Method of Allocating Airport Runway Slots

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Each operation (takeoff or landing) at an airport takes some period of time, referred to as a "slot." Federal Aviation Administration (FAA) regulations set quotas on the number of operations per hour at each of four major U.S. air-carrier airports: Washington National, New York LaGuardia, Chicago O'Hare International, and New York Kennedy International. The runway slots designated for scheduled air carriers are assigned to the various carriers in advance, and airline schedules are built around them. How many slots each airline gets each hour at each airport is determined by mutual agreement among the airlines through airline scheduling committees. These committees have served since the quotas were put into effect in 1969. With the advent of the Airline Deregulation Act, these committees have been questioned as being anticompetitive. If the committees are abolished, their function might have to be performed by FAA. In view of this possibility, FAA is considering several possible approaches. Among them are auctioning of slots, peak-hour pricing, and direct assignment of slots. There are many ways to effect any of these approaches. This paper presents one approach to slot assignment, which was designed to be implementable with as few changes to the current system as possible. The decision criteria consider the current airline requests and constraints (the historic share of the slots) and airline service to the local public in determining which airline gets a contested slot.

Federal Aviation Administration (FAA) regulations designate an upper limit to the number of operations (takeoffs or landings) per hour at four major U.S. airports: Washington National (DCA), New York LaGuardia (LGA), New York Kennedy International (JFK), and Chicago O'Hare International (ORD). The quotas apply only to instrument operations. During good visibility, operations (particularly nonscheduled ones) can exceed the quota. The quota rules (from Code of Federal Regulations, Title 14, Part 93, Subpart K) are shown in Table 1.

The use of the runways for one operation is referred to as a "slot." The runway slots designated for scheduled air carriers are assigned to the various carriers in advance, and airline schedules are built around them. How many slots each airline gets for each hour at each airport is determined through mutual agreement among the airlines through airline scheduling committees. These committees, which consist of representatives of the airlines that serve a particular airport, have served since the quotas were put into effect in 1969. They were granted a special exemption to the antitrust regulations by the Civil Aeronautics Board (CAB).

With the advent of airline deregulation, the possibility that the committees inhibit airline competition has been suggested, and CAB is currently questioning whether these exemptions should be continued. If the committees are abolished, their functions might have to be performed by some governmental authority such as FAA. The administration's proposed 1979 Airport and Airway Improvement Act (S. 1582) would give the Secretary of Transportation the authority to establish allocation procedures.

In view of this possibility, FAA's Office of Aviation Policy is considering several possible approaches. Among them are the auctioning of slots, peak-hour pricing, and administrative assignment of slots. There are many possible ways to do each.

Actions and pricing methods would involve a financial burden on the air carriers, which would be passed on (perhaps inequitably) to the airline passengers. These methods favor airlines that can best afford the slots, which are not necessarily those that would make the best use of them. On the other hand, the assignment of slots opens up the danger of political pressure. Thus, assignment rules must be complete and adhered to firmly.

This paper presents an administrative assignment technique to maximize both passenger service and consideration of the airlines' constraints and requirements. It is hoped that this procedure will take the place of the current procedure with as little disruption as possible and that it will result in an improvement in passenger service.

CURRENT PROCEDURES

The following discussion relates to the assignment of slots to certificated air carriers. Slots are currently assigned to air taxi and commuter carriers by separate procedures, which are less sophisticated. The following is a brief summary of the current procedures:

1. Airline scheduling committees meet twice a year--in July to assign slots for the winter schedule and in January to assign slots for the summer schedule. A separate committee meets for each airport. Additional meetings are called when needed.
2. The airlines submit a request for the number of slots desired each hour of each day of the week at each airport to the reservation center about one month prior to the meeting. The reservation center handles all the bookkeeping involved in the process, both during and between meetings.
3. At the meetings, these requests are whittled down by voluntary concessions from the participating airlines until the quota levels are reached. The committee concentrates on one particular day (when requests are maximum). Other days (different days of the week or different weeks) then generally fall into place. The first step is to reduce the requests to a total number of slots that does not exceed the total available. The second step is to get the airlines to slide their submission so that the number requested does not exceed the quota for any hour. Some airports are easy to resolve (e.g., JFK) and some are difficult (e.g., DCA).

