Appendix A-3),  
 $s_i$  be the available supply (in number of units) of item  $i$ .

The activity index of any item  $i$  in round  $t$  is:

$$a_i^t = \omega_{mab\_weight} * d_i^t + (1 - \omega_{mab\_weight}) * a_i^{t-1} \quad (1)$$

Using the activity index of item  $i$  in round  $t$ , the minimum acceptable bid percentage increment for item  $i$  in round  $t$ , when demand greater than supply, is:

$$y_{mab\_i}^t = \text{smaller of } \left\{ \left( 1 + \frac{a_i^t}{s_i} \right) * y_{mab\_floor}, y_{mab\_ceiling} \right\} \quad (2)$$

The minimum acceptable bid percentage increment will be zero for all items with demand less than or equal to supply.

### b. Minimum Acceptable Bid Amount of an Item

- Let  $y_{mab\_i}^t$  be the MAB percentage increment for item  $i$  in round  $t$ ,  
 $MAB_i^t$  be the minimum acceptable bid price for one unit of item  $i$  in round  $t$ .

The minimum acceptable bid amount for one unit of item  $i$  in round  $(t+1)$  is:

$$MAB_i^{t+1} = MAB_i^t * (1 + y_{mab\_i}^t) \quad (3)$$

### c. Minimum Acceptable Bid Amount of a Package

Let  $I$  be the set of auctioned items,  
 $|I|$  be the cardinal number of set  $I$ ,  
 $Q_j = (q_{1,j}, q_{2,j}, \dots, q_{|I|,j})$  be the vector of quantities for package  $j$ ,  
 $q_{ij}$  be the demand quantity for item  $i$  in package  $j$ ,  
 $MAB^t(Q_j)$  be the bid amount of package bid  $Q_j$  in round  $t$ .

The minimum acceptable bid amount of package  $j$  in round  $t$  is:

$$MAB^t(Q_j) = \sum_{i \in I} q_{ij} * MAB_i^t \quad (4)$$

### A-2. Calculation of Item Clearing Revenue and Revenue Improvement at the End of every Clock Round

The clock phase “revenue” in round  $t$  is:

$$R^t = \sum_{i \in I} s_i * MAB_i^t \quad (5)$$

where  $s_i$  is the number of available units of item  $i$  in the auction.

The percentage revenue improvement,  $r(t-1, t)$ , from round  $(t-1)$  to round  $t$  is:

$$r(t-1, t) = \frac{R^t - R^{t-1}}{R^{t-1}} * 100 \quad (6)$$

### A-3. Calculation of Item Demand

Let  $B^t$  be the set of bids placed in round  $t$ . The demand for each item  $i$  in round  $t$  is:

$$d_i^t = \sum_{j \in B^t} q_{ij} \quad (7)$$

### A-4. Calculation of Package Clearing Unit Price Estimates at the End of Clock Phase

This section lays out the set of optimization problems that have to be solved to determine the linear item unit prices based on package clearing at the end of the clock phase. When

alternative (1) is chosen for the stopping criterion, these linear prices will be used as the lower bounds for valuations on new packages submitted by bidders in the last round. The following two problems have to be solved:

- a. Determination of package clearing maximum revenue.
- b. Calculation of unit price estimates for items.

### a. Determination of package clearing maximum revenue

When the stopping criterion is satisfied, the clock phase ends. A combinatorial optimization problem is then solved to determine the package clearing maximum revenue over all bids placed throughout the clock phase.

Let  $b(Q_j)$  be the last bid amount on a package bid  $Q_j$ ,  
 $B$  be the set of package bid indices placed in the clock phase,  
 $B_k$  be the subset of package bid indices placed by bidder  $k$ ,  
 $A$  be the set of participating bidders (agents) in the auction,  
 $r_i$  be the auctioneer's reserve price for one unit of item  $i$ ,  
 $y_i$  be the number of unsold units of item  $i$ .

The integer variables,  $x$  and  $y$  are defined as follows:

$$x_j = \begin{cases} 1, & \text{if package bid } Q_j \text{ is in a winning bid set} \\ 0, & \text{otherwise} \end{cases}, \forall j \in B$$

and

$$y_i \in \{0, 1, 2, \dots, s_i\}, \forall i \in I$$

The revenue maximization problem can now be stated as follows:

$$R^* = \max \left[ \sum_{j \in B} b(Q_j) x_j + \sum_{i \in I} r_i \cdot y_i \right]$$

Subject to:

$$\sum_{j \in B} q_{ij} x_j + y_i = s_i, \quad \forall i \in I \quad (8)$$

$$\sum_{j \in B_k} x_j \leq 1, \quad \forall k \in A \quad (9)$$

$$x_j \in \{0, 1\}, \quad \forall j \in B$$

$$y_i \in \{0, 1, \dots, s_i\}, \quad \forall i \in I$$

*Constraints (1):* These ensure that the number of units of an item  $i$  assigned to the winning set of bidders and the unsold add up to the number of available units,  $s_i$ .

*Constraints (2):* These ensure that no more than one package bid is allocated to any single bidder (or agent).

### b. Calculation of unit price estimates for items

The lower bounds on values for all new packages submitted by bidders in the proxy phase are computed by solving a sequence of linear programming problems that minimize the maximum deviation of the package price from the bid amounts while ensuring that the sum of the prices of all allocated packages satisfy the maximum revenue constraint exactly. When there exists an item that was not covered by any placed bid, we will exclude this item from this price calculation, and set its unit price equal to its *MOB*. Thus, we can safely consider that the remaining unallocated units (if any) exist due to package wise market clearing.

Let  $\pi_i$  be the unit price variable of item  $i$ ,  
 $I^d$  be the set of items, which were demanded by a bidder,  
 $R^*$  be the package clearing maximum revenue.  
 $\delta$  be the slack variable,

Formally, the first iteration of the price estimation problem can be stated as follows:

$LP(1): \delta_1 = \min \delta$
<p>Subject to:</p>
$\sum_{i \in I^d} q_{ij} \pi_i + \delta \geq b(Q_j), \quad \forall j \in B \quad (10)$
$\pi_i + \delta \geq r_i, \quad \forall i \in I^d \quad (11)$
$\sum_{i \in I^d} s_i \pi_i = R^* - \sum_{i \in I \setminus I^d} s_i r_i \quad (12)$

Let  $(\hat{\pi}_1, \hat{\pi}_2, \dots, \hat{\pi}_{|I^d|})$  be the solution for  $LP(1)$ , then create set

$$J_1 = \left\{ j \mid \sum_{i \in I^d} q_{ij} \hat{\pi}_i + \delta_1 = b(Q_j), \forall j \in B \right\} \text{ and } I_1 = \left\{ i \mid \hat{\pi}_i + \delta_1 = r_i, \forall i \in I^d \right\}, \text{ and set}$$

