FLIGHT TRANSPORTATION LABORATORY
REPORT R85-3

A SURVEY OF APPROACHES TO THE SLOT ALLOCATION PROBLEM

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May 1985

MIT

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1. Introduction

The allocation of slots at congested major commercial airports is one of the most difficult problems facing the aviation community today. The stakes involved are very large and the controversy generated by the various proposed approaches to the problem is heated. This report is an attempt to provide a concise summary of the various proposed approaches and to discuss briefly the advantages and disadvantages of each.

Four important airports (JFK International and LaGuardia in New York City, O'Hare International in Chicago and National in Washington) are now -- and have been since 1969 — designated as "high density terminal area" (HDTA) airports. Runway access to these airports is allocated among airline users through scheduling committees which meet twice a year. Access to these airports by commuter/air taxi operators and by general aviation aircraft is also rationed. At the same time, several other important airports now experience (or are on the verge of experiencing) habitually-high levels of congestion during the peak traffic hours of the day.

The costs associated with this state of affairs are high. Although no particularly-reliable data exist, there is little doubt that the additional <u>direct operating costs</u> to the airlines due to airport congestion run in the hundreds of millions of dollars a year (and, possibly, may even exceed the one-billion-dollar mark). Indirect costs (loss of passenger time, disruption of airline schedules, missed appointments or missed flight connections, anguish and aggravation, etc.) may be just as large or larger.

A successful slot-allocation system would accomplish two things simultaneously: it would "alleviate" the congestion problems just referred to until that time, if ever, when increased airport capacity becomes available, and it would provide access to the congested airports to those aircraft operators whose use of the facility offers the highest "social benefits". Unfortunately, underlying such lofty statements there are two difficult questions to be addressed, namely, "what is the optimum level of delay/congestion?" and "how does one identify the flights that offer the highest social benefits?" While the presence of a market economy provides considerable assistance in answering these questions at the theoretical level, implementation of a successful slot-allocation system is made difficult by a number of complicating factors, as will be seen later in this report.

It is appropriate to classify approaches to the slot-allocation problem into two broad categories and several sub-categories:

1. Administrative Approaches
   - a) Historically-based (or "current-use-based") allocation
   - b) Allocation on the basis of optimization
   - c) Allocation by lottery
   - d) Scheduling committees

2. Economic Approaches
   - a) Time-dependent user charges
   - b) Auctions

As suggested by this classification scheme, the main distinguishing feature that we could identify in comparing alternative approaches is whether or not an economic mechanism is explicitly used in the allocation process.

The rest of this report is organized as follows: Section 2 summarizes the disadvantages of the "do nothing" strategy concerning slot allocation. Section 3 covers the administrative slot-allocation approaches and Section 4 the economic approaches. Section 5 presents a review of several important questions in this area which are yet unresolved. Finally, Section 6 presents a quite-thorough annotated bibliography of the existing literature.

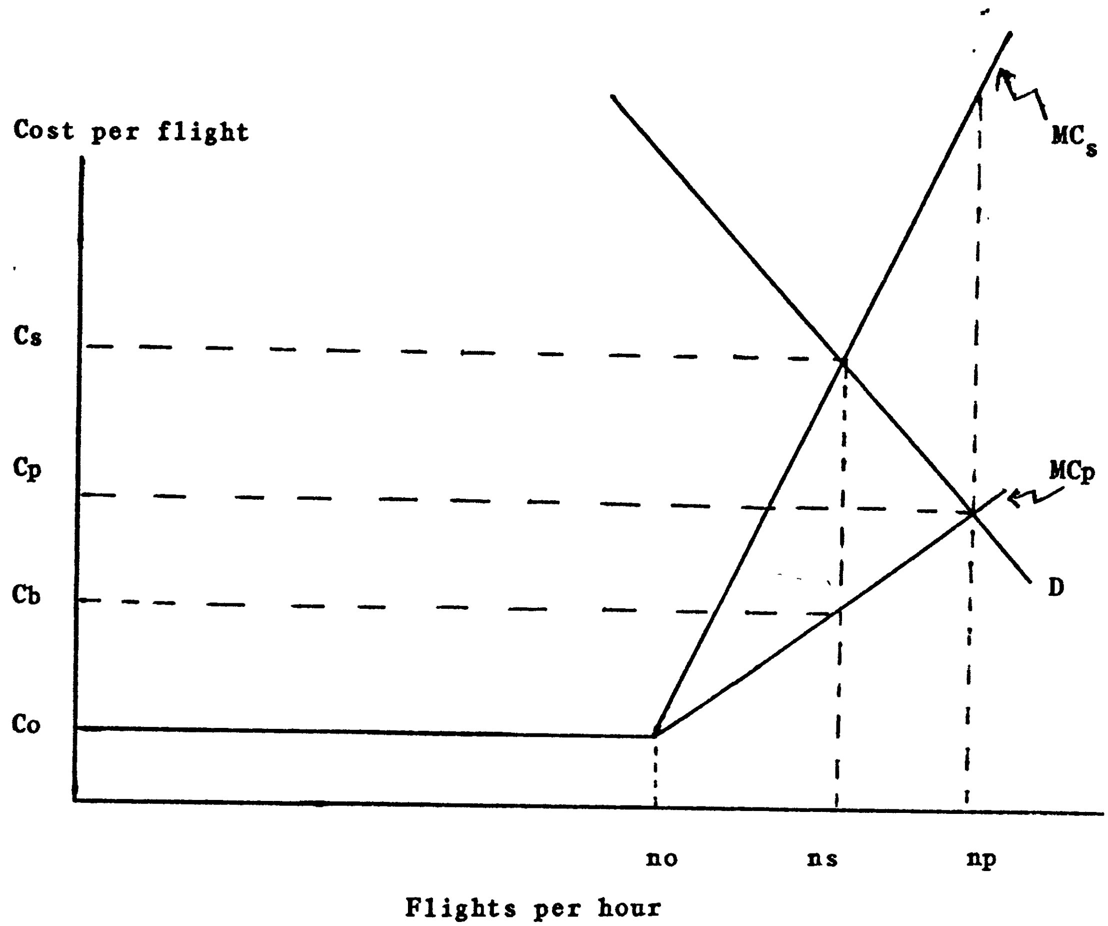
2.The Adverse Effects of "Doing Nothing"

Access to airside facilities of commercial airports has traditionally been provided without restrictions on a first-come, first-served basis. Airport users, to gain such access, have to pay a landing fee which, as a rule, is determined on an average-cost basis: that part of total airport costs which is allocated to airside facilities and operations is divided among airside users, with each user usually being charged an amount directly proportional to the (maximum landing or take-off) weight of that user's aircraft.

If unrestricted access (with a charge based on average cost) continues to be offered after an airport becomes severely congested, then delay becomes the instrument for bringing about a balance between supply of capacity and airport demand. Under this "do nothing" policy, those users who find the delays unacceptable will not use the airport in question: those for whom the benefits derived from access to the airport exceed the costs of delay will continue using the airport. Unfortunately, this will not necessarily lead to an efficient allocation of available resources and, in fact, the delays associated with this type of "equilibration process" will be excessive.

This last point has been discussed and explained thoroughly in the available literature.1 While the technical arguments will not be repeated here (see, however, Figure 1), the fundamental underlying reason for the excessive delays is that, under "do nothing", no mechanism exists through which external delay costs can be internalized. This means that users perceive only the cost of their own delay and not the costs that their use of the airport imposes on others. For example, suppose airline A decides to schedule the arrival of a flight X during the already-congested 5-6 p.m.

Airport Demand Model



MC_s = marginal social cost

MC_p = marginal private cost

D = demand for flights

n_o = number of flights, below which there is no congestion

ns = number of flights at which marginal social cost equals demand

n_p = number of flights at which marginal private cost equals demand

Co = cost associated with No flights

C_s = social cost associated with ns

Cp = cost associated with np flights

C_b = private cost associated with ns flights period at a particular airport. Assume that, after the scheduling of flight X, the expected delay per landing aircraft between 5 and 6 p.m. increases to 20 minutes. Thus, flight X (and airline A) will sustain — and pay the cost of — a delay of 20 minutes. However, flight X will preclude any other flight from using the runway for an amount of time equal to the duration of one landing "slot" and this will "push back" in time all the other operations which follow flight X on the same runway during the same runway "busy period", i.e., period of continuous runway use. For instance, if the duration of the "slot" is 1.5 minutes and if 30 aircraft operations are pushed back as a result, flight X causes 45 minutes of delay to the other aircraft. The cost of these 45 minutes of delay is the "external cost" imposed by flight X on other aircraft.