SUGGESTED PROCEDURE

The procedure suggested in this paper also handles one given day for a given airport at a time. It requires as input the number of slots requested in each hour by each airline. It also consists of two steps: (a) allocating a total for the day to each airline and (b) assigning slots by hour to each airline. A schematic diagram of the proposed procedure is shown in Figure 1. The number of slots currently allocated to an airline is recognized by almost every other airline as a valid consideration. It represents an investment made by the airline and a vital interest not to be drastically altered.

Passenger service can be defined in many ways, but the measure suggested here is the average number of passengers enplaned (for departures) or deplaned (for arrivals) per operation. This indicates how many passengers are served for a given slot. Some advantages of this definition are as follows:

1. Data for this measure are available (CAB Form 536);

2. It is based on demonstrated passenger preference;
3. The operations with the highest service tend to be more profitable to the airlines and to the airport operator, except that stage length increases airline profitability but not passenger service;
4. It favors larger aircraft (more service per slot); and
5. It fosters airline competition (more business means more slots).

This procedure also has provision for special exemptions to permit slots to be allocated based on government policy. Examples of this would be honoring international agreements made with foreign carriers and flights that provide essential service to small communities. These must be considered on a case-by-case basis, but the total should be restricted to a small percentage of the total slots.

Increasing passenger service and respecting historic shares of runway slots are somewhat contradictory goals. This procedure allows the balance between the two to be set by a control variable called the reallocation factor. Setting this variable will require some experience and experimentation and an executive decision. It might appear reasonable to disregard current allotments altogether. But this could result in a 10-slot airline getting 100 slots and a 100-slot airline getting 10 slots--a change neither airline could absorb. Even if the airlines could absorb the change, overrewarding one or two airlines would eliminate competition on the next round rather than foster it. Also, the statistics used are based on current schedules and are not valid for gross variations from them.

A realistic but hypothetical example will show how the procedure works. It is based on actual requests for slots at DCA submitted for August 1979. For practical purposes, there are about 620 usable slots during the day: 40 slots/h between 6:00 a.m. and 10:00 p.m. and 20 slots/h at 10:00 p.m. (because of low airline demand for this hour and a voluntary jet curfew after 10:00 p.m.).

The hypothetical allocation is shown in Table 2.

Table 1. Quota rules.

Class of User	Instrument-Flight Operations per Hour			
	DCA	LGA	JFK	ORD
Certificated air carrier	40	48	70-80[a]	115
Scheduled air taxi and commuter	8	6	5	10
Other	12	6	5	10
Total	60[b,c]	60[c]	80-90	135[c]

Note: Hours in force: DCA, all day; LGA, all day; JFK, 3:00-8:00 p.m.; ORD, 3:00-8:00 p.m.

[a] 70/h between 3:00 and 5:00 p.m.; 80/h between 5:00 and 8:00 p.m.
[b] Does not include charter flights or other nonscheduled flights of scheduled or supplemental air carriers.
[c] Does not include extra sections of scheduled air-carrier flights.

Figure 1. Schematic diagram of proposed slot assignment procedure.