$J^* = J_1$  and  $I^* = I_1$ . Then permanently fix  $\delta = \delta_1, \forall l \in J_1 \cup I_1$ . We can now solve the problem sequentially, where at iteration  $k$ ,  $LP(k)$  would be as follows:

$LP(k): \delta_k = \min \delta$	
Subject to:	
$\sum_{i \in I^d} q_{ij} \pi_i + \delta \geq b(Q_j),$	$\forall j \in B \setminus J^* \quad (13)$
$\sum_{i \in I^d} q_{ij} \pi_i = b(Q_j) - \delta_p,$	$\forall j \in J_p, p \in \{1, \dots, k-1\} \quad (14)$
$\pi_i + \delta \geq r_i,$	$\forall i \in I^d \setminus I^* \quad (15)$
$\pi_i = r_i - \delta_p,$	$\forall i \in I_p, p \in \{1, \dots, k-1\} \quad (16)$
$\sum_{i \in I^d} s_i \pi_i = R^* - \sum_{i \in I \setminus I^d} s_i r_i$	$(17)$

where  $J^* = \bigcup_{p \in \{1, \dots, k-1\}} J_p$ , and  $I^* = \bigcup_{p \in \{1, \dots, k-1\}} I_p$ .

The algorithm terminates when  $J^* = B$  and  $I^* = I^d$ . We note that this algorithm may take many sequential steps since the number of steps is dependent upon how many inequalities get “fixed” simultaneously. A worst-case instance may require as many steps as the number of bids and items.

The set of prices  $\hat{\pi}_i$  upon termination will be used as the lower bound of unit prices for each item  $i$  in the proxy phase. Then, the minimum acceptable value for a new package  $j$ , created by a standing high bidder, in the proxy phase is:

$$\Pi(Q_j) = \sum_{i \in I} q_{ij} * \hat{\pi}_i \quad (18a)$$

## A-5. Activity Rule

### a. Clock Phase

The RPAR (Revealed Preference Activity Rule) is used to decide whether a package is biddable or not in current round. The description of RPAR is provided in the subsequent paragraphs. An active bidder may place no more than one biddable package in a round. To be considered active a bidder must have placed one biddable package in every past round.

Suppose a bidder places package bid  $Q_1$  in round 1. It is *implicit* that the profit of winning package  $Q_1$  is the highest against any other package combination. Then, suppose in round 2, this bidder places biddable package  $Q_2$ , and  $Q_1 \neq Q_2$ . Now let  $V(Q_1)$  and  $V(Q_2)$  be their values. The bidding decisions in these two rounds makes it *explicit* that winning package  $Q_1$  yields more or equal profit than winning package  $Q_2$  at round 1 price level. And winning package  $Q_2$  yields more or equal profit than winning package  $Q_1$  at the round 2 price level. Or mathematically,

$$V(Q_1) - b^1(Q_1) \geq V(Q_2) - b^1(Q_2) \quad (19)$$

$$V(Q_2) - b^2(Q_2) \geq V(Q_1) - b^2(Q_1) \quad (20)$$

where  $b^t(Q_j)$  is the MAB of package  $Q_j$  in round  $t$ . Adding these two inequalities yields the RPAR for this specific bidder in round 2

$$b^2(Q_1) - b^1(Q_1) \geq b^2(Q_2) - b^1(Q_2) \quad (21)$$

This rule says that any package  $Q_2$  is biddable in round 2 if and only if the price increment of package  $Q_2$  is not greater than that of package  $Q_1$ . For otherwise, in round 1, package  $Q_2$  would be more profitable than package  $Q_1$ .

In general, the RPAR for a bidder with any chosen package  $Q_t$  in round  $t$  is the following:

$$b^t(Q_k) - b^k(Q_k) \geq b^t(Q_t) - b^k(Q_t), \forall k \in \{1, \dots, t-1\} \quad (22)$$

where package  $Q_k$  is the package which was placed by this bidder in round  $k$ . Similarly, any package  $Q_t$  is biddable in round  $t$  if and only if it satisfies constraints (22) above.

Obviously, bidding truthfully based on profit maximization will not be stopped by RPAR. In other words, a package bid, which maximizes profit over a given set of fixed package bids values, will always satisfy RPAR at every round in clock phase. Thus, this RPAR can perfectly accommodate profit maximization bidding strategy in the absent of common value.

In the present of common value, a bidder may change its valuation on packages due to the price changes and/or budget limits and/or any other reasons. Consequently, this RPAR could be too restrictive. In order to accommodate these valuation changes, a relaxed RPAR with a relaxed factor  $\alpha_c$  is provided *once* for every bidder in the clock phase. The upper bound of allowable  $\alpha_c$  will be set by the auctioneer. The following is the relaxed RPAR for a bidder and any chosen package  $Q_t$  in round  $t$ :

$$\alpha_c [b^t(Q_k) - b^k(Q_k)] \geq b^t(Q_t) - b^k(Q_t), \forall k \in \{1, \dots, t-1\} \quad (23)$$

**Example:**

- Assume only one unit of each item is available.
- Assume there was excess demand on items  $A$ ,  $B$  and  $C$  in each round, resulting in a price increment on all items.
- The bidder bids on package  $AB$  in round 1, and package  $B$  in round 2.
- The value of  $\alpha_c$  is set to  $\mathbf{1}$ .
- Below is the bidding decisions and prices history for round 1 and 2, and current round 3.

	Unit Price Vector			$Q_1$	$Q_2$	Candidate Packages for Round 3 ( $Q_3$ )	
	A	B	C	AB	B	BC	C
<b>Round 1</b>	\$91	\$136	\$182	\$ 227	\$136	\$ 318	\$182
				√			
<b>Round 2</b>	\$100	\$150	\$200	\$ 250	\$150	\$ 350	\$200
					√		
<b>Round 3</b>	\$110	\$170	\$220	280	\$170	\$ 390	\$220
						<b>X</b>	
							√

**Note:** A package MAB is equal to the sum of the MABs of the items that make up the package. For example a bid of \$227 on package AB in Round 1 implies a bid on the item A at \$91 and item B at \$136.

The RPAR for these bidding decisions in round 3 is:

$$\begin{aligned} b^3(AB) - b^1(AB) &\geq b^3(Q_3) - b^1(Q_3) \\ b^3(B) - b^2(B) &\geq b^3(Q_3) - b^2(Q_3) \end{aligned}$$

Based on all available prices:

$$\begin{aligned} 280 - 227 &\geq b^3(Q_3) - b^1(Q_3) \\ 170 - 150 &\geq b^3(Q_3) - b^2(Q_3) \end{aligned}$$

Computing the differences:

$$\begin{aligned} 53 &\geq b^3(Q_3) - b^1(Q_3) \\ 20 &\geq b^3(Q_3) - b^2(Q_3) \end{aligned}$$

**Does package BC satisfy RPAR in round 3?** To answer this question, we can simply substitute  $b^3(BC) = 390$ ,  $b^2(BC) = 350$ , and  $b^1(BC) = 318$  into the above RPAR constraints. The answer is “NO” since a qualitative constraint is violated.

$$\begin{aligned} 53 &\geq 390 - 318 = 72 \text{ (inconsistent)} \\ 20 &\geq 390 - 350 = 40 \text{ (inconsistent)} \end{aligned}$$

Thus, this bidder **cannot** bid on package BC in round 3.