Interestingly, in addition to resulting in excessive delays, the "do nothing" strategy has two other perverse effects. First, and most important, by relying on internal costs to bring about a balance between capacity and demand, it penalizes the "high-value-of-time" users and encourages "low-value-of-time" users to seek access to the congested facility. Second, with landing fees estimated on the basis of average cost, as the number of users of the congested airport increases, the landing fee decreases -- thus inviting more users and more congestion.

In summary, a "do nothing" policy encourages users with low costs per unit of time to use congested airport facilities. Some (or many) of these users probably would not choose to use these facilities if they also had to pay for the marginal costs they impose on others.

Several analyses to date2 have estimated these "marginal costs to others" as very large (well in excess of $1,000 and several times larger than the typical landing fees charged) at major commercial airports in the United

States during peak hours. After all, at typical direct costs of $25-$60 per aircraft minute, it only takes 16-40 minutes of marginal delay increase to all other users combined for a cost of $1,000 to be incurred.

Notes for Section 2

1. For two seminal early papers on the subject, see Steiner, Peter, "Peak Loads and Efficient Pricing", Quarterly Journal of Economics, 71 (1957), and Vickrey, William, "Optimization of Traffic and Facilities", Journal of Transport Economics and Policy, 1 (1967). For an excellent early treatment of the airport problem, see Levine, M.E., "Landing Fees and the Airport Congestion Problem", Journal of Law and Economics, 12, (1969).

2. See, for example, Chapter 4 in Odoni, A.R. and J.F., Vittek, Airport Quotas and Peak Hour Pricing: Theory and Practice, Report FAA-AVP-77-5, U.S. Dept. of Transportation, May 1976.

3. Administrative Approaches

3.1.1 An Allocation Procedure Based on Current Use

Allocating slots on the basis of current use is a form of administrative assignment which has been modeled in a detailed manner. The procedure described here, formulated by Kenneth Geisinger for the FAA, consists of two steps: (a) allocating a total quota for a typical day to each airline, and (b) assigning slots by hour to each airline.

For each congested airport the airlines would be called upon to submit initial slot requests for each hour of each day to government administrators. These submissions would be tabulated and returned to the airlines, with the tabulations showing exactly where and when requests hourly exceed quotas. Some airlines might wish, at this point, to voluntarily reduce the number of slots requested in order to eliminate conflict, and a second submission and tabulation would provide the opportunity for them to do so. If resolution (the number of slots desired does not exceed the quota in any hour) is not reached through a second tabulation, an administered allocation would be required as described below.

For each airport under this method of slot allocation, airlines would submit: a list of slots currently used at that airport, the current average number of passengers per operation during the quota period, and a list of airports for which they currently provide non-stop service to or from the airport in question. In the case of more than one airport requiring such allocation, the airport whose problem is the most severe will be considered first. Airports will be considered subsequently in order of decreasing severity. Severity is defined by the number of hours in which slot requests exceed the quota. After each airport's allocation is resolved, airlines will be informed of their assignments and given the opportunity to revise submissions for the next airport under consideration, in order to accommodate necessary schedule changes.

Allocation of slots is based upon three factors. The first is the current allocation. Using this as a basis recognizes the investment the airlines have made in developing existing markets and helps to prevent wholesale changes in schedules.

The second factor is passenger-service provided, per slot, in the current allocation. This is defined in the "Geisinger model" as the number of passenger explaned or deplaned per aircraft movement. There are several advantages to using this factor, such as: (1) it promotes efficient use of slots, (2) the necessary data is easily obtainable. (3) it is based on demonstrated passenger preference, (4) the operations with higher number of passengers tend to be more profitable for airlines (note, however, that profitability increases with stage length, while the number of passengers served may not), (5) it fosters competition among airlines.

The third factor for consideration is the number of cities served in the current allocation. The passenger-service measure, if used alone, would favor large-capacity aircraft on dense markets at the expense of less-dense markets, e.g. smaller communities. In order to make this "breadth of service" measure an easy one to compute, it is defined as follows: the number of locations served by the airline is divided by the number of slots in its current schedule, and only non-stop service to or from the airport in question is considered. Each different airport served is counted as a different location, and if more than one airline serves a particular location, each airline is given credit for serving that airport.

These three factors are combined into one formula, along with "weight factors" which must be set in order to obtain a balance among these three somewhat-conflicting goals. The values of the weight factors obviously reflect the preferences of the decision-maker(s). A simplified example of an allocation formula based on these three factors might be:

Example

$$Z_i = N \cdot \left[R \left(\frac{C_i}{C} \right) + P \left(\frac{e_i}{E} \right) + Q \left(\frac{h_i}{H} \right) \right]$$

where

Z_i = number of slots airline i is entitled to during a day

N = number of slots to be awarded per day

C_i = number of slots currently held by airline i during a day

e_i = number of passengers currently served by airline i during a day

h_i = number of locations (airports) served by airline i

C, E, H = total number of slots, passengers and locations served,
= respectively

R, P, Q = non-negative constants specified by administrator
= (R + P + Q = 1)

If all airlines were to serve the same number of passengers and locations per slot, use of the above formula would result in an allocation exactly the same as the current allocation. In any case, each airline will receive at least R times its current allocation. In general, actual assignments would generally fall somewhere between these two extremes.

3.1.2 Assignment Procedures

After each airline has received its quota for the day, the assignment of these operations to particular hours of the day will follow. The assignments by hour are subject to the dual constraints of the total airport quota for that hour and the total quota for the day for each airline. Practically, this scheduling process must consider actual airline schedules with their attendant conflicts and restrictions: crew schedules, gate availability, passenger demand, equipment availability, etc. As it is, obviously, impossible to account for all of these factors for each airline without the help of the airlines themselves, the procedure requires that each airline present a number of slot plans to authorities, with the relative desirability of each plan indicated. All possible combinations of these plans would then be examined in order to find a set of plans that both meets quota requirements and is acceptable to all concerned. If no such set of plans can be found, more alternatives must be submitted.

Once resolution has been achieved, there may be hours during which slots are still available. Some airlines may also find that they cannot use all of the slots assigned to them. All of these openings can be placed into a new slot "pool" and then assigned to airlines requesting them, with priority given to airlines that were the least successful in originally obtaining their preferences.

A further element of the procedure is that special arrangements will be required for certain kinds of service. New entrants to a market, for example, will not have a previous history of service upon which to base allocation. A pool of exempted slots, therefore, will be necessary, and new entrants will be awarded four of these positions, initially. The new entrant will acquire the status of incumbent only after one "base" period (the time period upon which current allocation is based) has been completed.

A special guarantee of slots may be required for other types of airlines, as well. A notable one is that of foreign flag carriers that may be able to claim slots on the basis of bilateral agreements. Again, assignments will be made from a pool of special, exempted slots. Geisinger has suggested that these exemptions not be considered as part of an airline's slot-base in future rounds of assignments. This raises the question of whether foreign carriers will participate in administrative allocations on an equal basis as domestic airlines and whether bilateral agreements will allow for this.

The actual allocation procedure would be more complicated than described here, both because some airlines will request fewer slots than they are entitled to, and because some exempted slots (such as those for new entrants) are not shown in the formula. The advantages claimed for this procedure are:

(1) it could easily replace scheduling committees, where such committees are currently in use,

(2) its objective is improvement of service, in terms of both numbers of passengers served and numbers of locations served,

(3) it will avoid disruptions in service and will produce gradual changes in slot allocation,

(4) airlines are directly involved in hourly slot assignment, and their scheduling constraints can be made clear throughout the process.

Problems do exist with this model, however. Among them are:

(1) the weighting factors in the formula, R, P, and Q, are yet to be determined,

(2) the number of alternative slot plans submitted by airlines could turn out to be very large, and acceptance criteria for these plans are not spelled out,

(3) there is no procedure outlined for the case in which all submitted

slot plans fail to yield resolution.

(4) there is no method given for detecting and preventing "cheating", e.g., one airline requesting unwanted slots in order to prevent another carrier from winning them.

3.2 "Optimization" Basis

Some attempts have been made to develop optimum allocations on the basis of maximizing some type of social-welfare function, subject to a number of constraints. Linear programming and other techniques of mathematical modeling are used in this case. Such a model was developed for the FAA by J. Watson Noah, Inc., in 1980.[4]

Given a table of airline slot requests, this model produces a solution which claims to maximize overall profits for the airlines involved. Profit maximization is performed subject to a series of constraints, and the model can be used to allocate time-slots on a daily or an hourly basis.