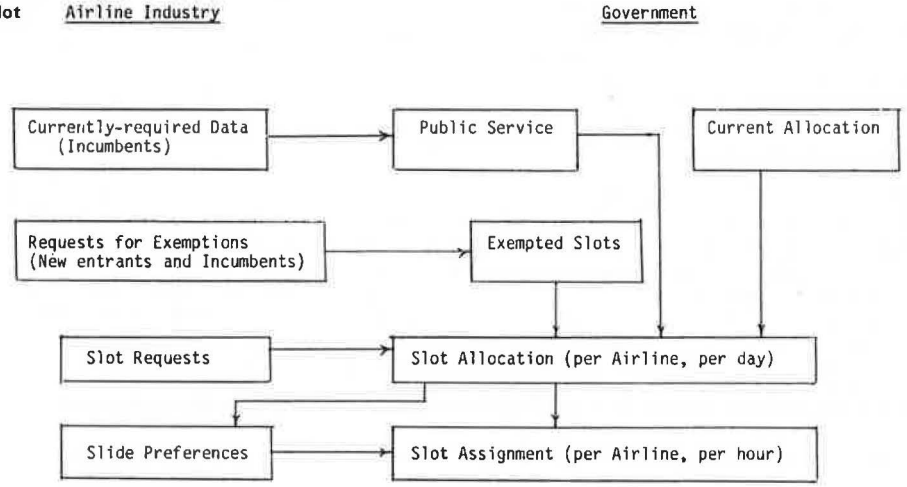

Table 2. Hypothetical slot allocation for DCA on weekdays, August 1979.

Airline	Current Slots	Requested Slots	E+D per Operation	Computation of Slot Allocation					
				Base	FM	Δ	Raw	Share	New
A	74	63	70.3	37	2 601	37	74	0.119	64
B	82	78	50.0	41	2 050	29	70	0.113	70
C	22	28	51.5	11	5 665	8	19	0.031	20
D	34	34	88.5	17	1 504	21	38	0.061	34
E	142	144	64.5	71	4 580	64	135	0.218	140
F	48	46	58.5	24	1 404	20	44	0.071	46
G	42	42	70.8	21	1 487	21	42	0.068	42
H	68	72	46.8	34	1 591	22	56	0.090	58
I	40	44	81.6	20	1 632	23	43	0.069	44
J	68	70	68.6	34	2 332	33	67	0.108	70
K	0	6	NA	6	0	0	6	0.010	6
L	0	6	NA	6	0	0	6	0.010	6
M	0	4	NA	4	0	0	4	0.006	4
N	0	8	NA	8	0	0	8	0.013	8
O	0	4	NA	4	0	0	4	0.006	4
P	0	4	NA	4	0	0	4	0.006	4
Total	620	653		342	19 748	278	620	0.999	620

Column 1 shows the current allocation and column 2 shows the number of slots requested. Column 3 shows the enplanements and deplanements (E + D) per operation for each incumbent carrier (average for all DCA operations). The new entrants have no passenger service history and are given a special exemption for a duration (assuming that their requests are reasonable). In general, incumbent carriers could qualify for both regular and exempted slots.

Computations begin with column 4, in which a base number of slots is allocated to each carrier by multiplying the current share by the reallocation factor (0.50 was used in this example). Exempted slots are added directly to the base. The product of columns 3 and 4 forms a figure of merit (FM), shown in column 5. The number of base slots is 342, which leaves 278 of the 620 slots to be allocated. This is accomplished by taking the fraction of FM to the total of FM times 278. This yields an increment (Δ) to the base (column 6). The base plus the increment form the raw allocation to each carrier (column 7). The fractional fair share of the total slots is obtained by dividing by 620 and is shown in column 8. The final allocation is shown in column 9. Here, slots allocated in excess of requests are redistributed proportionally to other carriers. For DCA the final allocation is rounded to an even number, since the quota period covers the whole day and every flight in is matched to a flight out.

Several observations can be made for this procedure:

1. It is perfectly general and can apply to any airport.
2. Slots are assigned based on a balance of historic share and local passenger preference. Since this process is iterated every six months, carriers would be encouraged to adjust their schedules, fleet mix, or both to improve passenger service or face a possible loss of slots on the next round.
3. An airline cannot gain more slots simply on the basis of asking for more nor can an airline retain all of its slots simply because it has had them.
4. If no more slots are requested than are available, this procedure will allocate to each airline the number requested.
5. Even if an airline has a low public service rating compared with others, it will not lose as many slots as its fair share would indicate because of limited requests by higher-rated carriers.

