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

I wish to acknowledge the guidance and direction of Scott Sutton, Acting Director of the FAA Office of Aviation Policy, who initiated this study, and to other individuals who offered helpful suggestions--Harvey Safeer, Walter Faison, John Wesler, and John Rodgers. I also wish to thank Walter Coleman of the Airline Reservation Center for his courtesy and for the information he provided. The proposal presented here is only one approach being considered and does not represent an official FAA position.

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

Table 5. Results of two methods of slot allocation among incumbent carriers.

	Raw Allocations		Final Allocations	
Airline	Geisinger	Brander	Geisinger	Brander
A	74	67	64	64
B	70	63	70	78
C	19	33	20	28
D	38	55	34	34
E	135	99	140	114
F	44	49	46	46
G	42	51	42	42
H	56	54	58	68
I	43	55	44	44
J	67	63	70	70

run. Given this peak-demand problem, there arises the question of how the available capacity can best be allocated among users. It would be generally agreed that there exist three demand-management techniques that might be applied in these circumstances. There are peak-hour pricing, the auctioning of available capacity, and the development of artificial allocation mechanisms. In his paper, Geisinger focuses on the third of these mechanisms; he dismisses the first two on the grounds that they would have undesirable side effects on the existing carriers that serve a given airport. It is my intent here to discuss these issues.

By way of introduction, it may be instructive to inquire what a particular airline is demanding when it asks for a particular slot at a particular airport. Implicitly, Geisinger suggests that it is seeking to carry out a single operation in isolation. There is, however, much more involved. This is a true case of joint demand in the economic sense. The demand for a takeoff slot at one airport leads automatically to the demand for a runway landing slot at some other and for space on the airways that link the two together. This fact must be incorporated into the analysis. The initial criticism of the Geisinger approach, therefore, is that it is too narrow and does not meet the needs of the air transportation system as it now exists.

ALLOCATING SLOTS TO AIRLINES

The Geisinger approach involves a two-stage allocation procedure. The initial step allocates the total daily slots among the airlines. The second step adjusts for peak-hour problems. Both need to be discussed. However, the whole issue cannot be divorced from the question of the deregulation of air transportation. Deregulation is predicated on the assumption that market forces are better able to allocate resources in air transportation than is some government agency. The suggested allocative mechanism appears to substitute one form of government regulation for another. More specifically, as will become clear below, the Geisinger approach to slot allocation is overly protective of the existing carriers and discriminates against the entry of new competitors.

With respect to the initial step in the process, the major problem is that Geisinger's attempt to balance historic shares with local passenger preference results in a serious bias in the allocations. More specifically, there is a bias in favor of those airlines that have a large number of current slots but only a moderate enplanement plus deplanement (E + D) per operation. In contrast, airlines that have a higher E + D per operation but a much smaller current allocation suffer. An examination of Geisinger's Table 2 makes this clear (specifically, compare Airline D with Airline E). This bias is created by giving double weight to the current slots held--the first time when computing the base allocation, the second time when computing the change.

Changing the factor of merit, the means by which nonbase slots are allocated, significantly alters the raw allocation of runway slots. In order to test this hypothesis, the nonbase slots were reallocated among the existing airlines by using only the E + D per operation. A χ^2-test was then applied to the raw allocations shown in Table 5. The calculated χ^2 was 32.90 with 9 df. At the 0.005 level of significance, the critical value of χ^2 is 23.59. The conclusion is that the two raw allocations differ significantly. The difference is caused by the double use of the current slot allocations.

The final allocations determined by using both approaches are also set out in Table 5. As one might suspect, these two distributions are not significantly different, largely because of the upper limits placed on allocations to individual airlines by their total requests.

The second part of the allocation mechanism involves slot slides to ensure that hourly runway capacities are not exceeded. Geisinger suggests that a reasonable number of slides would be twice the square root of the number of slots allocated to each airline. However, this procedure introduces another bias in favor of those carriers that currently possess a large number of slots. The problem is that as the number of slots held increases, the proportion of required slides to be offered to slots held declines. By using Geisinger's approach, Airline E receives 140 slots and must offer 24 slides, or 17 percent of its slots. However, Airline C, which receives only 20 slots, must offer 9 slides, or 45 percent. Because of the small number of slots received, the new entrants must offer still higher percentages of their allocations as slides. Airlines M, O, and P have a slide/slot ratio of 1.0.

