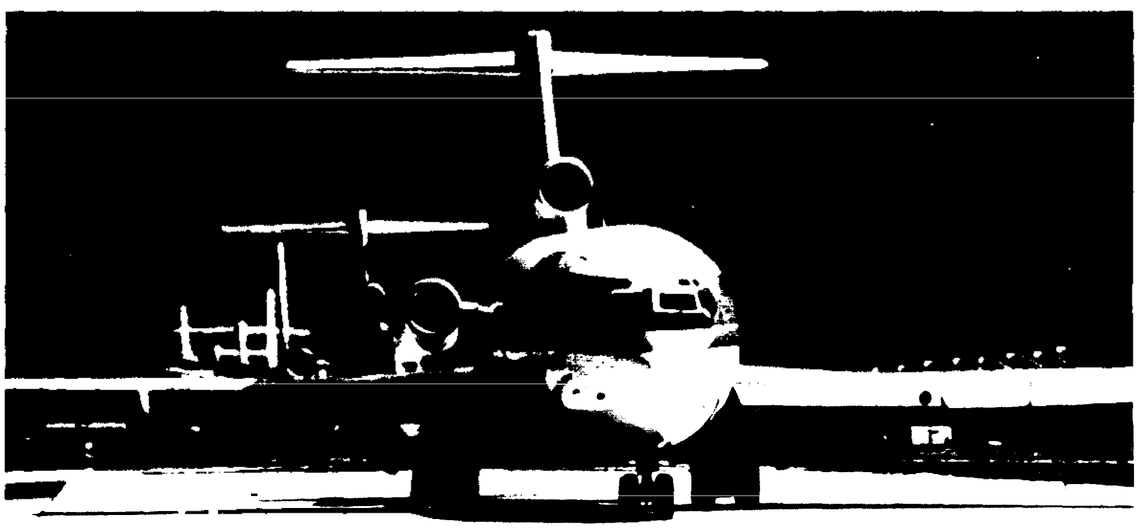
Chapter 3

THE PROBLEM OF CAPACITY AND DELAY



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THE PROBLEM OF CAPACITY AND DELAY

A major concern of airport users and operators is delay. Flights cannot be started or completed on schedule because of the queue of aircraft awaiting their turn for takeoff, landing, or use of taxiways and gates at terminal buildings. These delays translate into increased operating costs for airport users and wasted time for passengers. The cause for this delay is commonly referred to as a "lack of capacity," meaning that the airport does not have facilities such as runways, taxiways, or gates in sufficient number to accommodate all those who want to use the airport at peak periods of demand.

The solutions generally advocated by airport operators, airlines, and the Federal Aviation Administration (FAA) are to build additional facilities at crowded airports or to find ways to make more efficient use of existing facilities. The latter course is viewed as attractive because it requires less capital investment and avoids many of the problems associated with increasing the size of the airport and infringing on the surrounding communities. A third course advocated by some is not to increase capacity but to manage demand by channeling it to offpeak times or to alternate sites. The rationale underlying all these approaches is that capacity and demand must somehow be brought into equilibrium in order to prevent or reduce delay.

The relationship of capacity, demand, and delay is considerably more complex than the foregoing suggests. Before addressing solutions, it is necessary to look more closely at matters of definition and to examine how and where delays occur. It is also necessary to look at specific airports where delays are now being encountered to obtain a clearer picture of the severity of the problem and the points at which it could be attacked.

CAPACITY, DEMAND, AND DELAY

Capacity generally refers to the ability of an airport to handle a given volume of traffic (demand)—i.e., it is a limit that cannot be exceeded without incurring an operational penalty.1 As demand for the use of an airport approaches this limit, queues of users awaiting service begin to develop, and they experience delay. Generally speaking, the higher the demand in relation to capacity, the longer the queues and the greater the delay.

De Neufville explains the relationship of capacity, demand, and delay thus:

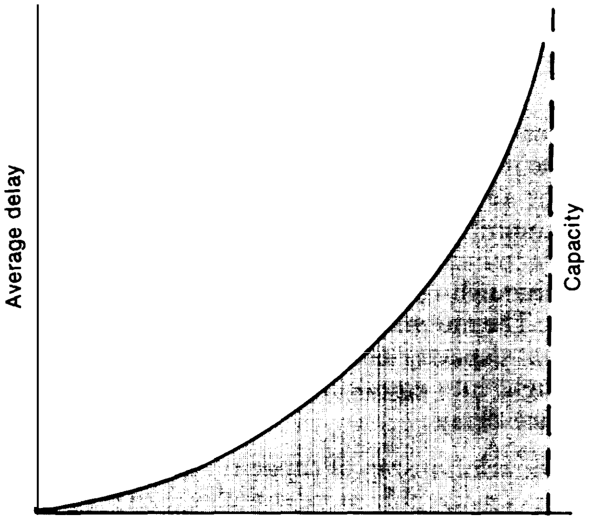
> The performance of a service system is, indeed, sensitive to the pattern of loads especially when they approach its capacity. The capacity of a service facility is, thus, not at all similar to our notion of capacity in everyday life, that is, the volume that a bottle or other vessel can hold. A bottle will accommodate any amount of liquid up to its capacity equally well; and after that, it can hold no more. A service facility, on the other hand, does not provide equal service at all times; its service rapidly deteriorates as traffic nears capacity. A service facility, can, furthermore, eventually handle more than its immediate capacity by delaying traffic until an opportunity for service exists.[2]