The objective function is based upon average profit per operation and can be expressed in terms of profit per flight hour or profit per mile. In either case, it consists of passenger revenue less operating costs:

$$\sum_{n=1}^{ops} \frac{1}{n} \left(PAX_n \cdot FARE_n - DIST_n \cdot COST/MILE \right)$$

Because the theoretical basis for the model is that allocation of a scarce resource among potential users should be performed so as to maximize social benefits, "socially desirable" constraints are introduced into the maximization-of-profits function. Among several specific constraints proposed are:

(1) Capacity — In a daily allocation, the total number of slots assigned is constrained by the number of operations allowed over the day (or by hour) at a given airport.

(2) Noise — This constraint is designed to ensure that the allocation of slots does not increase noise exposure at an airport.

(3) Equity — In this model, equity is defined as the assurance of two things: that each airline continues to hold a specific (arbitrarily-determined) percentage of operations at the airport, and that new entrants are awarded a minimal number of slots. This constraint will allow, over a period of time, successive reductions in slots for a truly-inefficient airline, but it tends to prevent drastic scheduling revisions in the short run.

(4) Public Service — Specific operations may be considered to offer a public service or a necessary service, and slots would be awarded for these operations, not necessarily on a profitability basis. A commuter flight (or other flights to small communities), may be one typical type of candidate for these slots. International carriers with bilateral agreement rights may be another.

The model outlined above was designed to be operative with only the information presently available to Airline Scheduling Committees: a slate of slot requests, by hour, from each airline. It was recognized that the initial allocation would result in subsequent shifting of slot requests from one time period to another, and some approaches to this problem were suggested.

One mechanism would allow a slot to be considered in an adjacent time period as well as the originally-requested one. This method might prove to be mathematically cumbersome, however, because of the great increase in the number of variables required. Another approach would be the upward adjustment of slot assignments in time periods in which requests are fewer than the maximum allowed. Because this method can result in network-wide scheduling disruptions, its use must be based upon knowledge of the airlines' individual scheduling patterns.

After testing this model, the authors of the cited document suggested that it has considerable usefulness for analyzing policy alternatives on critical markets, as a wide variety of socially-desirable constraints can be applied and tested. They feel the model may be better suited for this than for use in actual allocation, because, like any abstract model, it contains biases and simplifying assumptions.[5]

In addition, they raised the following issues:

(1) Because the model uses historical averages to determine slot values, new entrants are hampered by the lack of such historical data, and current slot holders who maintain reasonable load factors can become entrenched,

(2) When maximization of profit, enplaned passengers, or passenger-miles performed, is the basis for the objective function, commuter airlines (consisting of smaller, short-haul aircraft) cannot compete with large air carriers. Without a public-service constraint, therefore, commuters would be allocated slots only when excess capacity existed,

(3) There are currently no energy constraints formulated for the model and these may prove to be highly desirable in the future,

(4) "Equity" has been defined as a guarantee of a minimum number of slots per airline. A maximum-number-of-slots constraint has also been suggested. "Equity", then, must be clearly and specifically defined — a possible source of disagreements among participants.

As a final observation on this type of approach, we feel it is necessary to note that it would seem extremely difficult in practice to establish consensus on the proper objective function and constraints, to formulate a realistic version of the problem and to obtain the necessary data for running such a version.

3.3 Allocation by Lottery

A lottery would award a slot (or slots) by random selection among participant airlines holding lots or "chances". In order to use a lottery to award slots, certain issues would have to be settled first. Among them are:

- eligibility for participation,
- the assignment of probabilities to each given carrier for winning a given slot,
- what type of operation would actually be awarded by the lottery (e.g., arrival/departure pairs, specific time-slots, any slot within a given time interval, etc.),
- by what method the chances would be allocated among airlines.

The principal merit of a lottery system seems to be that it seemingly absolves the system's administrator from the responsibility of making the final allocation decisions. This does not actually avoid arbitrary decisions, however, because it becomes necessary to allocate "chances" to each slot requestor, in some way.

One of the main drawbacks of lottery allocation is that the element of uncertainty means there will be no assurance of efficient use of runway capacity or that the most competitive airline will win a slot. In fact, allocation by lottery is probably an inferior approach to other administrative allocation methods.6

3.4 Scheduling Committees

Two systems for allocating airport capacity by means of airline scheduling committees are currently in existence. One is used internationally and is run by IATA, another was developed in the United States to allocate slots at O'Hare, Kennedy, Washington National, and LaGuardia Airports. In the U.S., the committees at these airports have been operating under anti-trust immunity for fifteen years. However, ever since the Airline Deregulation Act came into existence, the Justice Department has unambiguously expressed the desire to allow market mechanisms to play a stronger role in slot allocation. The future of such anti-trust immunity, is, therefore, uncertain. Of all the administrative procedures for allocation of space at congested airports, however, committees represent the only procedure which has a long history of use and, it must be added, with some demonstrated success.

3.4.1 U.S. Scheduling Committees

In June, 1969, the FAA adopted its "High Density Traffic Rule" which restricted the numbers of IFR runway movements (imposed "quota") at the four U.S. airports mentioned above. The quota were allocated among scheduled air carriers, air taxis, and general aviation.

The general aviation quota are allocated on a first-come, first-served reservation basis. Reservations are made with the FAA's Advance Reservation Office no earlier than 48 hours in advance. Air taxis use a committee system for allocating their quota. Air taxis are effectively given property rights to slots, in that they may keep slots from one season to the next, as long as they use them. In this latter case, the most important criterion for allocating slots which are open is the length of time an air taxi's operator has been waiting for them.

A committee system is also used for the allocation of air carrier slots, but this system operates quite differently from that for air taxis. A separate air carrier committee operates for each airport with slot quota. It is made up of representatives of each of the user airlines. Foreign carriers also participate in the committees. Each committee meets twice a year to formulate the schedule for the upcoming winter or summer season. A "slot" is defined as one operation in a specified hour, and it pertains solely to runway use. Carriers do not have future rights to any slot awarded them at any meeting, and reasons for the need of a slot are not permitted to be discussed. In addition, discussion of origin-destination pairs is not allowed to be used as a basis for awarding a slot. Unanimous agreement of an airport's scheduling committee is required for approval of a set of schedules that satisfies the quota.

Requests for slots are submitted prior to each meeting to the Air Transport Association's Airline Reservation Center. These requests, along with the total slots requested per hour, are made public at the time of the meeting. Revisions to this listing are made as the meeting progresses.

Experience has shown that the main source of disagreement is over the total number of slots to be allocated to each carrier, rather than about slots assigned at particular hours. The committees, therefore, first decide the total number of slots to be assigned to each carrier, and then make hourly and daily adjustments for the most sought-after times. Private negotiations between carriers over these adjustments is officially prohibited, but seems to take place nonetheless to a limited extent.

Although both the level of quota and the method of allocation have been criticized by member air carriers, until recently failures to reach agreement have been rare. The consequences of consistent and continuing failure to reach agreement are not well-understood, and this is probably a contributing factor to the committees' history of "success" (and motivation) in reaching consensus.

Other criticisms of the procedure coming from the air carriers include objections to the seemingly-arbitrary determination of the number of slots to be allocated to air taxis and general aviation. Moreover, quota apply equally to all types of air carrier aircraft and runway operations, even though different mixes of operations can result in significantly-different airport capacities and levels of delay. Yet another problem is the difficulties faced by carriers operating between slot-controlled airports. This method of allocation, therefore, is far from receiving the unanimous approval and support of those involved.

3.4.2 IATA Scheduling Committees

At airports utilizing IATA scheduling committees, airport authorities review and possibly change existing quota twice a year. Quota may apply to terminals, gates, or runways, and may be in effect during all hours or only during peak times. All changes are then reported to the IATA Technical Department which, in turn, informs the schedule coordinators -- one from each participating airport. The coordinators, who usually come from the flag-carrying airline at their respective airports, are responsible for ensuring that schedules adopted by the carriers operating at that airport conform with established quota.

Most schedule changes are then made at the twice-yearly IATA Timetables Coordination Meeting. The coordinator sets up initial assignments, based upon carrier schedules and prescribed quota, prior to the meeting. Guidance is provided by a list of priorities, the highest of which is historical precedence: a carrier has rights to a time slot in all years subsequent to receiving it, unless it is not used. Remaining priorities deal with the financial consequences to carriers not receiving the slots they have requested: the carrier which, it is deemed, would be most financially-disadvantaged by not winning a contested slot is awarded the slot.

Carriers exchange tentative timetables just before the scheduling meeting, and the meeting is then used to "horsetrade" and resolve conflicts. Tentative timetables are collected twice daily, during this period, and made available to all carriers. Once issued, a slot cannot be taken back by a coordinator and bartering for slots is done primarily by carriers in informal meetings. Once the coordinator has the final set of schedules, a summary document is prepared. It indicates remaining capacity, if any, as well as those slots assigned and agreed upon. Finally, within about two months of the close of the meeting, there is a complete specification and exchange of final schedules. If any subsequent changes or problems arise, either the schedule coordinator or the airport authority deals with them.