Finally, there are intertemporal problems with which the approach in its present form cannot come to grips. Implicit in the allocation mechanism is the assumption that the E + D per operation is determined by factors exogenous to the model. This, however, is only partly true. It must be admitted that a major determining factor here is the route density of the average route flown by a given airline. However, at least one endogenous factor is involved as well. There is ample evidence (which need not be reviewed here) that, other things being equal, load factors--and therefore E + D per operation--are sensitive to time of day. This fact coupled with the biases noted above in favor of larger operations increases the probability that such airlines will receive relatively larger proportions of the preferred slots and must be viewed as essentially anticompetitive.

All these shortcomings could be dealt with, at least in part. Both components of the allocation mechanism could be modified to meet these criticisms. It seems preferable, however, to explore the mechanisms that were rejected by Geisinger.

OTHER ALLOCATION MECHANISMS

Peak-Hour Pricing

The first of the rejected approaches to be considered is peak-hour pricing. The theory of peak-hour pricing has received considerable attention in the literature and involves setting the

price equal to the marginal social cost in order to ration available capacity. So viewed, the price at peak periods is composed of two elements. The first is a basic user fee charged at all times, the purpose of which is to finance the infrastructure involved. The second is a congestion tax, which is set at zero during periods of low use and rises as the volume/capacity ratio increases.

Peak-hour pricing suffers from one of the major deficiencies of the mechanism discussed above: It typically considers a single facility in isolation from the remainder of the system. It could be applied to links in a transportation system by a process of aggregation. In such a scheme, the prices of each component in a given link would be separately estimated and the results added together. However, such a practice would be both cumbersome and costly, assuming that the marginal social cost involved could be estimated at all. As a consequence, this approach must be rejected as well.

Auctioning of Slots

The final approach to be considered here is auctioning of slots. The first step in considering it is the introduction of the Marshallian concept of quasi-rent (1, p. 74). Stigler (2, p. 95) argues that

> the theory of quasi-rents is essentially the explanation of the return on what is called fixed (overhead) investments. Once capital has been invested, it will remain invested until it can be depreciated through use and its salvage value, and throughout its service life, it will continue in that use regardless of its return. . . . The earnings of the fixed investment are price-determined in the short run and thus partake of the nature of rent. In the long run, however, they must be covered or capital will leave the industry.

The relationship between quasi-rents and airport slots is straightforward. The larger the number of such slots is and the more desirable the slots held are, the larger will be the quasi-rents earned. At the same time, it must be noted that the airlines possess all the requisite information to allow them to compute these quasi-rents on a link-specific basis. It need hardly be noted that this calculation can also be done for specific aircraft types (3). [I have recently given an example of the relationship between highways and site rent and a justification of the approach (4).] Geisinger suggests that airlines can place values on different slot combinations and, in so doing, they would presumably use precisely these data.

With an auction system for slot allocation, each airline would submit a bid for each slot in which it was interested. These bids, in turn, would presumably be based on the quasi-rent that could be earned. A given slot would be awarded to the airline that submitted the highest bid. In order to offer revenue security to the airport operators, an upset price could be attached to each of the slots. Any slot not allocated in the initial round could be auctioned a second time, and the process could continue either until all airlines were satisfied or until all slots were allocated.

Such a system of slot allocation seems to offer a number of advantages. First, it reflects the nature of the joint demand for facilities and the nature of the industry, since it is based on the concept of links in a system rather than operations at a single airport. Second, it does not protect the existing carriers at the expense of new entrants into a market. Third, it avoids the necessity of developing an artificial slide mechanism, for slots are allocated uniquely except for the possibility of identical bids for a given slot. In this case, a retendering would take place. Fourth, it, like the approach Geisinger attempts to develop, takes account of passenger preference (at least as far as these are reflected in the quasi-rents). Finally, and this is important in a period when deregulation is being considered, it places primary reliance on the forces of the market. A major concern with the Geisinger approach must be that it substitutes one form of regulation for another. One is driven to the conclusion that the auction approach to runway-slot allocation offers overwhelming advantages.

A postscript is necessary. Geisinger opposes the auction approach on the grounds that it does not guarantee the best use of slots and that it might cause inequity. The former is not true. The latter is irrelevant.

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Author's Closure

Brander raises some interesting points that deserve some further discussion. First, it would be well to review some developments that have occurred since my paper was written.