The illustration of this theoretical relationship in figure 4 shows that delay is not a phenomenon occurring only at the limit of capacity. Some amount of delay will be experienced long before capacity is reached, and it grows exponentially as demand increases.[3]

‘R. De Neufville, ***Airport Systems*** Planning (London: Macmillan, **1976), p. 135.**

[3]The term congestion, referring to the condition where demand approaches or exceeds capacity, is not commonly defined in the technical literature and is used in this report only as a qualitative descriptor of a situation where demand is high in relation to capacity.

Figure 4.—Theoretical Relationship of Capacity and Delay



SOURCE: Office of Technology Assessment,

Capacity

There are two commonly used definitions of airfield capacity: "throughput" and "practical capacity. " The throughput definition of capacity is the rate at which aircraft can be handled—i. e., brought into or out of the airfield, without regard to any delay they might incur. This definition assumes that aircraft will always be present waiting to take off or land, and capacity is measured in terms of the number of such operations that can be accomplished in a given period of time. Practical capacity is the number of operations (takeoffs and landings) that can be accommodated with no more than a given amount of delay, usually expressed in terms of maximum acceptable average delay. Practical Hourly Capacity (PHOCAP) and Practical Annual Capacity (PANCAP) are two commonly used measures based on this definition.[4] PANCAP, for example, is defined as that level of operations which results in not more than 4 minutes average delay per aircraft in the normal peak 2-hour operating period.[5]

[4] ***Airfield and Airspace Capacity/Delay Policy Analysis,*** FAA-APO-81-14 (Washington, DC: Federal Aviation Administration, Office of Aviation Policy and Plans, December 1981).

[5] ***Airside Capacity Criteria Used in Preparing the National Airport pLAN,*** AC 150/5060-lA (Washington, DC: Federal Aviation Administration, July 1968).

Delay

Delays occur on the airfield whenever two or more aircraft seek to use a runway, taxiway, gate, or any other airside facility at the same time. One must wait while the other is accommodated. If all users of the airfield sought service at evenly spaced intervals, the airfield could accommodate them at a rate determined solely by the time required to move them through the facility.

Aircraft, however, arrive and leave not at a uniform rate but somewhat randomly, which means that delay can occur even when demand is low in relation to capacity. Further, the probability of simultaneous need for service increases rapidly with traffic density, so that the average delay per aircraft increases exponentially as demand approaches throughput capacity. When demand exceeds capacity, there is an accumulation of aircraft awaiting service that is directly proportional to the excess of demand over capacity. For example, if the throughput capacity of an airfield is 60 operations per hour and the demand rate is running at 70 operations per hour, each hour will add 10 aircraft to the queue awaiting service and 10 minutes to the delay for any subsequent aircraft seeking service. Even if demand later drops to 40 operations per hour, delays will persist for some time since the queues can be depleted at a rate of only 20 aircraft per hour.

Figures indicates the relationship between practical and throughput capacity. As demand approaches the limit of throughput capacity, delays increase sharply and, theoretically, become infinite when demand equals or exceeds throughput capacity. Practical capacity, which is always less than throughput capacity, is that level of airfield utilization which can be attained with no more than some acceptable amount of delay.

The acceptability of delay is the key to the concept of practical capacity. Unlike throughput capacity, which can be objectively determined by analysis of airfield components and traffic patterns, practical capacity is value judgment-a consensus among airport users and operators—about how much delay they can tolerate.

Although practical capacity is usually stated in terms of an average figure, the acceptability of