ASSIGNING SLOTS BY HOUR

Once the allocation of total slots for the quota period has been determined, the next step is to assign a given number of slots to each airline for each hour.

Table 3 shows the DCA slots requested at a special meeting in April 1979 for August 1979 by each airline for each hour at DCA. Note that for some hours the number requested is greater than the quota and for some hours the number is less than the quota. Even when the total allocation is reduced to 620, it will be necessary to slide some of the requested slots from one hour to another.

One of the best features of the current procedure is that the negotiations are conducted by airline officials with the ability and the authority to adapt their tentative schedules to accommodate slides. In many cases this can be done with little inconvenience to the airline (e.g., when an operation is planned near the beginning or end of an hour). In other cases this requires a considerable sacrifice and a slide is offered only when competing airlines have made suitable concessions. One disadvantage of the current system is that, since the decisions must be unanimous, stubbornness is rewarded by both the quantity and the placement of the slots obtained.

Some of the participants come to the meeting with preplanned slides to offer, and others consider revisions to their schedules during the course of the meeting. Under this procedure it will be necessary to have all airline slide offerings available simultaneously so that they can all be considered together and an assignment can be selected that maximizes the total benefit.

Each airline will be required to submit a package of proposed slides. The form of this submission has yet to be determined, but the net result would be similar to the hypothetical submission by one airline shown in Table 4, assuming that it is given 28 slots for the day (as it was by the committee). Each row in the table corresponds to the distribution of slots that could result from one or more slides.

The total number of slots must not exceed the quantity allocated. The airline assigns a value from 1 to 100 to each row to indicate the relative desirability of that distribution compared with the others. Row 1 is the distribution originally requested; therefore its value is presumed to be 100. As the row number gets higher, less-desirable slides are listed. Row 16 corresponds to slots actually used; this shows a rather large deviation from the original request, which evidently would have also been acceptable. It is quite possible to have two or more distributions given the same value, which indicates alternatives that are equally desirable.

The first step is to examine the slide preferences to see whether a feasible solution exists. A feasible solution would consist of a set of slots (one set from each airline) distributed so that the total slots in each hour did not exceed the quota. If one or more feasible solutions exist, the solution is chosen that maximizes the sum $\Sigma_i (F_i/A_i)(S_i/Z_i)V_i(k_i)$ in which i is the airline index, A_i is the number of slots allocated, F_i is the fair share, S_i is the number of slot-distribution choices provided, Z_i is the fair number of distribution choices, and $V_i(k_i)$ is the airline's evaluation of slot distribution k_i. The selected slot distributions indicated by k_i form the solution set.

The objective function shown above accomplishes three objectives:

1. It considers the slot-distribution preferences of the airlines.
2. If a decision has to be made between airlines for a preferred choice, an airline that received fewer slots than its fair share relative to other airlines will be given an advantage.
3. The airlines that have offered more slot-distribution choices relative to the number of choices they should have provided will be given an advantage.

The fair number of slot-distribution choices should be based on the number of slots allocated. A reasonable value is given by $Z_i = 2\sqrt{A_i}$. To prevent an airline from submitting a large number of slot distributions that differ from each other only in the off-peak hours and offer no help in the problem hours, some criteria could be adopted to determine whether a suggested distribution should be counted in the S_i.

Table 3. Actual slot submission for DCA, August 1979.