**Is package C biddable in round 3?** Again substitute  $b^3(C) = 220$ ,  $b^2(C) = 200$ , and  $b^1(C) = 182$  into the above RPAR constraints. The answer is “YES” since all qualitative constraints hold.

$$\begin{array}{l} 53 \geq 220 - 182 = 38 \\ 20 \geq 220 - 200 = 20 \end{array}$$

Thus, this bidder **can** bid on package  $C$  in round 3.

### b. Proxy Phase

A rule based on RPAR may be too strict when comparing a round in the clock phase with the final sealed-bid phase. Due to the linear pricing in the clock phase, the bidders have an incentive to reduce demand below their true demand. One purpose of the final sealed-bid phase is to let the bidders undo any inefficient demand reduction that would otherwise occur in the ascending phase, and to defect from any collusive split of the items that would otherwise take place.

Hence, it is important to let the bidders expand their demand in the sealed-bid phase. The amount of expansion required depends on the competitiveness of the auction. Therefore, a *relaxed* RPAR is proposed for values submitted in the proxy phase. The relaxed rule applies differently, depending on whether a bidder is a standing high bidder or not.

The bidder is also required to state a value for each biddable package on which the bidder has already bid in the clock phase.

#### Theoretical Development:

Let  $\alpha_p$  be the RPAR relaxation factor allowed in the proxy phase,  
 $B^c$  be the set of all package bids submitted in the clock phase,  
 $B^{new}$  be the set of all new biddable package bids submitted in the proxy phase,  
round  $f$  be the final round of the clock phase.

Generalizing the inequalities in (19) and (20), the following is the relaxed RPAR for a bidder's set of values:

$$\alpha_p [V(Q_k) - b^k(Q_k)] \geq V(Q_j) - b^k(Q_j), \forall j, k \in B^c, j \neq k \quad (24)$$

$$\alpha_p [V(Q_k) - b^k(Q_k)] \geq V(Q_j) - b^k(Q_j), \forall j \in B^{new}, k \in B^c \quad (25)$$

No bidder will be allowed to state a value below their previous highest bid amount on any existing package bid. The parameter  $\alpha_p \geq 1$  is chosen by the auctioneer based on the competitiveness of the auction. For highly competitive auctions little demand reduction is likely to occur in the clock phase and  $\alpha_p$  can be set equal to **1**. On the other hand, if there is little competition then a higher  $\alpha_p$  is appropriate (anywhere between **1.1** and **1.5**).

## **Appendix II: Congestion Management Toolbox Presentation Materials**

# NEXTOR CONGESTION MANAGEMENT PROJECT Toolbox of Options

**sponsored by the U.S. Department of Transportation  
(Office of the Secretary & FAA)**

**University of Maryland - George Mason University  
MIT - U of California, Berkeley - Harvard – GRA**

**June 3, 2005**



# Toolbox

1. Basic slot auction mechanism.
2. Secondary market based on slot auction.
3. Procedure for fair allocation of slot leases based on incumbency rights.
4. Congestion pricing board.
5. Setting congestion prices based on cost of delays caused to system.
6. Congestion pricing: price setting/scheduling iterative loop with various options.
7. Congestion pricing with long-term contracts.
8. Congestion pricing: charging based on time of operation vs scheduled time of operation.
9. Per-Slot fees.
10. Using slot or congestion fees to off-set existing landing fees.
11. Revenue neutral fees based on per-seat (or passenger) rebates.
12. Reduction/exemption of slot fees for small community use.
13. Exemption from congestion prices for small community access.
14. PA implementation of mechanisms based on MOU, revenue neutrality & 3<sup>rd</sup> party collections.
15. Obtaining airline gate flexibility in exchange for property rights ceded to airlines in an auction.
16. Forced periodic participation in secondary market + FAA fees tied to market prices.
17. Performance-based slot re-allocation.
18. Average aircraft size standards.

**TOOLBOX SUMMARY**

MAIN OPTIONS	ANY AIRPORT		LGA						
	Congestion Begins	NO SLOTS	SLOTS						
	Flat landing fee	Laissez faire	congestion pricing	a/c size	perf based	auction	congest fee	fee and auction	Status Quo
	Chng rates/charges		pricing sked loop	initial distrib.	initial distrib.	initial distrib.	initial distrib.	initial distrib.	initial distrib.
			pricing board	slot life?	slot life?	slot life?	slot life?	slot life?	slot life?
				redistribution	redistribution	pct auctioned?	setting fee	setting fee	HDR or ORD
				2ndary mkt?	2ndary mkt?	2ndary mkt?	2ndary mkt?	2ndary mkt?	2ndary mkt?
				use/ lose?	use/ lose?	use/ lose?	use/ lose?	use/ lose?	use/ lose?
	Revenue neutral		rev neutrality?			rev neutrality?	rev neutrality?	rev neutrality?	
ACTOR	Any Airport	FAA	FAA/PANYNJ	FAA	FAA	FAA/PANYNJ	FAA/PANYNJ	FAA/PANYNJ	FAA
SUMMARY	When congestion first emerges at an airport, FAA best practices should state that airport should eliminate weight from landing fee and charge every operation the same fee; total fees collected would be revenue neutral	Do nothing; eventually the airport will stabilize	Establish a pricing board with authority to set prices at any level; request binding schedules from carriers; alter fees; request new schedules; continue until expected delays meet a target; allow variations from schedule for a premium above set prices.	Redistribute slots periodically based on seats offered per flight	Redistribute slots periodically based on other performance measures	Auction a portion of slots each year using simultaneous ascending clock design; all monetary sales via a secondary auction market	Charge users a fee per slot day; rebate funds based on seats offered or passengers per seat; fee could be based on congestion costs.	(a)Charge users a fee per slot day; rebate funds based on seats offered or passengers per seat; fee based on auction of some slots. (b) auction off some long term slots; pricing board sets prices to hold down remaining operations	Renew the HDR program or modify it to be closer to the ORD program including the blind secondary market

# Outline

1. Goals and Motivation
2. Airline Feedback
3. Options under a “Slot” Regime
4. Congestion Pricing Approaches
5. Final Thoughts

# Goals

1. Control of congestion and delays
2. Minimize or eliminate distortions to free market behavior -- evidence to the contrary under present rules:
  - Aircraft gauge at LGA is “smaller than average”
  - Very little slot turnover; new entry and expansion opportunities limited.