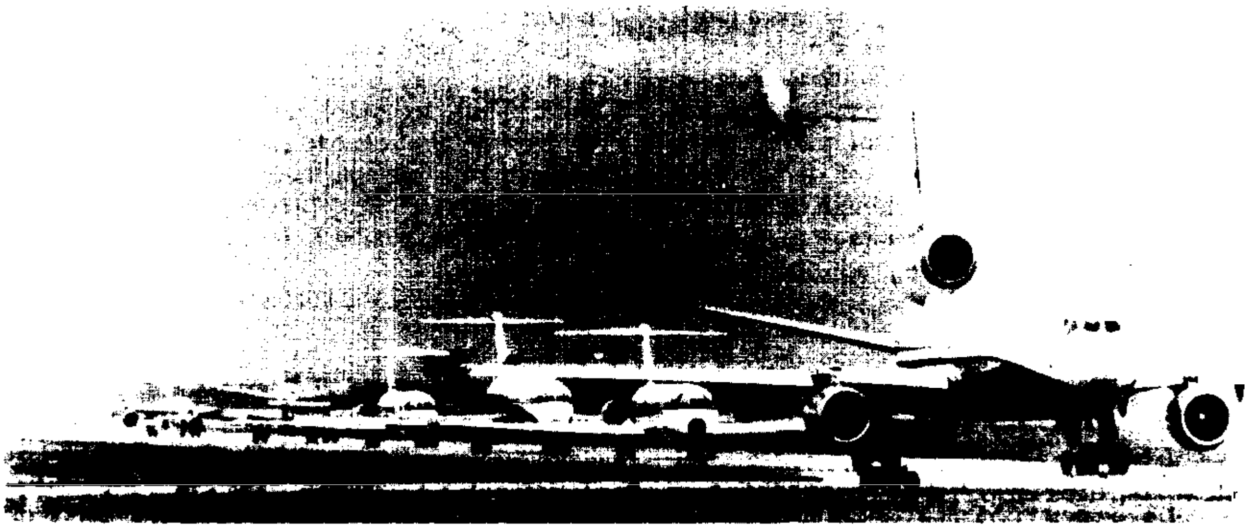
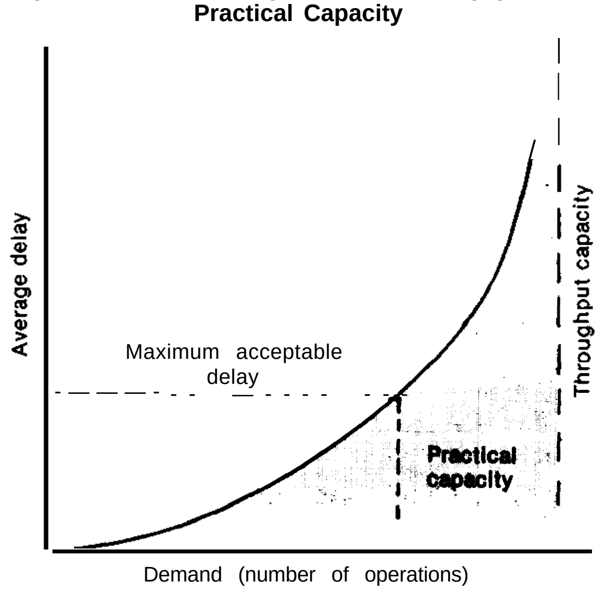


Photo credif Federa/ Aviation Administration

As demand approaches capacity, queues develop

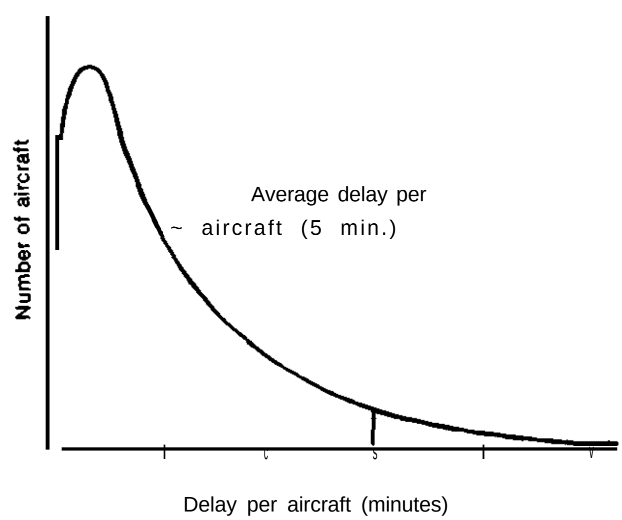
delay is actually determined not so much by the average but by the probability that the delay for a given aircraft will be greater than some amount. Just as demand tends to be nonuniformly distributed, so, too, is delay. Figure 6 shows a typical distribution of delays encountered by aircraft at a particular level of demand. Note that most delays are of short duration and that, even though the average delay is low (5 minutes), there are a few aircraft encountering relatively long delays of 15 minutes or more. Thus, while practical capacity is usually specified as that level of operations which—on average—will result in a given amount of delay, it is understood that the average implies that some percentage of delays will be considerably longer.

Figure 5.— Relationship Between Throughput and Practical Capacity



SOURCE: Office of Technology Assessment,

Figure 6.–Typical Probability Distribution of Aircraft Delay



SOURCE: **Office of Technology Assessment**

How much delay is acceptable? This is a judgment involving three factors. First, it must be recognized that some delay is unavoidable since it occurs for reasons beyond anyone's control—wind direction, weather, aircraft performance characteristics, the randomness of demand for service. Second, some delay, though avoidable, might be too expensive to eliminate—i.e., the cost of remedial measures might exceed the potential benefit. Third, even with the most vigorous and successful effort, the random nature of delay means that there will always be some aircraft encountering delay greater than some "acceptable" length. Thus, acceptable delay is essentially a policy decision about the tolerability of delay being longer than some specified amount, taking into account the technical feasibility and economic practicality of available remedies. [b]

[b] ***Airfie/d*** and ***Airspace Capacity/Delay Policy Analysis,*** op. cit.