Airline	Hour[a] 06[b]	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22[b]	Total
A	0	7	3	4	3	4	5	4	2	5	4	4	3	6	3	4	2	63
B	0	3	9	8	2	3	4	6	7	2	4	6	5	4	6	5	3	78
C	0	1	1	2	0	2	2	3	2	2	3	2	2	2	2	2	0	28
D	0	3	2	2	2	2	2	2	2	2	2	4	2	2	3	0	2	34
E	0	11	12	7	10	9	9	7	10	8	9	7	10	9	9	11	6	144
F	0	1	1	4	5	6	1	2	5	5	2	4	3	2	3	2	0	46
G	0	3	2	2	2	1	4	2	2	4	3	2	2	3	3	3	4	42
H	1	3	3	5	5	4	6	4	4	4	5	5	6	3	4	5	5	72
I	0	2	2	3	3	2	3	2	3	2	3	2	4	2	3	5	3	44
J	0	4	4	4	7	8	1	7	4	3	2	4	6	6	3	3	4	70
K	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	6
L	0	0	1	1	0	0	1	1	0	0	0	1	1	0	0	0	0	6
M	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	4
N	0	0	2	0	0	0	2	0	0	0	2	0	0	2	0	0	0	8
O	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	4
P	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	4
Total	1	40	43	43	40	42	42	40	41	38	40	42	45	43	41	42	30	653

[a]Example: 15 = 3:00-3:59 p.m. [b]No turbo-jet operations before 7:00 a.m. or after 10:00 p.m.

Table 4. Hypothetical slot slide submission, Airline C.

No.	Value	Hour 06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
1	100	0	1	1	2	0	2	2	3	2	2	3	2	2	2	2	2	0	28
2	99	0	0	2	2	0	2	2	3	2	2	3	2	2	2	2	2	0	28
3	85	0	0	2	1	1	2	2	3	2	2	3	2	2	2	2	2	0	28
4	85	0	1	1	2	0	2	2	3	3	2	2	2	2	2	2	2	0	28
5	70	0	1	1	2	0	2	2	3	4	2	2	2	1	2	2	2	0	28
6	70	0	0	2	2	0	2	2	3	4	2	2	2	1	2	2	2	0	28
7	60	0	1	1	2	0	2	2	3	3	3	2	2	1	2	2	2	0	28
8	55	0	0	2	2												2	0	28
9	50	0	0	1	2	.	.	.	.	.	.	.	.	.	.	.	2	0	28
10	50	0	0	1	2	.	.	.	.	.	.	.	.	.	.	.	2	0	28
11	50	0	0	1	2	.	.	.	.	.	.	.	.	.	.	.	2	0	28
12	45	0	1	1	2												2	0	28
13	45	0	1	1	2	0	2	2	4	3	2	2	3	1	1	2	2	0	28
14	45	0	1	1	2	0	2	2	4	3	2	3	2	1	1	2	2	0	28
15	40	0	1	1	2	0	2	2	3	4	2	3	2	1	1	2	2	0	28
16	40	0	1	1	2	0	2	2	3	4	3	2	2	1	1	2	2	0	28

Note: No. 1 was actually requested; nos. 2 through 15 are hypothetical; no. 16 was actually flown, August 10, 1979.

If no feasible solutions exist, the airlines could be offered another chance to provide more flexibility in their slot distributions. If this fails, slots could be administratively deleted based on criteria similar to the airline preference criteria already presented.

After this process has been completed, some slots may remain unused. Applications for these slots can be entertained, and preference can be given to airlines who have received less than their fair share compared with other airlines.

CONCLUSION

The procedure described here is preliminary and is subject to change. It has been programmed in FORTRAN, and experiments are being conducted to see how the process would react to realistic slot requests at different airports and for different values of the reallocation factor. Procedures for handling exemption requests and slide submissions are being developed. This procedure was designed for certificated air carriers. It could not be applied to unscheduled operations. It might be applicable (perhaps with some modifications) to commuter services, the present system for which is based on a waiting list and not on a periodic reassignment. That system, which is probably less fair than the present certificated air-carrier system, rests on the approval of FAA and not CAB. It should be emphasized that the method proposed in this paper is only one solution to the problem (if, indeed, it even becomes FAA's problem).

ACKNOWLEDGMENT

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Discussion

John R.G. Brander

A basic problem in the provision of transportation infrastructure is the temporal variation in demand coupled with a capacity that is fixed in the short