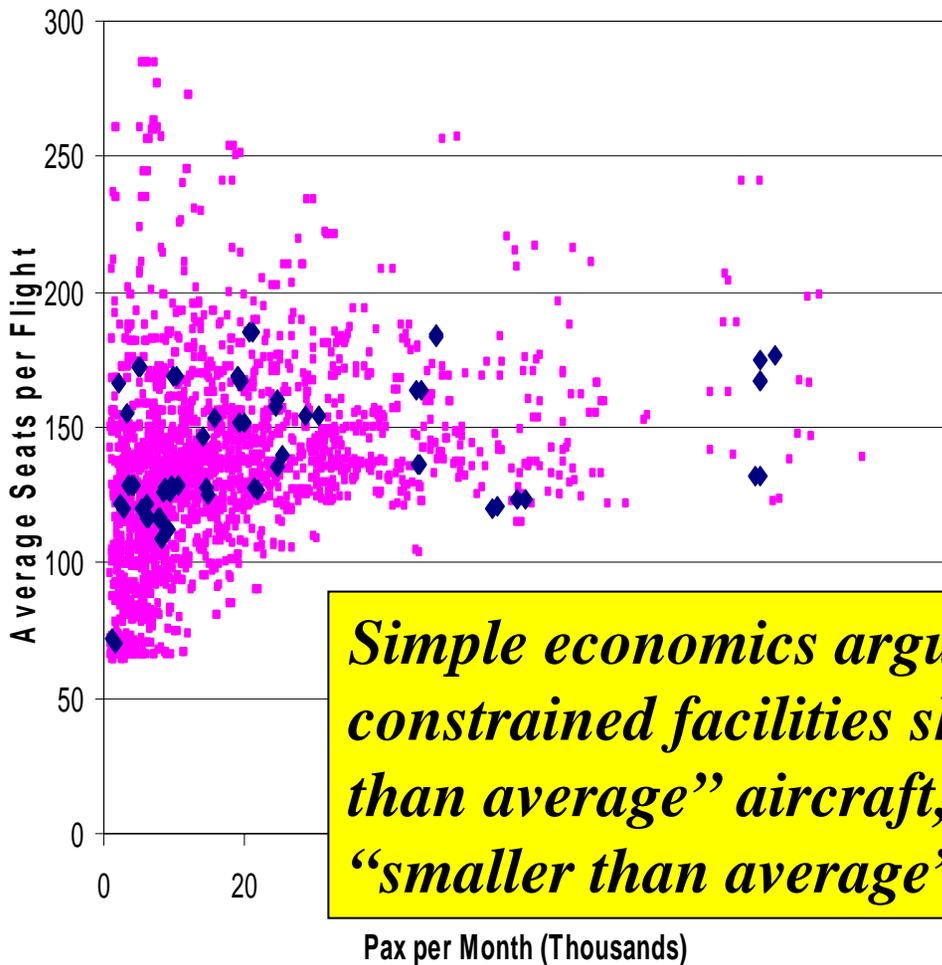
What is justification for considering goals under 2??

- Airport Competition Policy, Insuring access to essential facility.

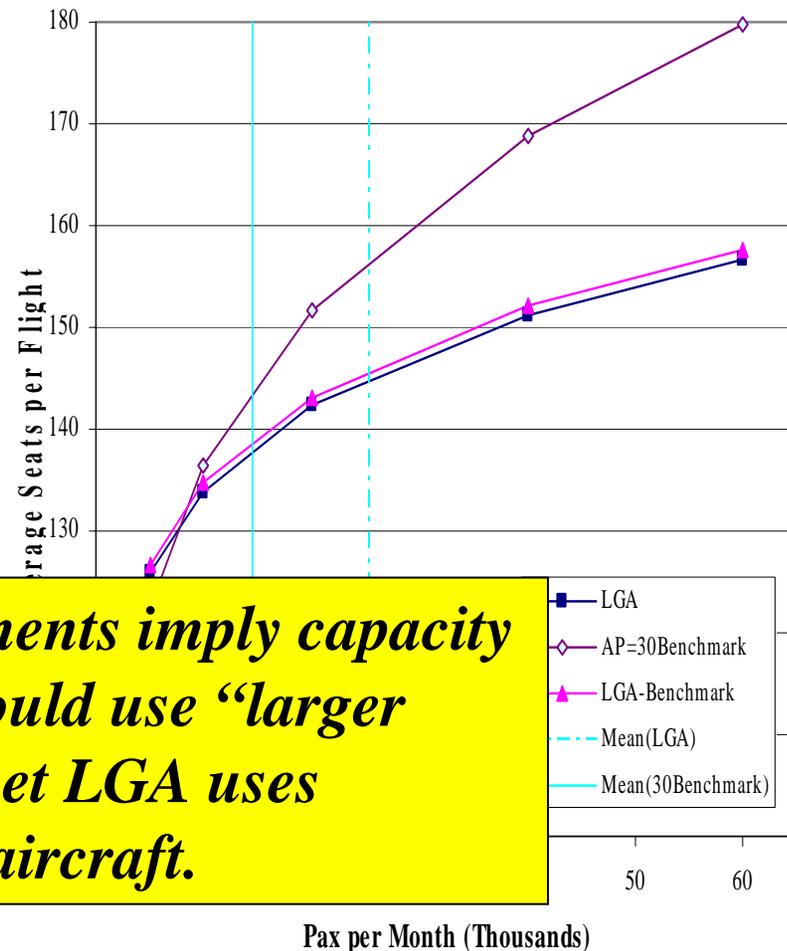
# Current LGA Policies Lead to Use of Smaller Aircraft