FACTORS AFFECTING CAPACITY AND DELAY

The capacity of an airfield is not constant over time; it may vary considerably during the day or the year as a result of physical and operational factors such as airfield and airspace geometry, air traffic control rules and procedures, weather, and traffic mix. When a figure is given for airfield capacity, it is usually an average based either on some assumed range of conditions or on actual operating experience.

In fact, it is the variability of capacity, rather than its average value, that is more detrimental to the overall operation of an airfield. Much of the strategy for successful management of an airfield involves devising ways to compensate for factors that, individually or in combination, act to lower capacity or to induce delay. These factors can be grouped in five categories.

Airfield Characteristics

The physical characteristics and layout of runways, taxiways, and aprons are basic determinants of the ability to accommodate various types of aircraft and the rate at which they can be handled. Also important is the type of equipment (lighting, navigation aids, radar, and the like) installed on the airfield as a whole or on particular segments. For any given configuration of runways and taxiways in use, capacity is constant. Capacity varies, however, as configurations change,

Airspace Characteristics

The situation of the airfield in relation to other nearby airports and in relation to natural obstacles and features of the built environment determines the paths through the airspace that can be taken to and from the airport. Basically, the airspace geometry for a given airfield does not change over time. However, when there are two or more airports in proximity, operations at one airport can interfere with operations at another, causing the acceptance rate of one or both airports to suffer or requiring aircraft to fly circuitous routes to avoid conflict. In some cases, the interdependence of approach and departure paths for nearby airports can force one to hold departures until arrivals at the other have cleared the airspace or necessitate that each leave gaps in the arrival or departure streams to accommodate traffic at the other.

Air Traffic Control

The rules and procedures of air traffic control, intended primarily to assure safety of flight, are basic determinants of airfield capacity and delay. The rules governing aircraft separation, runway occupancy, spacing of arrivals and departures, and the use of parallel or converging runways can have an overall effect on throughput or can induce delays between successive operations. ATC rules and procedures have an especially important influence on capacity and delay at airfields where two or three runways may be in use at the same time or where there may be several arrival streams that must be merged on one final approach path.

A related factor affecting delay is the noise-abatement procedures adopted by FAA and by local airport authorities. These usually take the form of restrictions on flight paths over noise-sensitive areas or reduction (or outright prohibition) of operations during certain hours. These noise-control measures can have an adverse effect on capacity. For example, the runway configuration with the highest capacity may not be usable at certain times because it leads to unacceptably high noise levels in surrounding areas. Similarly, some noise-abatement procedures involve circuitous flight paths that may increase delays. The airport must thus make a tradeoff between usable capacity and noise control, with the usual result being some loss of capacity or increase of delay.

Meteorological Conditions

Airport capacity is usually highest in clear weather, when visibility is at its best. Fog, low ceilings, precipitation, strong winds, or accumulations of snow or ice on the runway can cut capacity severely or close the airport altogether. Even a common occurrence like a wind shift can disrupt operations while traffic is rerouted to a different pattern; if the new pattern is not optimum, capacity can be reduced for as long as the wind prevails. A large airport with multiple runways might have 30 or more possible patterns of use, some of which might have a substantially lower capacity than the others.

For most airports, it is the combined effect of weather, runway configuration, and ATC rules and procedures that results in the most severe loss of capacity or the longest delay queues. In fact, much of the effort to reduce delays at these airports, through airfield management strategy and installation of improved technology, is aimed at minimizing the disparity between VMC and IMC capacity. [7]

Demand Characteristics

Demand—not only the number of aircraft seeking service, but also their performance characteristics and the manner in which they use the airport—has an important effect on capacity and delay. The basic relationship among demand, capacity, and delay described earlier ***is*** that as demand approaches capacity, delays increase sharply. But, for any given level of demand, the mix of aircraft with respect to speed, size, flight characteristics, and pilot proficiency will also determine the rate at which they can be handled and the delays that might result. Mismatches of speed or size between successive aircraft in the arrival stream, for example, can force air traffic controllers to increase separation, thus reducing the rate at which aircraft can be cleared over the runway threshold or off the runway.

For any given level of demand, the distribution of arrivals and departures and the extent to which they are bunched rather than uniformly spaced also determines the delay that will be encountered. In part, this tendency of traffic to peak at certain times is a function of the nature of the flights using the airport. For example, at airports with a high proportion of hub-and-spoke operations, where passengers land at the airport only to transfer to another flight, the traffic pattern is characterized by closely spaced blocks of arrivals and departures. Accommodating this pattern can cause much greater delays than if arriving and departing flights are spread and more uniformly intermixed.