The proposed administrative method has been revised as follows:

1. The measure of passenger service has been modified to include locations served as well as passengers served. The locations served per slot is defined as the number of different airports served by the airline by direct flight to or from the airport in question divided by the number of slots. Both factors are combined into a single measure through the use of weighting factors. This balances the original measure's preference toward large aircraft that serve dense markets with a preference toward airlines that serve many small communities with few slots.
2. Some guidelines on acceptable distribution choices were developed; these included a limit on the number of slots an airline could request in any hour (based on the airline's share of slots for the day).

In February 1980, FAA conducted a test of the revised administrative allocation and an auction method that handles all quota airports simultaneously (somewhat similar to Brander's proposal). The test involved airline schedules and a computerized airline-management game. The airline schedulers ran a set of five simulated airlines that served 16 simulated airports. No conclusive

findings were reached about which method was superior; both proved workable and some valuable lessons were learned.

FAA is preparing a draft Notice of Proposed Rule Making (NPRM), which will present both the administrative method and the auction method for comment. This should have been released by the time that this article is published.

Brander's points will now be discussed in the order in which they were raised.

1. Slots used at one airport are linked to slots used at other airports. Therefore, the suggested procedure is too narrow and does not meet the needs of the air transportation system as it now exists.

It is true that every scheduled operation at a quota airport is linked to a scheduled operation at some other airport. But only four airports have quotas, and for two of those the quota applies only during 5 h of the day. Thus, the majority of flights that require a slot at one end do not require a slot at the other end.

However, the problem of getting slots at both ends of some flights does exist. The existing scheduling committees (which have met the needs of the industry for over 10 years) solve the problem in this way. The quota airports are handled sequentially, beginning with the hardest to resolve (DCA) and ending with the easiest to resolve (JFK). Usually, the schedule at DCA is not completely resolved in the time allotted. In that case, the DCA committee resumes negotiations after the other airports' schedules have been resolved. In any case, there is provision for turning in unusable slots and obtaining unused slots after negotiations are closed. I would handle this problem in just that way.

2. The Geisinger approach to slot allocation is overly protective of the existing carriers and discriminates against new entrants.

New entrants do not compete with incumbents but are given a set of slots by exemption. The current thinking is that four slots would be a reasonable number. It could be 8, 16, or 100. The process itself does not discriminate.

3. There is a bias in favor of airlines that have a large number of current slots.

Yes, there is such a bias. In fact, if we neglected exempted slots and if all airlines had an equal measure of passenger service, they would all get their current allocations. The current allocation is the starting point and deviations are made only as passenger service differs and then only in modest amounts. The airlines with more slots do risk losing a larger number of slots in the process, however.

The reasons for this bias are as follows: (a) The current allocation is recognized as an investment that an airline has made in developing markets and providing service capacity; (b) the measure of service is an average made over the current schedule and is not valid for gross variations (many more or many fewer slots) from that schedule; and (c) turbulence caused by sudden and drastic changes in allocations would be harmful to everyone.

Nevertheless, if service differentials persist, significant changes in allocations could occur after repeated applications of the procedure (every six months).

4. Airlines that have a large number of slots have to propose fewer alternative slot plans proportionately than do airlines that have a small number of slots.

This is true. Moreover, the number of variations mathematically possible increases much faster than linear proportion to the number of slots. But the problem is that preparing alternative slot plans is a great burden to the airline schedulers, and the airlines that have many slots are faced with serious real-life constraints that counteract their supposed flexibility. FAA tests revealed the need to ask for as few alternatives as possible.

5. Airlines that have many slots will receive a disproportionate share of slots during the prime hours and get an advantage in increasing their service measure.

A limit is now placed on the number of slot requests that each airline can make in any hour. This limit is proportional to the total number of slots allocated to the airline. FAA tests revealed that this limit should be applied only for the problem hours.

6. A slot auction offers overwhelming advantages.

The objective of this paper was not to debate the relative merits of alternative allocation methodologies but rather to set forth one of many alternatives and stimulate public discussion thereof.

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Method for Forecasting General Aviation Activity

FRANK R. WILSON AND HAROLD M. KOHN

This paper describes a study of the method used to develop demand-estimation models for itinerant and local movements of general aviation aircraft. The study area consisted of seven airports in the Maritime Provinces of Canada (New Brunswick, Nova Scotia, and Prince Edward Island). Confidential data on aircraft movements were made available from the Aviation Statistics Centre for this study. Econometric models were developed for each airport separately, and one system model was developed for all traffic that flows on the 49 links between the seven airports. The approach used generation-distribution-type models in contrast to the pure generation models attempted by others and found to be only marginally successful. Cross-section demo-