**Seats per flight vs pax per month in various markets: NAS vs LGA**

**Data**



**Functional Model**



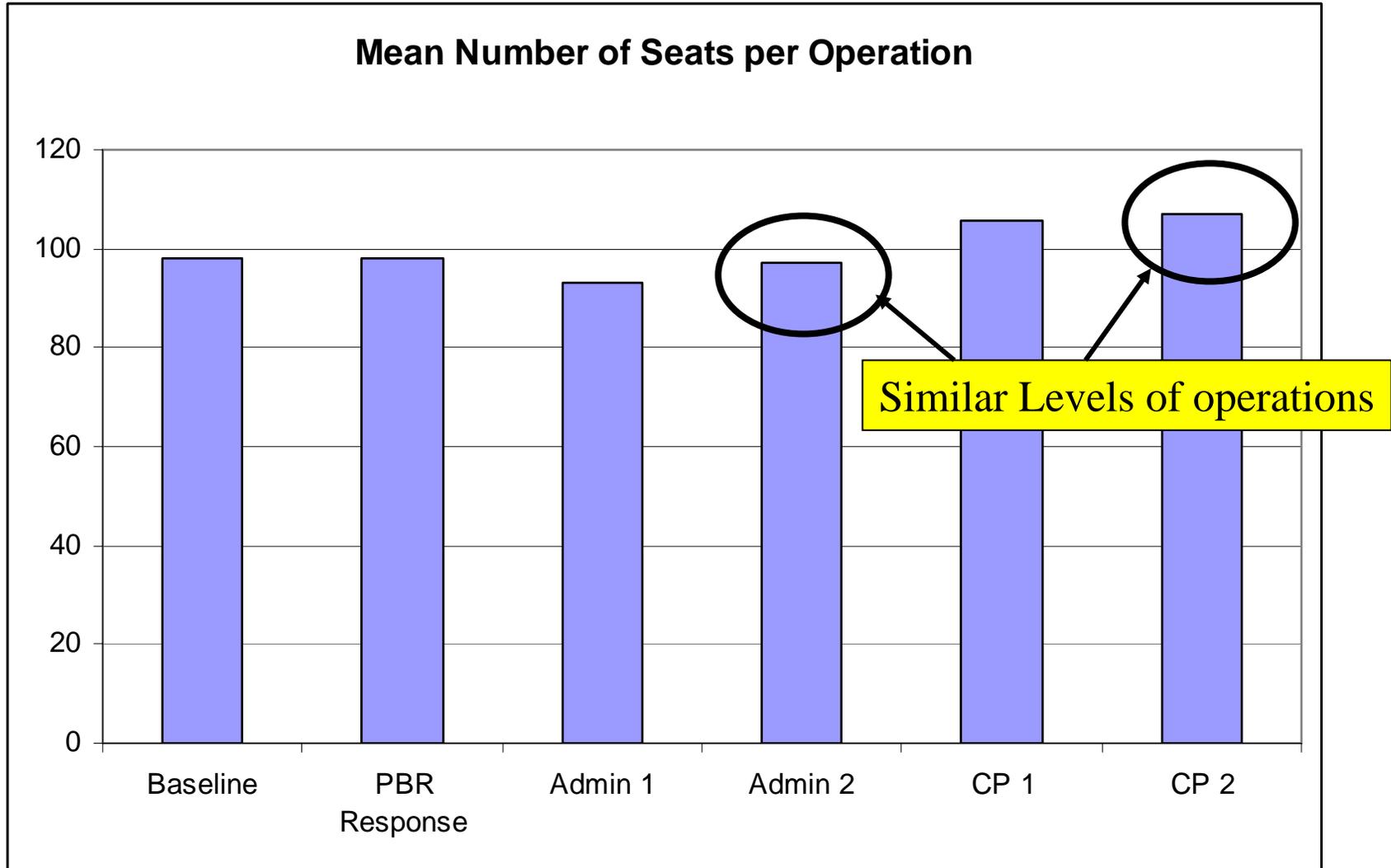
*Simple economics arguments imply capacity constrained facilities should use “larger than average” aircraft, yet LGA uses “smaller than average” aircraft.*

*Does this service frequency make sense given scarcity of slots and high levels of delay/congestion??*

**Number of LGA departures April 19, 2005 OAG:**

Buffalo, NY	13
Burlington, VT	7
Columbus, OH	15
Greensboro, NC	11
Greenville/Spartanburg, NC	5
Indianapolis, IN	10
Manchester, NH	10
Norfolk/Va Beach, VA	8
Portland, ME	8
Raleigh/Durham, NC	22
Richmond, VA	11
Rochester, NY	8
Syracuse, NY	9

# Results of Simulation 1: Market Mechanism (congestion pricing) Leads to Up-gauging When Compared to "Equivalent" Administrative Measures:



# Most Large Slot Sales Made by Seller in Distress

*Slot exchanges since 2001*

Lose Carrier Code	Lose Carrier Name	Gain Carrier Code	Gain Carrier Name	Slots	Year	NOTE
0042	FIRST SECURITY BANK, NATIONAL (as Trustee)	TWA	TWA AIRLINES, LLC (TWA INC. prior to 4/9/01)	52	2001	
TWA	TWA AIRLINES, LLC (TWA INC. prior to 4/9/01)	AAL	AMERICAN AIRLINES	28	2001	
TWA	TWA AIRLINES, LLC (TWA INC. prior to 4/9/01)	AAL	AMERICAN AIRLINES	14	2002	Sale of TWA to AA
TWA	TWA AIRLINES, LLC (TWA INC. prior to 4/9/01)	EGF	AMR EAGLE HOLDING COPR. (FORMERLY AMR EAGLE INC.)	10	2002	
ASH	MESA AIR d.b.a. LIBERTY EXP./FLA GULF	ALO	ALLEGHENY COMMUTER	1	2001	
CHQ	CHAUTAUQUA	ALO	ALLEGHENY COMMUTER	1	2001	Trade within US Air Commuter group
0040	MITSUBISHI BANK, LIMITED	NWA	NORTHWEST AIRLINES	25	2002	
NWA	NORTHWEST AIRLINES	0051	PENSION BENEFIT GUARANTY CORPORATION	49	2003	Title Changes
ACA	AIR CANADA	0050	WELLS FARGO BANK NORTHWEST, N.A.	45	2003	
0001	FAA (TEMPORARY HOLDER)	COM	COMAIR AIRLINES	1	2002	
0001	FAA (TEMPORARY HOLDER)	USA	US AIRWAYS	3	2004	Slot Recapture from FAA
AAL	AMERICAN AIRLINES	0001	FAA (TEMPORARY HOLDER)	1	2003	
AAL	AMERICAN AIRLINES	0001	FAA (TEMPORARY HOLDER)	1	2004	Slot Recapture by FAA
USA	US AIRWAYS	0001	FAA (TEMPORARY HOLDER)	2	2004	
USA	US AIRWAYS	EGF	AMR EAGLE HOLDING COPR. (FORMERLY AMR EAGLE INC.)	5	2003	
ALO	ALLEGHENY COMMUTER	EGF	AMR EAGLE HOLDING COPR. (FORMERLY AMR EAGLE INC.)	10	2003	Actual Slot Sales / Transfer
USA	US AIRWAYS	EGF	AMR EAGLE HOLDING COPR. (FORMERLY AMR EAGLE INC.)	3	2004	

# Airline Feedback

- There is a definite feeling that acquiring and maintaining slots at LGA (even if used non-profitably) is worthwhile to protect one's position relative to future FAA actions.
- Established carriers believe that they de facto own slots due to the large investment they have made in LGA.
- Open to:
  - new approaches to secondary markets (admit this is difficult because of competitive environment; many transactions are currently non-cash)
  - changes in fee structure (small changes could have significant impact)
  - eliminating slot designations
- Negative reaction to auctions:
  - Long term leases + uncertainty → risk.
  - Inability to “see” and react to competitors' moves.
  - Fear of highly strategic behavior, e.g. airline with deep pockets will come in and buy up many slots.
- Airlines will not cooperate unless they believe government is strongly committed to a plan of action.