Photo credit Federal Av/a//on Administration

Much delay is in the terminal

[7] Visual Meteorological Conditions (VMC) are those in which atmospheric conditions permit pilots to approach, land, or take off by visual reference and to see and avoid other aircraft. Instrument Meteorological Conditions (IMC) are those in which other aircraft cannot be seen and safe separation must be assured solely by ATC rules and procedures. Under IMC, pilots must also rely on instruments for navigation and guidance to the runway.

MEASUREMENT OF DELAY

FAA regularly collects and analyzes data on delay, which are maintained in four data bases.[8] The most extensive data base is that maintained by the National Airspace Command Center (NASCOM). It is made up of daily reports from controllers at about 60 major airports and contains information on the number of delays, the time of beginning and end, and judgments by controllers about the primary and secondary causes. The principal value of NASCOM is that it allows FAA to monitor general trends of delay at major airports on a continuous basis. The subjective nature of controller reports limits the value of NASCOM data in analyzing the causes of delay.

The Standard Air Carrier Delay Reporting System (SDRS) contains reports from American, Eastern, and United Air Lines on their entire systems and at 32 specific airports (about 13 percent of all air carrier operations). SDRS provides data on the flight phase where delays are incurred (taxi-out, taxi-in, at gate, and airborne), measured against a standard ground time and a computer-projected flight time. The cause of delay is not reported. Like NASCOM, SDRS is used principally to monitor trends in delay on a daily basis.

The Performance Measurement System (PMS) is similar in structure to NASCOM, except that it is maintained manually rather than on a computer. Delays of 15 minutes or longer are reported by controllers at about 20 airports. A fourth delay monitoring system, developed by the FAA Office of Systems Engineering Management (OSEM), uses data from the Civil Aeronautics Board on operational times actually experienced by air carrier flights. Delay is measured by OSEM as the difference between an arbitrary standard flight time and the actual time reported for each flight.

All of these delay measurement and reporting systems suffer from basic faults. NASCOM and PMS are based on controller reports, and the quality and completeness of reporting vary considerably with controller workload. Further, NASCOM and PMS include only the longer delays (30 minutes or more for NASCOM, 15 minutes or more for PMS).[9] Since delay is a highly skewed distribution, measuring only the "tail" of the distribution produces a distorted picture of the incidence and magnitude of delay. It is impossible to infer the true value of average delay from such extreme statistics, and both NASCOM and PMS probably exaggerate mean delay by a substantial margin.

All four FAA data bases measure delay against the standard of flight times published in the Official Airline Guide. This, too, probably results in an overestimation of delay since there is wide variation in the "no-delay" time from airport to airport and, at a given airport, among various runway configurations. Many operations, when measured against a single nominal standard, are counted as delays but are, in fact, within the normal expectancy for a given airport under given circumstances. There may also be a distortion in the opposite direction. Most airline schedules—especially for flights into and out of busy airports—have a built-in allowance for delay. In part this is simply realistic planning, but there is also a tendency to inflate published flight times so as to maintain a public image of on-time operation,

Finally, all the delay measuring systems incorporate whatever delay may be experienced en route. Delays en route may not be attributable to conditions at the airport; and including them in the total for airports probably leads to overestimation.

While it is clear from the data that delays do occur at many airports, it is probably true also that actual delay is not as great as FAA data bases indicate, either in terms of the number of aircraft delayed or the average length of delay. The following estimates, based on FAA data, should therefore be interpreted with caution. They afford the best available picture of the pattern of delay,

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‘*Airfield and Airspace Capacity/Delay Policy Analysis,* op. cit., pp. 32-35.

‘At the beginning of 1982, the threshold for reporting delay in the NASCOM system was lowered to 15 minutes. While this makes the NASCOM and PMS data bases more compatible, it prevents direct comparison with NASCOM data from previous years when only delays of 30 minutes or more were reported. As a rule of thumb, FAA estimates that changing the definition of reportable delay from 30 to 15 minutes increased the number of recorded delays by a factor of between 2 and 3.

but they almost certainly overstate the length of average delay and the number of air carrier operations affected. It may also be that, because some are based on subjective reports, the cause of delay is not correctly attributed. '"

NASCOM data for 1976 through 1983 (table 9) indicate that, through the first half of 1981, roughly 80 percent of all delays were due to weather, which either forced temporary closing of the airport or required that operations be conducted under Instrument Flight Rules (which usually entail greater separation than under Visual Flight Rules) in order to assure safety. The next largest category of delay was also weather-related (weather and equipment failures), typically occurring when landing aids required for instrument operations malfunction or are otherwise unavailable at a time when visibility is reduced by rain, fog, or snow. Delays caused by traffic volume in excess of throughput capacity typically accounted for about 6 percent of all delays reported by NASCOM. Nearly all volume-related delays (over 95 percent) were at the departure airport.