3.4.3 Comments on Scheduling Committees

The principal weakness of both committee systems is that no guarantee exists that slots will be allocated to those carriers that place the highest value on them. The admission of new entrants may also be inhibited by such committees. The IATA system can also be criticized for being most reliant on the status quo and allowing the possibility of anti-competitive agreements. On the other hand, by assigning slots on the basis of their perceived value to carriers and by allowing the one-to-one exchange of slots, the IATA system purports to better approximate a market system. It also offers more flexibility by allowing carriers to negotiate for slots at different airports at the same time.[7]

A claim which should be noted in evaluating the U.S. Scheduling Committees was made in connection with the testing of the J. Watson Noah linear programming model:

> "This research does not seem to validate the contention that the Scheduling Committee is anti-competitive and develops inefficient solutions. Since deregulation, at least 10 new entrants have been accommodated (at Washington National) in the air carrier allocation process....Profits for the Committee allocations were only 6 to 8 per cent less than the model's solution hardly a difference large enough to be deemed inefficient"8

In general, arguments in favor of the Scheduling Committees are:

(1) they work (most of the time),

(2) new entrants have been able to obtain slots from the air carrier committees,

(3) their legality has never been challenged in court by any carrier,

(4) the results of a committee working session have never been challenged,

(5) there have never been allegations of impropriety in their operation.9

3.5 Conclusion

In summary, administrative allocation can be structured to ensure service to small communities, to allocate slots in order to bring about reasonably-efficient use, and to be equitable within constraints. However, this form of allocation may be complicated and costly to implement and administer. Further, the economic value of a slot to users often is not fully considered when the slot is allocated, and there is no adequate mechanism for determining whether another potential user would derive more value from the slot indefinitely. Purely—administrative measures, then, are effective (in the sense of expediency) in the short term, but tend to be biased toward the status quo in the long term.

Notes for Section 4

1. FAA Notice of Proposed Rulemaking, "Special Air Traffic Rules and Airport Traffic Patterns," 4910-12, February 1980, p. 15.
2. Rodgers, John, "Issue Paper: Allocation of Runway Capacity, Washington National Airport," FAA Office of Aviation Policy, Octoer 22, 1979, p. 24.
3. Geisinger, Kenneth, "A Method for Administrative Assignment of Runway Slots," FAA-AVP-80-5, Office of Aviation Policy, June 1980, pp. 1-4.
4. Day, C.F. and White, J.M., "A Slot Allocation Model for High Density Airports," for J. Watson Noah, Inc., FAA-APO-80-13, Office of Aviation Policy, August 1980.
5. Ibid., p. 54.
6. John Rodgers, op. cit., pp. 12, 13.
7. Descriptions of Scheduling Committee Operations are based upon Swoveland, Cary, "Airport Peaking and Congestion: A Policy Discussion Paper," for Quantalytics, Inc., August 1980, pp. 2-14 through 1-31.
8. C.F. Day and J.M. White, op. cit., p. 57.
9. FAA Notice of Proposed Rulemaking, "Metropolitan Washington Airports," January 1980.

4. Economic Approaches

4.1 Time-Dependent Charges (Peak-Hour Surcharges)

The four main reasons for imposing peak-hour surcharges are: (1) to reduce peak-hour airport usage, (2) to discourage lower-valued users in favor of higher-valued ones: (3) to postpone the need for additional facilities, and (4) to provide information on the value of new capacity in order to determine when new facilities should be built. Three approaches have been suggested for calculating surcharges. These are: setting them at equilibrium marginal-delay costs, determining target levels of airport usage, and setting surcharges to bring traffic to this level, setting charges arbitrarily, at relatively-low levels.1

The first approach would require calculating the marginal delay costs, which are the total congestion costs that one additional runway operation imposes on subsequent users. Each additional user causes added delay to all subsequent users which is equal to the service time of that additional operation.

Although models exist to estimate marginal-delay costs, it is highly unlikely that setting surcharges equal to marginal-delay costs under any given status quo will lead to equilibrium. A fee equal to current marginal costs would cause some operations to shift to non-peak times, and this would reduce delays and the marginal cost of delays. The previously-set fees would then be too high. Fees would have to be readjusted, and some operations would return to the peak hour. Then fees would, yet again, have to be readjusted.2

This continuing process would be the result of setting surcharges at current marginal cost, unless there is some means of computing exact equilibrium prices at the outset. There is no such method, partly because the price elasticities of airport demand are not known. Furthermore, none of the mathematical models, to date, for computing marginal-delay costs considers demand elasticity, even theoretically.3

A second method of calculating surcharges would be to set a target level of usage for the airport, and attempt to impose sufficiently-high charges at peak hours as to bring demand to this preset level. The model required for this would be similar to one for calculating marginal-delay costs. This approach, however, requires less information in order to be implemented. it, therefore, lends itself to a trial-and-error process of determination to a much greater extent than do marginal-delay costs.

The third method of setting surcharges at a low and arbitrary level has been tried, on a limited basis, in both New York (as mentioned earlier) and at London's Heathrow. One method that has been proposed for calculating the charges is to set them equal to a proportion of marginal-delay costs.4 This is just as arbitrary, however, as less-complicated methods. In any case, if not sufficiently large, charges will have little effect on major carriers which are faced with inflexible and complex schedules. It has been concluded, however, that even modest peak-period surcharges will discourage low-valued flights, such as general aviation flights.5

Instituting peak-hour surcharges may significantly change airport user fees. Current U.S. landing fees are based on aircraft weight and are non-variable throughout the day. Surcharges large enough to influence peak-hour demand could generate large amounts of revenue. It has been estimated, in fact, that if full marginal-delay costs could be charged, runway use charges might be six to eight times greater than presently.6

The question has been raised whether surcharges, if instituted, should be levied against airlines or directly against passengers. If a congestion charge is imposed on a flight rather than on passengers, the cost of operating the flight increases, and airlines will increase prices to offset this cost. Under a regulated system, however, fares are not easily increased, therefore, the airline will attempt to increase revenues by flying with higher load factors. Because prices do not change, passenger demand does not change, and the results is fewer, more fully-loaded flights. Thus, the trend is to greater efficiency and less congestion.

If the passengers are directly assessed a congestion charge, the perceived cost of flying will increase and demand will fall. Delay will also decrease, because with lower demand a reduced need for flights will exist. The airline's operations costs per flight will not change, however, and they will fly at the same inefficient, breakeven load factors. Assessing passengers in a regulated environment, then, leads to an inefficient solution.[7]

When fares are not regulated, it is speculated that surcharges will be passed on to passengers, in any case. If, however, the charges were levied directly against the passengers, administrative confusion would result, caused by airlines having to collect the charges from passengers and account for them.[8] The consensus, then, is that surcharges should be levied on aircraft movements, especially in environments in which fares are regulated.

Notes for Section 4.1

1. Swoveland, Cary, "Airport Peaking and Congestion: A Policy Discussion Paper," Quantalytics, Inc., prepared for Canadian Air Transportation Association, (Vancouver: August, 1980), pp. 3-10 and 3-14.
2. Odoni, Amedeo and Vittek, Joseph, "Airport Quotas and Peak Hour Pricing: Theory and Practice," Federal Aviation Administration, FAA-AVP-77-5, (Washington, D.C.: May 1976), pp. 39, 30.
3. *Ibid*.
4. Swoveland, *op. cit*., p. 3-20.
5. *Ibid*., p. 2-32.
6. *Ibid*., p. 3-23.
7. Odoni and Vittek, *op. cit*., pp. 18-19.
8. Swoveland, *op. cit*., pp. 3-12 and 3-13.

4.2 Slot Auctions

Among the numerous methods through which slots could be allocated to airport users, auctions have received a great deal of attention from the FAA and the CAB. Polinomics Research Laboratories prepared a report for the FAA and the CAB jointly, in 1979, recommending an auction procedure. In 1979 and 1980, Econ, Inc. performed a study for the FAA testing a proposed auction procedure. If the demand for slots exceeds the number available, and the guiding principle behind allocation is that slots should go to those who value them most, then an auction of some sort suggests itself as the logical solution. Governmental officials have also expressed a desire to see market mechanisms play a larger role in slot assignment procedures. For these reasons, auctions have been extensively examined by aviation administrators. The problem is to formulate a procedure which is simple to administer and will result in an economically-efficient allocation of slots.