# Implications of Decision

- Airlines sense lack of direction in this area – strong signal here will discourage continuation of strategic behavior, e.g. slot hoarding.
- Introduction of market-based approach will set new, positive direction and reduce current distortions.
- This issue clearly will arise at other airports in the coming years – consider NAS-wide implications of decisions made here.

# Progression of Options under a "Slot" Regime

flat per-operation fee →

per-slot fee →

eliminate use/lose →

eliminate slot designations, provide rebates on slot fees for small community use →

higher per-slot fee made revenue neutral thru rebates based on passengers carried →

blind secondary market →

blind secondary market w slot fees tied to market prices →

limited term leases + auction-based primary market

***Revenue neutral  
approaches***

# General Guidelines for Any “New” *Revenue Neutral* Slot-Based Approach

- FAA creates access rights and distributes based on incumbency.
- FAA approves (via MOU) a PA proposal to collect revenue neutral fees:
  - *Approach 1*: fees used to pay for airfield costs → existing landing fees are reduced or eliminated
  - *Approach 2*: fees collected are rebated.
- Fee collection and accounting handled by 3<sup>rd</sup> party (bank).

**Flat per-operation fee:** replace current weight-based landing fee with flat fee or fee with substantial “fixed price” → service with smaller numbers of passengers become less profitable → mild incentive to up-gauge.

**Per-slot fee:** replace landing fee with monthly slot usage fee → mild incentive to up-gauge, mild incentive to more effectively use slots (or to sell/lease).

**Eliminate use/lose:** with per-slot fee, use/lose can be eliminated since fee imposes cost on ineffective slot use (incl slot non-use) – however, fee must be high enough for this argument to be effective.

**Eliminate slot designations:** eliminate commuter, Air21, etc. slot designations – provide slot fee reductions or rebates (negative reductions) for small community use.

# Per-slot fee + no use/lose + no slot designations

- Flat per-slot fee → wgt-based landing fee incentive for use of small aircraft eliminated & cost attached to holding a slot.
- Small community access incentive: Per-slot fee reduced or eliminated or turned into rebate for small community use (measured after the fact)
- Fees/rebates:
  - Total net revenues designated to off-set PA airfield costs → automatic reduction (or elimination) of wgt-based landing fees. → cap on fees
- No use/lose → reduction in regulation & more airline flexibility
- No slot designation → ditto + immediate added value to airline bottom lines.

***Major question: given cap on fees, can they be high enough to have an effect and justify elimination of administrative controls??***

Increase per-slot fee & maintain revenue neutrality  
via rebates based on passenger counts

- Per-slot fee increased; excess revenue rebated to operators based on number of seats (or number of passengers) flown.
- Higher fee strengthens incentives previously discussed; per-seat rebate provides stronger incentive to up-gauge.

# Sample Fee Structure: break-even at 97 seats

- If the fee is set at average delay costs and rebate based on breaking even at **current** average seat size (97 seats), the fee structure results in revenue neutrality.

April 19 2005 OAG Schedule

## Net Congestion Tax at Target Gauge and Initial Weekday Schedule

Target = 97 seats

			\$10.32			
SEATS	Total Ops	Congest Fee	Per Seat Rebate	Net Cong Cost/Op	Net Cong Cost/Seat	Total Cong Revenues
19.0	14	\$1,000.00	\$196.08	\$803.92	\$42.31	\$11,254.94
33.0	68	\$1,000.00	\$340.55	\$659.45	\$19.98	\$44,842.42
35.0	94	\$1,000.00	\$361.19	\$638.81	\$18.25	\$60,047.93
37.0	78	\$1,000.00	\$381.83	\$618.17	\$16.71	\$48,217.12
44.0	14	\$1,000.00	\$454.07	\$545.93	\$12.41	\$7,643.02
50.0	292	\$1,000.00	\$515.99	\$484.01	\$9.68	\$141,331.26
70.0	2	\$1,000.00	\$722.38	\$277.62	\$3.97	\$555.23
100.0	4	\$1,000.00	\$1,031.98	(\$31.98)	(\$0.32)	(\$127.91)
106.0	20	\$1,000.00	\$1,093.90	(\$93.90)	(\$0.89)	(\$1,877.93)
110.0	30	\$1,000.00	\$1,135.18	(\$135.18)	(\$1.23)	(\$4,055.26)
124.0	136	\$1,000.00	\$1,279.65	(\$279.65)	(\$2.26)	(\$38,032.71)
126.0	8	\$1,000.00	\$1,300.29	(\$300.29)	(\$2.38)	(\$2,402.33)
127.0	80	\$1,000.00	\$1,310.61	(\$310.61)	(\$2.45)	(\$24,848.93)
141.0	126	\$1,000.00	\$1,455.09	(\$455.09)	(\$3.23)	(\$57,341.15)
142.0	40	\$1,000.00	\$1,465.41	(\$465.41)	(\$3.28)	(\$18,616.33)
155.0	70	\$1,000.00	\$1,599.57	(\$599.57)	(\$3.87)	(\$41,969.58)
171.0	14	\$1,000.00	\$1,764.68	(\$764.68)	(\$4.47)	(\$10,705.55)
187.0	94	\$1,000.00	\$1,929.80	(\$929.80)	(\$4.97)	(\$87,401.03)
253.0	10	\$1,000.00	\$2,610.90	(\$1,610.90)	(\$6.37)	(\$16,109.03)

**Current Schedule** →

1194

Over-recovery at Initial Schedule

\$10,404.18

Over-recovery at Initial Schedule

0.9%

# Blind Secondary Market

- Government runs auction periodically, e.g. quarterly.
- Airlines wishing to sell slots provide government with slot information + reserve price; airlines required to place each slot they own in auction at certain times, e.g. every 5 years.
- Auction employs format previously described (February exercise).
- (Non-monetary) Slot trades handled as they are today.
- Even if slots are not sold, market prices are established.

# Blind Secondary Market with Slot Fees Based on Market Prices

*Secondary market may have very few transactions since current slot holders can buy back their own slots (for free).*

**Concept:** make slot fee proportional to market price set by auction → if offered price becomes very high and owner does not sell then owner incurs (subsequent) high slot fee → incentive to sell is higher

- equivalent to declaring joint government/airline slot ownership with government share of selling price paid over time.
- should substantially increase incentive to sell if price becomes high.

*In concept, this approach could be made revenue neutral through rebates.*

# Complete Slot/Auction Proposal

- Slots with staggered 5-year lifetimes
- Initial allocation: administrative measure based on incumbency rights (initial lease lengths:  $1+Y$  yrs,  $2+Y$  years,  $3+Y$  yrs,  $4+Y$  yrs,  $5+Y$  yrs :  $Y$  is transition increment)
- Reallocation via auction
- Secondary market that is “almost identical” to primary market
- Rebates on slot fees for use in designated small communities.