Since 1981, the pattern of causality suggested by NASCOM data is somewhat confused by two factors. First, the requirement for reporting delays to NASCOM was lowered from 30 to 15 minutes. Thus, part of the sharp increase in the number of delays in the past 2 years is simply an artifact of the reporting procedure. FAA estimates that this factor alone has led to as much as a threefold increase in the number of reported delays. A second factor contributing to more reported delays is the imposition of flow control procedures by FAA, initially to cope with the effects of the strike by air traffic controllers in August 1981 and now to prevent overloading of certain airports at peak periods. Flow control delays (which are volume-related delays) accounted for over half of all delays in 1982 and were running at slightly less than one-quarter of all delays for the first 6 months of 1983, Flow control shifts the phase of flight where delays occur, under the rationale that

[10]As pointed out earlier, the discussion here focuses on airfield delays encountered by air carriers, primarily because this is the only type of airport delay on which data are collected on a nationwide and continual basis. Delays experienced by noncommercial flights (general and business aviation) are probably of comparable magnitude and similarly distributed, but there are almost no studies to support this. De Neufville (in *Airport Systems Planning*, op. cit., pp. 135-139) presents a general discussion of the difficulty of measuring capacity and delay and notes the inadequacy of commonly employed measurement techniques. He also describes factors that affect estimation of capacity and delay in passenger facilities such as moving sidewalks, baggage conveyors, mobile lounges, and on-airport transit.

Table 9.–Air Carrier Delays Reported to NASCOM, 1976-83

	1976	1977	1978	1979	1980	Jan.-July 1981[a]	1981[b]	1982[c]	Jan.-June 1983[c]
Total delays.	36,196	*39,063*	52,239	61,598	57,544	39,24'/	95,352	322,321	IUY, [81
Percent due to:									
Weather	76	*83*	79	84	78	80	46	35	63
Equipment failures.	4	*2*	7	3	4	4	3	1	1
Weather and equipment failures . . .	11	*5*	3	4	6	5	3	1	3
Runway closed for construction	1	*3*	3	3	3	1	1	1	2
Traffic volume[d].	5	*2*	5	4	4	6	3	4	8
Other causes.	3	*4*	3	2	5	3	45	1	0
Flow control[e].	—	—	—	—	—	—	—	57	23
Total air carrier operations (millions) . . .	*9.57*	*9.88*	10.21	10.33	9.96	4.94[f]	9.34	9.16	4.85[f]
Delays (per 1,000 operations)	*3.8*	*3.9*	5.6	6.0	5.8	7.9	10.3	35.2	22.7

[a]The period before the air traffic controllers' strike in August 1981.
[b]Data distorted by the effects of the air traffic controllers' strike and the imposition of quotas at 23 major airports.
[c]Data not comparable with previous years because the threshold for reporting delays to NASCOM was lowered from 30 to 15 minutes
[d]Almost exclusively departure delays.
[e]Delays due to flow control were counted as "other causes" in 1981 and in a separate category thereafter.
[f]Estimated.

SOURCE: FAA National Airspace Command Center (NASCOM).

it is less wasteful of fuel and less burdensome on the ATC system to have delays on the ground at the departure gate than in the air at the arrival airport. Despite the high incidence of flow control delays, the NASCOM data for 1983 indicate that weather-related delays still accounted for about two-thirds of all delay.ll

Table 10, based on SDRS data, shows the distribution of delays by the phase of flight where they occur. While the average delay per flight has remained surprisingly constant over the 7-year period, the effects of flow control in 1981 and 1982 are evident. Airborne arrival delays have been cut nearly in half compared with 1976-80, and taxi-out (departure) delays have been correspondingly increased.

Table 11, also drawn from SDRS, shows the distribution of delay times by flight phase for a typical month in 1982. Average departure delays (gate-hold plus taxi-out) were 6.7 minutes, and average arrival delays (airborne plus taxi-in) were 4.5 minutes. Since roughly 96 percent of all flights encountered no delay at the gate, it can be inferred that the principal point of delay was in the taxi-out phase, where about one flight in five encountered delay of **10** minutes or longer. Similarly, about 55 percent of delayed arrivals were at the gate within **10** minutes of scheduled time and 93 percent were no more than 20 minutes late, with the delay about equally distributed between the airborne and taxi-in phases.

*'Some of these weather delays occur at airports where the runway configuration is inefficient for certain combinations of wind, visibility, and precipitation. This is an airport design problem, and at certain locations it may be possible to lessen weather delays by building new runways or otherwise changing the runway layout so that the airport is less vulnerable to meteorological conditions.