Auctions can be structured in many different ways. Among those which have been examined are:

Progressive Auction — Slots are auctioned individually, with each sold to the highest bidder.

Dutch Auction — The auctioneer announces an initial (high) asking price for a particular group of slots, and each carrier secretly bids for the number it is willing to buy at this price. The asking price is gradually lowered at each round until all the slots in the group are sold. The amount paid could be the amount actually bid or the selling price of the last slot sold.

Sealed-Bid Auction - Carriers submit sealed bids for the desired number of slots in a particular time period. Carriers are allowed to make multiple bids of varying amounts. Slots are sold to the highest bidders at the price bid or at the price of the lowest successful bid (called a "one-price" sealed-bid auction). All slots in a time period are auctioned simultaneously.

Trading-Post Auction -- This is identical to the sealed-bid method, except that the auctioneer can reject all bids. In this case, all bids are made public and a new round is called for. The auctioneer determines when the variation of bids is sufficiently small from one round to the next and at that point declares the auction over. Alternatively, the auctioneer can announce that the next round is the last, at any point. Sealed bid auction rules then apply.

In formulating an auction allocation procedure, it is necessary to consider the effects of certain characteristics of slots. Theoretically, the economic advantage to auctions is that carriers which place the highest value on certain slots will bid more for them, and the slots will then be used for the most-highly-valued operations. A faulty assumption contained in this argument, however, is that the value of slots is additive: that two slots, each worth, for example, $10,000 to a carrier, will be worth $20,000 together. If both are early-morning slots, however, and the carrier needs only one early-morning slot, the two together are only worth $10,000, while the second may be worth $10,000 to another carrier.

To take this example further, the carrier may decide that its best strategy, in order to be sure of winning an early-morning slot, is to bid $7,000 for each of the two. It may, thus, end up buying two slots for $14,000, one of which is valued at $10,000 and the other at zero. Alternatively, it may end up with no slots, while carriers who value these two at only $8,000 (and bid that amount) are awarded them.[1]

It must also be remembered that slots come in pairs: landings and takeoffs. A slot for landing at a cost of $10,000 is worthless without a corresponding slot for takeoff at a desirable time for that flight. A slot at one airport may also be useless if a corresponding slot at another airport cannot be won. In short, very strong inter-dependencies exist between individual bids for individual slots. Because of this, airlines would want to revise bids and modify sought-after allocations after any given round of bidding. Over a sequence of rounds, airlines will learn how much they must bid for particular slots, and they will also have a chance to coordinate across hours and airports.

In 1979 and 1980, Econ, Inc., in conjunction with Flight Transportation Associates, conducted a study for the Office of Aviation Policy evaluating certain methods of slot allocation, including an auction procedure, which they had formulated, called the Slot Exchange Auction.

The basic mechanism was to hold a sequence of auctions bidding for the right to make a choice among all remaining open slots. Auctions would continue until all slots were sold or no one wished to bid further. The reason behind this procedure was recognition of the fact that the preference of a user for a slot in one period is strongly dependent upon that user's ability to obtain slots in other periods. If auctions are held by selling off particular time periods, the sequencing of the time periods will have an effect on the outcomes. This approach, on the other hand, permitted continuous adaptation by the participants to the current situation. A problem with the method, however, was that it would require many rounds and would cause bidding for slots in time periods in which demand was less than capacity.

To improve the mechanism for pricing, a sealed-bid procedure was suggested. Each participant would submit a sealed bid for slots in each arbitrarily-determined time-period of the day. In order to be sure that true preferences were submitted, each bid would be accompanied by a fixed fee which was later treated as an advance payment and forfeited by those who won slots and did not use them. The requests would then be tallied and those in time periods with excess slot capacity were immediately awarded. The others would be rejected and the remaining capacity posted. The first auction would then be held to obtain the right of making the first choice for a slot. The winner would choose and the procedure would be repeated.(2)

To test this procedure by simulation, the study used the Airline Management Game (AMG). AMG, developed at MIT's Flight Transportation Laboratory, is a combination "game" and computer simulation in which the players make realistic airline-management decisions. These decisions are fed into a computer along with CAB air traffic data, airline operations cost parameters, and air transportation block times and distances. The computer allocates passenger demand among the competing carrier services offered by the players. It also provides profit-and-loss statements, balance sheets, schedules, route networks and operating statistics for the game participants. Players evaluate their performance, based upon this output and revise their decisions. After several iterations, the results can be regarded as final.

In December, 1979 the AMG was used in a trial exercise to test the usefulness of the game in evaluating the effects of slot allocation by auction. Members of the FAA, the staff of Econ, Inc., and Flight Transportation Associates participated in the exercise over five days at MIT. This trial exercise resulted in much fine tuning of both the game and the Slot Exchange Auction proposal. Among other problems discovered at this time was a clear need to have more rounds of bidding than the four of this trial run in order to bring the market into equilibrium.(3)

The trial run was followed by a simulation exercise in Washington, DC, in February, 1980. Management and professional staff from the airlines were invited to participate, and included representatives from Delta, Piedmont, Eastern, US Air, United, Braniff, American, and TWA. The purposes of the exercise were:

1. to test two slot allocation mechanisms: the proposed Slot Exchange Auction and the FAA Administrative Allocation,
2. to obtain from the airlines reactions to the two methods.
3. to obtain rough estimates of the economic and service effects of slot rationing.

In the game, each player-airline was represented by a team whose goal it was to schedule its flights so as to maximize short-run profits with a fixed fleet of aircraft. Each iteration simulated a six-month period of operations. The market strategies that were available consisted of changes in schedules and flights. Deregulation was assumed. The computerized traffic allocation process then determined levels of through and connecting passenger traffic on each segment of each flight. The allocation process was sensitive to differences in fares, differences in departure time and flight times (including necessary connections), as well as the effects of high load factors.

The scenario consisted of seventeen airports grouped into four classes:

(1) Four major hubs which handled about half of the total network's activity. Three of these were capacity-restricted with participants competing for slots.

(2) Six intermediate airports which interacted considerably with one another as well as with the four major hubs.

(3) Six minor airports which had significant traffic with the aforementioned ten, but none with one another.

(4) One single airport which represented a special long-haul case. There was traffic between this airport and the first two of the major hubs, but none with any other airport.

A system map was provided.

Five "airlines" competed in this network, each of which had a historical pattern of service established for it. Each airline owned between six and sixteen aircraft (DC9's, 727's and 707's). A large amount of learning of game procedures and sifting through of scenario data was required of the schedulers. Fares for all airlines were limited to a base of $23.40 plus ten cents per nautical mile.4

The exercise showed that it was possible to operate profitably in the simulated slot-restricted environment. Results also indicated that the Slot Exchange Auction could be used by the teams to acquire a valuable set of slots. The third significant result was that some teams made even better profits in a slot-restricted environment than before, while others gave up profits to slot payments. The improvement of profitability over successive rounds was probably due to a learning effect. Again, it was found that many more rounds would have been necessary to see if market equilibrium could have been reached. Slot awards demonstrated a tendency to convergence, but price convergence was slow to take place and did not occur during the number of iterations conducted.

The test was found to be inconclusive in regard to both convergence to equilibrium and economic efficiency of the method. Recommendations were made for further testing after improvements of the model. The improvements suggested included several made by the participants in the test, others were based upon observations of participants' game-playing behavior. The exercise, then, proved to be a useful test of the AMG, but not of the model's applicability to the real world.5

The Econ study is just one example of attempts to estimate what the actual results of an auction allocation procedure would be. Not enough research has been done on multi-objective auctions to make it possible to predict their outcomes, but some consensus on auctioning for slots has emerged. For example, it is not understood what bidding-strategy carriers would use, but since slot values are not additive, carriers would probably employ highly-complex strategies, which would result in some slots not going to their highest-value users, and in some carriers paying more for slots than the actual value these carriers place on these slots. Types of auctions that allow some adjustment in bids would, therefore, seem to be more promising than one-round auctions.6 Sequences of bidding rounds would provide more opportunity for the market to clear and an equilibrium to establish itself.

These considerations also point to a generally-recognized need for some sort of post-auction market for trading of slots among the various carriers. An airline cannot be certain of how highly it values a particular slot without knowing its total slot allocation over all time intervals. Further, in the time period between slot auctions, changes in the economic environment might cause airlines to seek to change their slot holdings. Another problem whch can be solved by trading in an after-market is that slots are indivisible. Therefore, for example, an airline may bid for two slots at $50.00 each, but receive only one for $50.00 because there have been thirty-five bids of more than $50.00, but the quota is thirty-six slots.