In spite of airline negativity auctions foster the most robust business environment ...

- ***“Pure” market approach:*** other approaches involve administrative manipulation with associated distortions.
- Robust primary market & slots with finite lifetimes will provide ***strong stimulus for secondary market.***
- Regularly selling slots should ***eliminate temptation to give them away.***
- ***No one should be surprised by airline resistance.***
- Incumbents argue they have made large investments and therefore have de facto rights to slots – ***“ownership” of gates and other facilities give incumbents great advantage and power.***

# Are airline fears reasonable??

- Strategic behavior and dominance by “deep” pockets:
  - Each participant will be limited in total market share → *difficult for single player to dominate.*
  - Each participant will be bidding on and acquiring many slots → there will be willingness to back-off 1 or 2 slots or to move in time → *prices will not get unreasonable.*
- Being permanently shut out:
  - Secondary market & yearly primary auctions → *unlikely that an airline will be shut out.*
- Inability to respond to competitor moves:
  - slots, like aircraft represent a fixed asset – *schedules must be adjusted using available slots* – no different than current situation, except that slot “haves” and “have-nots” may change.

# Initial Slot Allocation

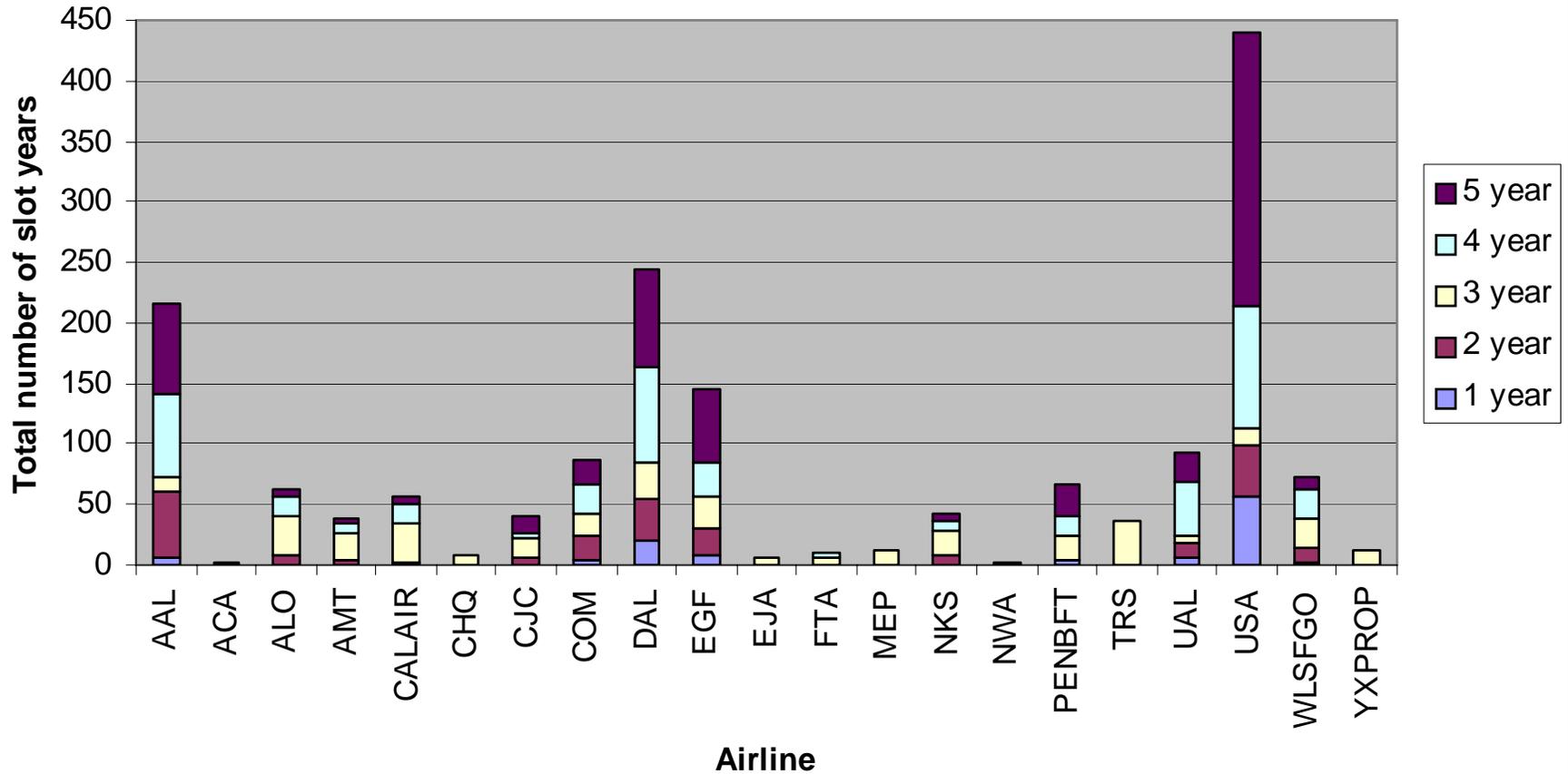
- All proposals that maintain a slot concept require an initial slot allocation since the existing law and slot regime will expire in 2007.
- NEXTOR has developed a model to allocate slots or slot leases based on incumbency rights.
- General concept: minimize deviation between measure of each owner's current holding and new allocation:
  - for entire day
  - on an hourly basis
- Important questions:
  - What is measure of current holdings?
    - Are all slots equal?
    - Slots vs slot usage (scheduled operations)?
    - Current holdings vs historical holdings/performance?
  - What is being allocated?
    - Permanent slots?
    - Slot leases with a duration?
    - Does number of slots change?

# Example: initial allocation of slot leases

- Given:
  - Existing # slots each airline has during different hours
  - Hourly variation in slot values
  - Proposed reduction from the current schedule – i.e. set a capacity limit
  - 20% of the slots expire after 1 year, 20% after 2 yrs, .....
- Objective:
  - Assign lifetime (1 yr, 2yrs,...,5yrs) to slots belonging to different airlines, such that the total number of slots during any hour does not exceed the proposed capacity.
  - Optimize certain equity measures:
    - Measure 1 insures holdings in each hour are close to “ideal” for that hour.
    - Measure 2 insures that overall holdings are close to overall “ideal”.
  - If number of slots stays the same, then ideal number of lease-years for an airline would be 3\*current slot holding.

# Sample Allocation

Number of slot years assigned to different airlines



## Other Possibilities

- Reduce or increase total number of slots. Allocate (infinite lifetime) slots based on current holdings.
- Allocate “uniform” slots or slot leases, where measure of current holdings takes into account slot designations and/or length of time slot has been held.
- Allocate slots or slot leases, based on historical levels of usage or scheduled usage (could be used to withdraw slots based on historical underutilization)

# Characteristics Common to any Congestion Pricing Approach

- Slots do not exist – airlines have the freedom to schedule (with some required lead time) as many operations as they are willing to pay for.
- Prices have to be set, both initially and recurringly, either by human or automatic means.
- Prices vary by time of day.
- Someone has to collect the money and do something useful with it, i.e. not revenue neutral .
- No explicit control over congestion.