Table 11 .—Distribution of SDRS Delay Time by Flight Phase, September 1982

Minutes of delay	Percent of operations delayed by flight phase			
	Gate-hold	Taxi-out	Airborne	Taxi-in
0	95.7	8.7	55.8	18.2
1	0.3	8.9	7.9	27.5
2	0.2	11.8	7.0	22.8
3-4 : ; : : :	0.5	23.2	11.4	21.9
5-9	1.0	29.2	12.5	7.5
10-14	0.7	10.6	3.7	1.2
15-19	0.5	4.1	1.0	0.5
20-24	0.3	1.7	0.4	0.2
25-29	0.3	0.8	0.1	0.1
30-44	0.4	0.7	0.2	0.1
45-59	0.1	0.2	0.1	0
60+ . : : : : :	0.1	0.1	0	0
Average delay (min.)	0.7	6.0	2.3	2.3

SOURCE: FAA Standard Delay Reporting System (SDRS)

Table 12 shows the mean delay at a sample of busy airports in 1982, when the average delay systemwide was slightly less than 6 minutes per operation. Delays at the 27 airports in the sample ranged from 3.5 to 9.9 minutes per operation. The average delay at most airports was of short duration, 7 minutes or less, as measured against the published schedule. Further, table 12 shows that mean delay is roughly correlated to the level of operations; the airports with the greatest mean delays tend to be those with the highest ratio of actual operations to PANCAP. Thus, while delay affects a large number of flights at the busier airports, the average delay at these airports is relatively short—7 minutes or less at all but seven airports, which is less than **10** percent of the average operating time of a flight from gate to gate.

Delay averaging, however, can be deceptive, in that it may diminish the apparent severity of the problem. Combining data for peak and slack

Table 10.–SDRS Trends, 1976-82

	Average delay per flight (minutes)						
	1976	1977	1978	1979	1980	1981	1982
Flight phase:							
Gate-hold.	0.06	0.12	0.12	0.12	0.17	0.57	0.84
Taxi-out	4.46	4.51	4.78	5.06	5.10	6.00	6.25
Airborne.	4.28	4.27	4.36	4.40	4.13	3.17	2.50
Taxi-in	2.16	2.23	2.41	2.57	2.43	2.25	2.23
Average per flight	10.96	11.13	11.67	12.15	11.83	11.99	11.91
Average per operation.	5.48	5.57	5.84	6.08	5.92	6.00	5.96

SOURCE: FAA Standard Delay Reporting System (SDRS).

Table 12.—Delay at Selected Airports, 1982

Airport	Mean Delay (min. per operation)	Operations	Ratio of operations to PANCAP[a]
Kennedy (JFK)	9.9	312,245	1.15
La Guardia (LGA)	9.5	307,719	1.25
Dallas-Fort Worth (DFW)	8.8	457,403	0.82
Chicago O'Hare (ORD)	7.8	591,807	0.96
Boston (BOS)	7.5	296,405	0.98
Los Angeles (LAX)	7.2	473,470	1.06
Washington National (DCA)	7.1	304,276	1.11
Newark (EWR)	6.9	215,026	0.77
Houston (IAH)	6.6	338,789	1.13
Denver (DEN)	6.4	467,508	1.32
Atlanta (ATL)	6.2	565,584	1.20
Miami (MIA)	6.2	349,368	0.88
Philadelphia (PHL)	6.1	328,313	1.11
Orlando (MCO)	6.0[b]	149,134	0.51
San Francisco (SFO)	5.8	315,003	0.79
Detroit (DTW)	5.7	250,481	0.53
Honolulu (HNL)	5.5	305,992	0.58
Phoenix (PHX)	5.3	350,995	1.06
St. Louis (STL)	5.0	289,826	1.16
Tampa (TPA)	5.0	244,467	0.69
Pittsburgh (PIT)	4.8	295,960	0.51
Las Vegas (LAS)	4.5[b]	296,256	0.90
New Orleans (MSY)	4.4	193,504	0.70
Seattle (SEA)	4.1	212,287	0.64
Fort Lauderdale (FLL)	4.1[b]	244,237	0.57
Minneapolis-St. Paul (MSP)	3.8	265,329	0.74
Cleveland (CLE)	3.5	208,436	0.71

[a]Practical Annual Capacity.
[b]Average for 3 months only (October, November, and December 1982).
SOURCE: FAA Standard Delay Reporting System (SDRS).

periods, obscures the impact of delay at times of heavy demand. If delays at peak periods alone were examined, delay would be longer, and there would be a much greater incidence of extreme delays of 30 minutes or more.

Table 12 also reveals an interesting aspect of PANCAP, which is defined as the level of operations that produces no more than 4 minutes average delay per aircraft in the normal peak 2-hour operating period. Practical Annual Capacity does not necessarily mean that the airport cannot accommodate more operations or even that congestion has reached an intolerable level. Actual operations at 10 of the airports in the sample exceeded PANCAP by a margin of up to 32 percent without delay running appreciably longer than the systemwide average of 6 minutes, except for the extreme cases of Kennedy and La Guardia.