The key features of an after-market should be administrative flexibility in approving private slot exchange transactions, and a resale procedure for unwanted slots that will not allow for profits, and, therefore, encourage speculation during the primary slot auction. The Econ study briefly described an example of such an after-market.

The simulation also suggested that offers should be communicated to the airport authority and posted without indicating who the bidders are. Those holding the desired slots could then choose to dispose of them through the airport authority. They would receive either the offered price or the price they originally paid, whichever was smaller. The airport would receive any excess.[7] A further advantage to allowing slots to be bought and sold for cash is that the selling prices would indicate the value of additional airport capacity, and could contribute to decisions on when to build additional facilities.

It also seems clear that a slot auction must allow airlines to bid on all peak hours at all airports simultaneously. Because the value of any slot depends upon the associated slots needed to schedule a complete flight, coordination among different peak hours at different airports is essential. Airlines can then prepare bids for packages of slots which correspond to flights. This will also enable the airline to put a value on the package which is related to the profitability of the flight.

In addition to the generally-recognized need for auctions to include these characteristics, several open questions remain. Multi-round slot auctions constitute a tatonnement process, and there is no mathematical guarantee that they will converge to equilibrium. The theory is that repeated rounds will contribute to the information and experience of all bidders, which can only help to bring about convergence. On the other hand, airport slot auctions feature inherent complex interdependence of the various slots, and this is an aspect on which little experimental evidence exists.[8]

During the AMG simulation in Washington in February, 1980, it was observed by one airline representative that, because slots won in a certain round of bidding were not guaranteed, it was usually necessary to increase the bid for that slot in the next round. This trend put an artificial upward pressure on prices and tended to lead away from convergence.[9] Another representative from a different airline concurred and offered the observation that the upward pressure on prices was caused by three factors: a tendency to protect existing operations, regardless of cost, the uncertainty of winning slots in a given hour, which caused bidding for extra slots in adjacent hours, and uncertainty about the real value of a slot.10

Disagreeement also exists over whether the final allocation of slots by auction would actually represent an economically-efficient equilibrium. Some of the airline spokesmen have stated that the bidding will be influenced by operational and scheduling constraints and sunk marketing and capital costs. They feel this will affect allocation so that slots will not be won by carriers that can use them most profitably or by carriers that operate more efficiently.[11]

The Econ, Inc., study counters this view by citing recent auction theory research:

> The equilibrium solution is Pareto optimal or efficient, that is, there is no solution under which all airlines are better off according to their own evaluations, it is a Nash equilibrium or non-cooperative equilibrium, that is, no airline acting alone could change its bids and thereby improve its position according to its own evaluations, and, finally, ... no coalition of airlines acting in concert could change their bids together and thereby arrange to improve each of their positions ..." (Underlining in text)[12]

A further concern regarding auctions is their implications for the shape of airline networks. It has been pointed out that airlines do not have flexibility to alter schedules at will. Schedule changes have ripple effects through all the segments of an affected flight, and passengers come to depend upon certain flights at certain times.13 In addition air carriers have protested that a bidding system will, in fact, result in the use of slots by carriers serving long-haul markets. Costs and revenues for specific city-pairs will be the driving factor in determining how much to bid for a slot, and the longer the market, the greater the revenue. Long-haul markets have an added advantage since average seat mile costs decline sharply with stage-length.[14]

The implication of such a trend is that service to some small communities might be reduced or be cut off. The City of Birmingham, Alabama made an interesting and original proposal in response to this issue:

> [Cities] should be permitted to either purchase landing and takeoff slots, or join with a carrier in bidding for a slot, with the carrier reserving the slot for service to its "city partner".[15]

It has also been suggested that slots be grouped by user class and auctioned within each class, without resale across user groups, thus giving smaller carriers and commuter airlines an ability to compete. With this approach, however, the problem arises of how to determine the number of slots to be allocated to each class, for auction within the class.

A final concern about auctions for slots is the effect on industry profits of the added expense of obtaining slots. Interestingly, this question has not been dealt with in the research and theoretical literature so much as it has in the industry's responses to that literature. The comments of the representative from TWA, in his evaluation of the Econ, Inc. study, are typical:

> This added expense obviously has to be passed on to the consumer either in the form of peak hour surcharges or across the board fare increases. This does not serve the best interests of the airline or the travelling public.[16]

He went on to note the difficulty of even minor schedule changes, and expressed concern that airlines will not be able "to restore the same profit potential to a flight or series of flights that must go through forced schedule moves."17

This is just an example of opposition from airlines to any allocation procedures based on auctions. No procedure can work without, at least, reluctant cooperation from the air carriers, and opposition to bidding for slots has been vigorous at least from some of the carriers. This represents, perhaps, the major obstacle to finding a workable auction method.

Notes for Section 4

1. Swoveland, Cary, "Airport Peaking and Congestion: A Policy Discussion Paper," Quantalytics, Inc., Vancouver, Canada (August, 1980), pp. 336, 3-37.

2. Balinski, M.L. and Sand, F.M., "The Allocation of Runway Slots by Auction, Vol. I," Econ, Inc., Princeton, N.J., (1979), p. 6.

3. Balinski, M.L. and Sand, F.M., "The Allocation of Runway Slots by Auction, Vol. II," Econ, Inc., Princeton, N.J., (1980), p.7.

4. Ibid., pp. 8-12.

5. Ibid., p.72.

6. Swoveland, op. cit., p. 3-43.

7. Balinski and Sand, op. cit., Vol. I, p. 10.

8. Balinski and Sand, "The Allocation of Runway Slots by Auction, Vol. III," Econ, Inc., Princeton, N.J., (1980), pp. 58, 59.

9. Balinski and Sand, op. cit., Vol. II, p. 45.

10. Ibid, p. 58.

11. Federal Aviation Administration, "Special Air Traffic Rules and Airport Traffic Patterns," Notice of Proposed Rulemaking, Washington, D.C., (February, 1980), p. 34.

12. Balinski and Sand, op. cit., Vol. III, pp. 37, 58.

13. Balinski and Sand, op. cit., Vol. II, p. 44.

14. FAA, NPRM, op. cit., p. 34.

15. City of Birmingham, Alabama, quoted in Swoveland, op. cit., p. 3-46.

16. Balinski and Sand, op. cit., Vol. II, p. 66.

17. Ibid, p. 68.

5. Some Important Open Questions

We summarize next a number of important questions which have yet to be satisfactorily resolved and must therefore be considered as still open. Some of these questions are relevant to all the approaches discussed in this report, while others are specific to only a subset of them.

a. Number of slots to be allocated: Selecting the number of slots to be allocated at a particular airport is a difficult and important step in the slot allocation process. The hourly capacity of an airport is not a unique number. In fact, capacity varies widely over time and depends on numerous factors, including weather/wind conditions, runway configuration in use, mix of traffic, mix of operations (landings vs. take-offs), performance of the ATC system and of the air traffic controllers on duty, etc. It is not unusual for a 2:1 or greater ratio to exist between the highest VMC capacity of a major airport and some of its typical IMC capacities. For example, at Boston's Logan International Airport, as many as 125 movements per hour can be conducted when operations are to the northeast and east under VMC and only about 40 movements per hour when operations are to the northwest under IMC.

With a wide range of values to choose from, it is clear that the number of slots finally selected for allocation plays a crucial role in determining the effectiveness of the airport's operation. If the number of slots allocated is too high (e.g., close to the highest VMC capacity), long delays will be the rule whenever the actual capacity falls considerably short of this nominal number. Conversely, selection of too low a number will lead to habitual underutilization of the airport. It is surprising then that this issue has not been addressed explicitly in the existing literature. For example, we are not aware of any documentation of the methodology for selecting the numbers (of slots) currently in use at the four HDTA airports where slots are allocated by the airline scheduling committees.

b. Allocation of slots among categories of users: Under existing rules at the four HDTA airports, available slots are subdivided into three categories resulting in scientific slot allocations for air carriers, commuters/air taxis and general aviation. The movement quotas in force in 1981 are shown in Table 1. The issue is whether these separate categories of slots should be continued and, if so, how many slots should be assigned to each category. Those in favor of continuation of current practice argue that separate quotas insulate commuters/air taxis (and, by implication, small communities) as well as general aviation from "unfair competition" for slots by the air carriers, especially in an environment where some kind of economic approach (auction, time-dependent charges) is used to allocate slots. On the other hand, this approach undoubtedly leads to some degree of inefficiency: users (e.g., air carriers) who might attach a high value to a slot are deprived from access to some slots (i.e., those allocated to commuters or to general aviation) through administrative *fiat*. In this respect, separate quotas can be viewed as constituting a form of regulation.