# Hybrid Congestion Pricing Proposal with Controls against Over-Scheduling

- Congestion pricing board sets prices
  - Aims at achieving a congestion goal, and has no other objective function
  - Pricing algorithm could be based on real performance measures, such as the marginal system delay imparted by flights during given time periods
  - Revenue could be earmarked to offset existing fees (in addition to other uses)
- Preliminary price-and-schedule-setting rounds
  - Mitigates against initial pricing uncertainty
  - Airlines bound (in some way) to offered schedule in order to mitigate against misleading or strategic carrier behavior
  - Many variants relative to number of rounds, lead-time, control placed on future schedule adjustments, etc.

# Minimalist Congestion Pricing Proposal

## No board or preliminary rounds:

- Prices are set via a transparent algorithm
- Appropriate initial prices must be estimated through some economic analysis
- Revenue disposition is also governed by formula
- Initial prices could be unstable – all actors have to be ready, from financial, congestion, and political perspectives, to wait some time before prices and demand equilibrate
- Airlines can make unilateral scheduling decisions on any time frame, and up to the last minute

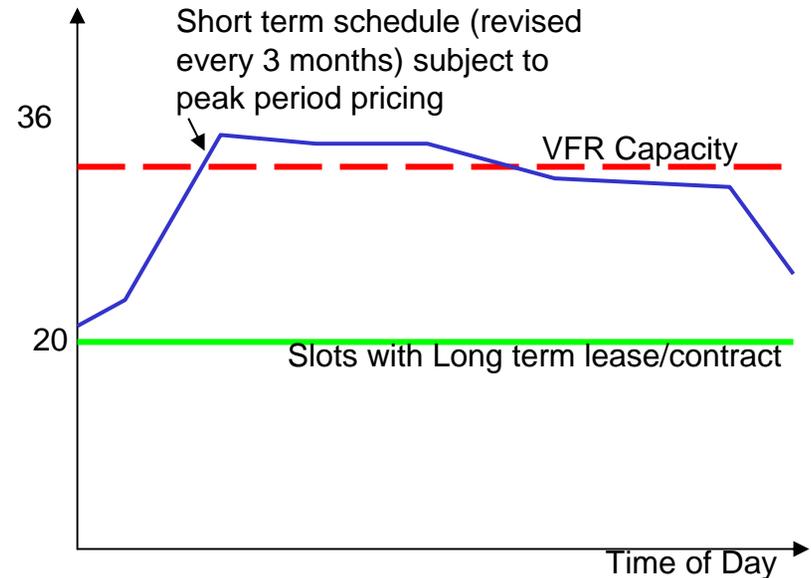
***This approach has more “risk” relative to congestion implications, but has advantage of simplicity and could be viewed as safety valve relative to laissez faire solution.***

# Pro's and Con's

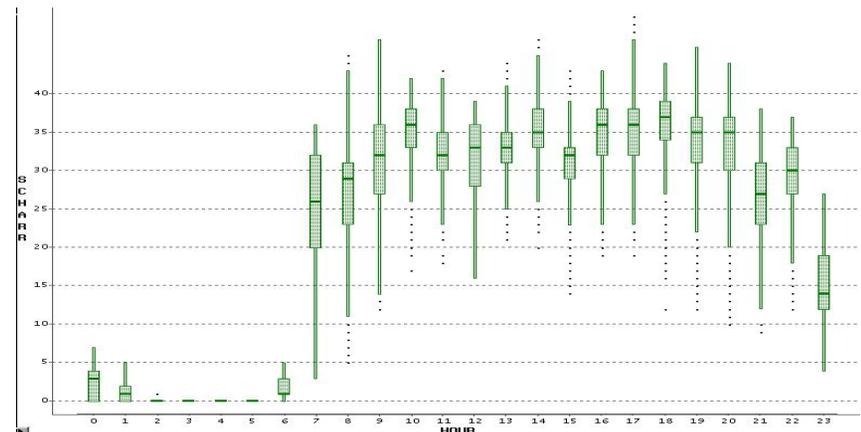
- Pro's
  - No slots: government and carrier overhead associated with slot administration is eliminated.
  - Carrier scheduling flexibility: carriers are free to try decreasing/increasing frequency, moving among markets, etc.
  - Reduced strategic behavior: no slot hoarding, slot baby-sitting, etc.
  - Reduced political activity: no need to lobby for slots since they don't exist.
- Con's:
  - Price uncertainty and volatility
  - Congestion uncertainty
  - Political influences in price-setting
  - Strategic behavior under hybrid regime
  - Constraints on schedule timing under hybrid regime

# Congestion Pricing with Long Term Contracts

- Long term (3 - 5 years) lease of certain number of slots in each hour:
  - Allocation via auction
  - Upfront payment; price of slots do not change until contracts expires
  - Secondary market transactions allowed between airlines
  
- Airlines can schedule operations (no slots) during any hour:
  - Short term schedule (revised every 3 months)
  - Subject to congestion pricing
  - During certain period, prices can be lower than the long term slot prices



Hourly variation in scheduled arrivals in last 5 yrs



# Pros & Cons

- Pros

- No one is denied access to the airport. If an airline cannot obtain enough (or any) long term slots, it can still schedule and operate subject to congestion pricing
- Seasonal variation in demand can be taken into account
- Long term contracts give higher predictability to both airport and airlines
- Airlines can avoid taking risk of long term contract and financial burden if they choose to do so
- Some airlines expressed interest in such a hybrid mechanism for congestion management

- Cons

- Complexity: requires both market mechanism (auction) for allocating long-term contracts and mechanism for setting congestion prices.
- Airlines will have partial information about total hourly schedules (and hence congestion level) while bidding for long term contracts

# Implementation Steps

- Administrative measure for initial allocation
  - Similar to a previously defined concept of assigning finite lifetime to current slots – 20% expire after 1yr, 20% after 2yrs, and so on.
- Determine what proportion of VFR capacity to be allocated under long term contract
- Certain number (based on the above proportion) of slots that expire each year are auctioned. Closing prices provide a basis for setting up congestion prices for short term schedules
- Hourly congestion prices are set for short term schedule every 3 months. Airlines submit their short term schedule, subject to congestion prices, that expires after 3 month period.

# Final Thoughts

Economic controls represent an essential part of the solution to rationalizing airspace demand and capacity.

Current effort represents opportunity for Federal Government to indicate willingness and desire to pursue market-based solution.

Ideal approach: gradual first step that can evolve into more comprehensive approach.