Operating experience such as this suggests that PANCAP is an unnecessarily low measure of practical capacity and that estimates of future capacity needs based on the ratio of actual operations to PANCAP tend to be inflated. FAA itself considers PANCAP not as a limit of acceptable delay but as a warning signal that an airport is approaching a congested condition and that action may have to be taken to increase capacity. In the National Airspace System Plan, for example, FAA's estimate of future airport capacity needs is based on 140 percent of PANCAP, i.e., when operations at an airport reach a level of 40 percent above PANCAP, the airport is considered to have "severe airside congestion"—a term not otherwise defined. Other sources at FAA have indicated that the upper limit of tolerable delay may not be reached until operations are at 190 percent of PANCAP, at which time mean delay per peak-period operation would run nearly 20 minutes. But even this may not be absolute. Tolerability is, after all, an essentially subjective judgment about the cost imposed by delay.

Photo credit: U.S. Department of Transportation

Airport access is another source of delay

A related, and more general, observation is that the present methods of measuring capacity and delay are not adequate. The absolute capacity of an airport, or its parts, cannot be determined except by computer simulation or measurement of an asymptote on a graph. The extreme condition of unlimited demand and infinite delay can be assumed theoretically, but never observed. The data bases themselves are partial and highly selective at best. There are virtually no published empirical studies of delay for all types of flights, much less delay encountered by passengers in all segments of an air trip (travel to and from the airport, in the terminal, and during the flight). Thus, it is difficult to quantify, except in the most general and inexact terms, the extent and severity of airport capacity and delay problems.

Cost of Delay

A 1981 FAA study attempted to estimate the cost of delay to air carriers and the extent to which this cost could be avoided.[12] FAA calculated the total delay cost in 1980 to be about $1.4 billion, based on 5.9 minutes average delay per operation systemwide, at a cost of $1,398 per hour. Of this delay, FAA estimated that about one-third was attributable either to weather or to unavoidable queuing delays at peak operating times. Subtracting these delays left about $904 million in potentially avoidable delay costs for airline operations in 1980, or about $89 per flight.

The FAA study also calculated future delay costs that would result if air traffic continues to grow and no remedial actions to reduce delay were undertaken. FAA estimated that by 1991 average systemwide delay would increase to 8.7 minutes, with annual delay costs to airlines reaching $2.7 billion (1980 dollars). Deducting unavoidable delays due to severe weather and queuing, FAA estimated that $1.7 billion per year might be subject to control. For the average flight, the cost of unavoidable delays would rise from $89 to $125, an increase of 40 percent, but still not much more than the average price of one airline ticket.

OTA finds these estimates to be reasonable, but probably near the high end of the range. For the

[12] *Airfield and Airspace Capacity/Delay Policy Analysis,* op. cit.

reasons cited above, FAA data bases tend to overestimate delay. Because of the skewed distribution of delay and the inaccuracies in the various reporting systems used by FAA, it is difficult to fix the magnitude of the overestimate, but it may be on the order of 25 to 50 percent. Thus, actual systemwide 1980 delay costs may have been between $0.7 billion and $1.4 billion, with the avoidable costs ranging from $0.5 billion to $0.9 billion.

A second reason for treating the FAA estimates with caution has to do with the tolerability of delay costs–either total costs or those defined by FAA as subject to control. The FAA report rightly points out that much of the avoidable delay results from airline scheduling practices. Airlines operations peak in part because of public demand to travel at certain times of day. However, another equally important cause of peaking is airline competitive practice and concern about losing market share to other airlines offering service at popular times. Airlines also concentrate arrivals and departures of flights to capture connecting passengers for their own airline. Presumably airlines find the delays caused by such practices tolerable since they continue to schedule operations in this way despite the cost. (Recall that all measures of practical capacity involve some judgment about what constitutes acceptable delay.) If, for the sake of illustration, delay of more than 15 minutes is assumed to be "unacceptable," the NASCOM data for 1982 show that only about 3.5 percent of flights were so delayed.

From this, one should not draw the conclusion that delay is an insignificant problem and that measures to increase airport capacity would be unwarranted. Delay is an important source of additional cost to airlines and passengers at the Nation's airports, and there is legitimate reason for concern about the future capability of airports to serve the expected increase of demand. The point is that there is not now a systemwide capacity crisis, nor perhaps even a crisis at the busiest air carrier airports, if crisis means intolerable delays. FAA data show that about 98 percent of all flights depart or arrive within 15 minutes of schedule.

Certainly, delays are being experienced, and they could increase as economic recovery leads to resumption of demand growth. If this increase cannot be accommodated, the air transportation system will suffer. But these problems are to some extent foreseeable and they can be managed, though not entirely eliminated, by a combination of the technological and administrative means which will be examined in later chapters.

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