The question concerning the proper number of slots for each aviation category — assuming that such separate quotas are desirable — has never been addressed explicitly, to our knowledge. For example, it is entirely unclear how the numbers shown in Table 1 were arrived at -- although historical precedent must have clearly played a role when these numbers were first set in 1969.

Table 1

Aircraft Movement Quotas
At Controlled U.S. Airports

User	Chicago O'Hare (1500 -1959)	Washington National (0600 -2359)	John F. Kennedy (1500 -1659)	John F. Kennedy (1700 -1959)	La Guardia (0600 -2359)
Air Carriers *	115	40	70	80	48
Air Taxis	10	8	5	5	6
General Aviation	10	12	5	5	6
TOTAL	135	60	80	90	60

* Charters and extra sections of scheduled flights do not count against quotas.

c. Permissibility/advisability of raising additional revenues through the various economic approaches: The economic approaches discussed earlier, e.g. auctions and time-dependent charges, could be an instrument for raising additional revenues for airport operators and/or DOT/FAA — to be used, presumably, for capacity expansion at the airports concerned. The advisability of raising such additional revenues is an open question. For example, airport authorities that, for the most part, operate airports under a "public utility" concept might be accused of raising excessive revenues from users if auctions or time-dependent charges resulted in a net inflow of revenues to these authorities. It is also not clear whether such additional revenues are even permissible under current statutes.

Should operators and/or the FAA opt for no additional revenues for themselves, then the economic approaches described earlier must be transferred into mechanisms for achieving "transfer payments" from some users to other users. Such transfer payments would be made from peak-hour users to off-peak users and from users that make inefficient use of their slots to those that use their slots efficiently (according to some definition of "efficiency"). The "zero-out" type of auction recently suggested by the Port Authority of New York and New Jersey and an approach that includes under-charging (a "negative surcharge") for using an airport during off-peak hours are two possible mechanisms for achieving such transfer payments.

On the other hand, should it be deemed desirable to raise additional revenues, through an economic approach to the slot allocation problem, a host of questions must be addressed: Who will receive the additional revenues? How exactly will they be used? (A "technical" solution must be in place involving some combination of ATC improvements and a feasible airport-expansion plan.) How will users be assured that these funds will be employed exclusively for the purposes for which they were raised? From the point of view of those who obtain access to an airport through a slot auction, is it desirable in the first place that the capacity of that airport be increased? (Such increase would clearly dilute the value of the slots.)

d. Eligibility for participation in slot auctions and in slot allocation processes: Once again, this is a still open question. A number of alternatives exist. Slot auctions and slot allocation processes in general could be open:

(i) Only to individual aeronautical users (e.g. airlines, commuter airlines, air taxis, general aviation users.

(ii) The above plus "coalitions" of these users (such as a group of airlines which will agree among themselves to share a slot according to "day-of-the-week", or such organizations as NBAA, AOPA, NACA, etc.

(iii) The above plus all parties with a "legitimate interest" in acquiring a slot (such as cities that may desire assured service to a congested airport of another city, as in the example of Birmingham, Alabama (mentioned earlier).

(iv) "All comers" (including, for example, brokers, investors, banks, etc.).

e. Treatment of foreign carriers at international airports: Slot-constrained airports already include three where foreign carriers operate (JFK, O'Hare and LaGuardia -- where Air Canada operates several flights to/from Canada every day). More international airports may become slot-constrained in the future. This raises a number of questions: Are foreign carriers automatically entitled to all the slots authorized under bilateral or multilateral agreements, independently of any airport capacity limitations?

Are they entitled to only some minimum number of slots (e.g., 2 per day)? Are they to be treated like domestic carriers?

The answers to these questions will determine the extent to which foreign carriers may have to participate in slot allocation procedures. For example, if the answer to the last question is positive, foreign carriers would have to participate in slot auctions, if any. It is to be noted that assurances of "non-discrimination" and of "treatment equal to that of national carriers" which are, as a rule, contained in bilateral and multilateral agreements would not be contradicted if foreign carriers were required to participate in slot auctions along with U.S.-flag carriers.

f. Rights and obligations of slot holders: Finally, there is a host of issues to be addressed concerning the rights and obligations of slot holders under any (and each) of the slot-allocation approaches described here. We list below a sample of these issues:

- Use-it-or-lose-it provisions for slots.
- Minimum use requirements.
- Policing of proper use of slots.
- Provisions for slot disposition when a slot-holder withdraws from service to an airport, goes bankrupt, etc.
- Selling rights and related rules for slot transactions.
- Protection, if any, to slot-holders against the dilution of the value of a slot (through airport capacity expansion or other means).
- Taxability of slots (if viewed as valuable property).

6. Annotated Bibliography

1. Aerospace Research Center, "Airport and Airway Congestion: A Serious Threat to Safety and the Growth of Air Transportation," Aerospace Industries Association of America, Inc. (November, 1981).

Takes the position that airports and the ATC system must be substantially expanded and makes suggestions regarding possible funding of these efforts.

2. Amos, P. and Lack, G., "A Model for Evaluation of Peak Pricing of Transport Facilities", Australian Transport Research Forum, 1975.

Develops a model for the effect of a peak charge upon users of a transport facility. The model predicts whether a user would continue to travel at peak times, divert to another travel time or choose not to travel at all. The model is an attempt to begin developing a theory on the elasticity of demand with respect to trip scheduling time.

3. Balinski, N., "Airport Congestion: The Need for an Economic Allocation," prepared for Air Transportation Association of America, (February, 1969).

An early attempt to examine economic methods for congestion pricing (auctions, surcharge on landing fees, etc.). Non-economic, administrative measures are not covered. Makes recommendations regarding further research and development of tools for implementing these ideas.

4. Civil Aeronautics Board, Airport Access Task Force, "Report and Recommendations" (March 1983).

This is a report prepared by a Task Force headed by D. McKinnon, CAB Chairman. It examines such impediments to increased airport access as: noise, environmental and airspace constraints, terminal space and gate availability, and groundside congestion. A number of recommendations on steps to relieve existing problems are made with emphasis on various forms of support from the Federal government.

5. Civil Aeronautics Board Airport Access Task Force, "Appendices to the Report and Recommendations of the Airport Access Task Force," (March, 1983).

Working papers, comments, and data used in compiling the Task Force report. Groups ranging from the FAA, to citizens' groups, to national and regional airlines offer their views, primarily on the subject of noise abatement.

6. Day, C.F. and White J.M., "A Slot Allocation Model for High-Density Airports," FAA Office of Aviation Policy and Plans, FAA-APO-80-13 (August, 1980).

Report on a model developed by J. Watson Noah, Inc. The linear-programming model is tailored to Washington National Airport and allocates slots by maximizing industry profits subject to constraints on runway capacity, equity, public service, and noise pollution. Two versions of the model are presented and then compared to the scheduling committee allocation system. Report also contains data on shadow prices generated by the model which might have uses in an auction environment.

7. Econ Inc., "A Slot Auction for Allocating Peak Hour Operations at the High-Density Airports," FAA Office of Aviation Policy (April, 1979).

An initial presentation of an auction procedure, along with a description of an auction simulation and a statement of work to be done on the study.

8. Econ, Inc., "The Allocation of Runway Slots by Auction, Vol. I", prepared for FAA Office of Aviation Policy (April,1980).

This is the first volume of a three-volume report (see below) dealing with auctioning of runway slots. The study conducted by Econ, Inc., used both a theoretical analysis and a simulation of an auction of runway slots to draw a set of recommendations to the FAA. The simulation was based on the Airline Management Game (developed at MIT) and involved airline participants in a four-day exercise. Volume I descries the study and summarizes its findings.

9. Econ, Inc., "The Allocation of Runway Slots by Auction, Vol. II: The Airline Management Game and Slot Auction Testing," prepared for FAA Office of Aviation Policy (April, 1980).

Continuation of Econ, Inc. study. Includes "Slot Auction Description and Instructions" and comments from airlines participating in the Airline Management Game. Results of the simulation are presented and discussed. Results are found to be inconclusive in regard to convergence to equilibrium, as well as economic efficiency and equitability.

10. Econ, Inc., "The Allocation of Runway Slots By Auction, Vol. III: Theory and Technical Issues For Implementation," prepared for FAA Office of Aviation Policy (April, 1980).

Auction theory approaches and mathematical programming approaches to slot assignment.

11. Ellison, Anthony, "Financial Problems of Airports in Developing Countries Can Be Alleviated," ICAO Bulletin (January, 1979).

An argument for congestion charges and off-peak landing fees as a solution to financial problems of some airports. Charges are to be set in terms of marginal cost pricing and elasticities of demand, but an actual method for establishing these is not discussed.

12. (i) Federal Aviation Administration, Docket No. 19950, "Metropolitan Washington Airports," Notice of Proposed Policy, (January 21, 1980).

(ii) Federal Aviation Administration, Docket No. 19948, Notice No.80-2"Metropolitan Washington Airports," Notice of Proposed Rulemaking, (January 21, 1980).

Discussion of proposed limitations on the number of operations and passengers per year at Washington National Airport, also, of extending the non-stop flight range for the airport to one thousand miles, while keeping its characterization as a short-and-medium haul airport. Also proposed are plans to improve and expand Dulles Airport to continue its role of serving all types of transportation needs.

13. Federal Aviation Administration, Docket No. ________ Notice No. 80-____ "Metropolitan Washington Airports," Notice of Proposed Rulemaking, (January, 1980).

Proposed auction system for slot assignment at National Airport. Includes background discussion of need for this action. Summary of the Polinomics study which recommended it. Some of the responses to the Polinomics study are included.

14. Federal Aviation Administration, Docket No. ______, Notice No. 80-_____, "Special Air Traffic Rules and Airport Traffic Patterns," Notice of Proposed Rulemaking, (February, 1980).

Proposes procedures for allocating hourly number of IFR operations at Washington National. Administrative allocation and variations of slot auctions are considered. A strong bias toward maximum reliance on competitive market forces is expressed by the FAA, in accordance with policy statements from both the CAB and the Department of Justice.

15. Federal Aviation Administration," Final Regulatory Evaluation:

Metropolitan Washington Airport Policy," Office of Aviation Policy and Plans, (October, 1981).

Evaluation of six types of regulatory action: quotas, landing fees,aircraft restrictions, noise limits, curfews, and market restrictions, all of which are proposed to be put into effect.

16. (i) Federal Aviation Administration, Docket No. 22050, SFAR No. 44-3, "Air Traffic Control System Interim Operating Plan: Transfers and Exchanges of Slots," (August, 1982).

(ii) Docket No. 22050, Notice NO. 82-8, "Air Traffic Control System Interim Operations Plan," Notice of Proposed Rulemaking, (June 15, 1982).

(iii) Docket No. 22050, SFAR 44-1, 44-5, "Analysis of Potential Changes in the Interim Operations Plan for Spring-Summer, 1982," Office of Aviation Policy and Plans (February 12, 1982).

Various notices and papers regarding the allocation of slots in order to enable the post-PATCO-strike ATC system to expand its capacity.

17. Geisinger, Kenneth, "A Method for Administrative Assignment of Runway Slots," FAA Office of Aviation Policy, FAA-AVP-80-5 (June, 1980).

An explicitly described administrative approach to slot allocation, including sample problems and an analysis of the results.

18. Hines, James, Toenniessen, Robert, and Rodgers, John, "Airport Access — Domestic and International Carrier Problems and Policy," FAA Office of Aviation Policy, (May, 1980).

Considers the limited capacity issue in the light of international agreements, as well as domestic promotion of maximum competition.

19. Howard, George P., "The Theory of Differential Pricing of Air Field Services," paper presented at the 30th Annual Conference of AOCI (September, 1977).

Brief overview of experiments with differential landing fees in the preceding ten years, with a discussion of the practical problems involved.

20. Levine, Michael E., "Airport Access and Regulatory Reform," speech delivered to the Air Traffic Control Association Fall Conference, (October, 1978).

Speech supporting some kind of economic solution to the airport congestion problem, gives a general overview of different approaches.

21. R. Travers Morgan Assoc., "Traffic Management Policies at a Major Airport," Australian Transport Research Forum (1977).

In considering congestion at Kingsford Smith Airport the surcharge option is examined and found lacking because of market imperfections and the practical constraints of some airline operations. A regulatory approach is compared to the surcharge approach.

22. Odoni, Amedeo and Vittek, Joseph, "Airport Quotas and Peak Hour Pricing: Theory and Practice," Federal Aviation Administration, FAA-AVP-77-5 (May, 1976).

The problem of airport congestion is considered, and measures such as a quota system or peak hour surcharges are reviewed as alternatives to capital-intensive airport expansion. The problems of implementation are discussed and applied to real world situations. The conclusion is that these alternatives could be effective, but that the institutional issues must be further examined before they could be put into widespread use.

23. Polinomics Research Laboratories, Inc., "Alternative Methods of Allocating Airport Slots: Performance and Evaluation," prepared for Civil Aeronautics Board, 79-C-73 (August, 1979).

Reviews the structure of the slot allocation committees and interprets the nature of their decisions using experimental techniques to demonstrate conclusions. Identifies a recommended process — sealed bid, one-price auction with an aftermarket — and demonstrates its efficiency through similar experimental techniques. Also reviews several alternative methods and compares all of them with the selection committee method.

24. Rodgers John, "Issue Paper: Allocation of Runway Capacity, Washington National Airport," FAA Office of Aviation Policy (October, 1979).

Describes background, issues, and options, and proceeds to analyze options in terms of several explicit policy criteria. Actual analysis is not presented in detail. Contains extensive primary source material.

25. Simat Helliesen, and Eichner, Inc. "Analysis of the Impact of Competitive Bidding Slot Allocation on Short-Haul and Small Aircraft Operations," prepared for Commuter Airline Association of America (January, 1980).

Report commissioned by CAAA which examines the Polinomics slot auctioning system and finds that smaller, short-haul aircraft and, consequently, the smaller communities that they serve will suffer disproportionately under such a system.

26. Straszheim, Mahlon, "The Theory of Public Utility Pricing and Its Application to Aviation Control Facilities", unpublished paper.

Analysis by a University of Maryland Economics professor of the financing of aviation facilities of all kinds. Takes the position that users should pay for the use of facilities based on long-run marginal cost pricing.

27. Sutton, L. Scott, "Alternative Methods of Allocating Scarce Airport Capacity," unpublished paper. Also, "A Note on Demand Functions and Programming Models for Slot Allocation," unpublished paper.

Briefly summarizes principal economic and pricing theories, and illustrates how these might be applied at the Metropolitan Washington Airports.

28. Swoveland, Cary, "Airport Peaking and Congestion: A Policy Discussion Paper," Quantalytics, Inc., prepared for CATA Airport Services and Security Branch (August, 1980).

A comprehensive review of issues associated with airport peaking and slot allocation. Examines peak-hour surcharges and quotas, and describes both the U.S. and the IATA procedures for administrative allocation of slots under quota controls. Examines slot auctions as an alternative, and discusses issues such as how capacity and use-rights are defined and allocated, how surcharges should be calculated, whether use-rights are transferable, etc. Policy options are presented and recommendations made.

29. Williams, Ray, "Summary of Airport-Air Carrier Agreements," FAA Office of Aviation Policy, AVP-210, (November, 1979).

Describes major features of twenty-seven airport-airline agreements, and concludes that, in practice, these agreements do not exclude new entrants from any of the markets represented.

30. Zywokarte, Michael, "Alternative Approaches for Scheduling of Air Carriers at High Density Airports," Graduate Report for the University of California Institute of Transportation and Traffic Engineering (August, 1971).

Develops a model to test air carrier and air taxi scheduling algorithms. Compares real-world delays to those predicted by the model using the two algorithms.

31. Articles dealing with auctions and auction theory:

Bieniewicz, Donald J., "Fair Market Value and Statistically-Unbiased Bid-Rejection Procedures," Department of the Interior, Office of Policy Analysis, (April, 1980).

Dougherty, Elmer and Lohrenz, John, "The Effect of Aggressive and Conservative Bids in Federal Offshore Oil and Gas Lease Bonus Bidding," Applied Research and Analysis Section, Conservation Division, U.S. Geological Survey.

Holt, Charles and Sherman, Roger, "Waiting Line Auctions," Unpublished paper, (February, 1980).

McDonald, John and Jacquillat, Bertrand, "Pricing of Initial Equity Issues: The French Sealed-Bid Auction," Journal of Business, Vol. 47, #1, (January, 1974), p. 37.

Reece, Douglas K., "Competitive Bidding for Offshore Petroleum Leases," Bell Journal of Economics, Vol. 9, #2, (Autumn, 1978), p. 369.

Samuelson, William, "Competitive Bidding in Defense Contracting," unpublished paper.

Swidend, C.M., "Noncompetitive Lenders in Treasury Auctions: How Much Do They Affect Savings Flows," Federal Reserve Bank of New York Quarterly Review, Vol. 3, No. 3, (Autumn, 1978).

Sugrue, Paul, "Optimum Bid Estimation for Construction Contracts," Unpublished paper.

"Auction Methods" - Bibliography available from U.S. Dept. of Transportation Library, Washington, D.C.