*Abridgment*

# Relief of Congestion Delays at Major Airports

Herbert B. Hubbard, United Airlines

An airport system is congested whenever the actual demand is greater than the volume that the system can handle without delays or when one flight must wait for another flight. Airlines have developed reporting systems to measure the actual congestion delays by flight by comparing the actual times against standard times for each airport when there is no interference from other traffic. At least 85 to 90 percent of departure delays are due to holding for congestion in the terminal airspace or airfield at the destination.

The direct costs incurred by United Airlines for such congestion delays range from $36 to $38 million/year. The total industry costs are probably four to five times those for United Airlines alone, exceeding $150 million/year. Directly chargeable costs range from $5 to $25/min of delay for the various equipment types. This only includes crew time in excess of schedule, maintenance, and jet fuel (which is about 50 percent of all costs). The real costs of delay provide solid cost/benefit justification for improving procedures, instrumentation, equipment, and concrete. The total added jet fuel consumption for the industry, at 28 to 189 L/min (6 to 50 gal/min) for the various equipment types, probably exceeds 0.8 million $m^3$ (5 million bbl/year). This is a fruitful area for energy conservation.

The direct costs incurred by United Airlines at O'Hare International Airport are five times as great as those for the next most critical airports; therefore, United Airlines actively participated in the joint study by the O'Hare Delay Task Force composed of representatives of Federal Aviation Administration (FAA), airlines, and operators. This study provided the bases for several of the following examples and conclusions.

Figure 1 illustrates the underlying relations of average congestion delays during peak periods as a function of the ratio of demand to capacity. This curve is typical of many queuing situations; delay gradually increases as demand increases, up to an apparent knee in the curve. Beyond the knee, a small increase in demand results in a substantial increase in delay. Similarly, a reduction in capacity of only 5 to 10 percent can increase substantially the delay level for a constant demand. Congestion delays can be reduced by (a) limiting or controlling the demand during the peak period or (b) increasing the capacity of the system.

The actual traffic demand at O'Hare is approximately 17 movements/h until 6:00 a.m., 120 movements/h between 8:00 a.m. and 1:00 p.m., and 137 movements/h until 8:00 p.m., when the demand drops off.

The cumulative method of charting, shown in Figure 2, highlights the spread between the actual demand and the processed demand; the shaded area represents congestion delays. A major irregularity illustrated is the effect of a 40-movement/h reduction in capacity from 1:00 p.m. until 4:45 p.m. The horizontal lines show the delays incurred by individual flights, and the vertical line shows the backlog of 150 airplanes at 4:45 p.m.

The airlines have been accused of contributing to congestion delays by scheduling arrivals and departures on the hour or at 5-min intervals for the convenience of the traveling public. For example, up to eight flights have been scheduled to arrive at O'Hare at 3:59 p.m., considerably above the average capacity of 1.5 arrivals/min. Similar peaks occurred at 4:10 p.m. and 4:30 p.m. However, because of such factors as departure delays at the up-line stations and variations in en route winds, the actual arrival times in the O'Hare area vary considerably from scheduled times. As a result, the expected actual arrivals by minute vary from 1 arrival/min to a maximum of 1.8 arrivals/min. Because of the variations in actual arrival times, detailed analyses and simulations show that the nominal peaking of schedules contributes less than 1 min of delay per flight.

To determine the potential increase in delays at O'Hare that would be incurred under increased demand, the O'Hare Delay Task Force conducted a series of validated simulation runs. They established that an increase in demand of 10 movements/h, from 137 to 147, would increase the average delay by more than 45 percent under visual flight rules (VFR) conditions. In fact, the addition of only 1 operation at the 137 level raises the total system costs by at least $300 in delay to that flight and added delay to all subsequently affected flights. This imputed cost per added operation ranges from $100 to $600.

The best way to reduce congestion delays is to increase the effective airfield capacity or maximum throughput over a period of time. The capacity of an airfield varies directly with the number of independent runways in use and the average speed and varies inversely with the average in-trail separation, as shown in Figure 3. For example, an average separation between airplanes of 105 s [equivalent to 6.5 km (3.5 nautical miles) at an average speed of 62 m/s (120 knots)] would result in an effective capacity of 34 movements/h for one runway, 69 movements/h for two independent runways, and 103 movements/h for three independent runways. At most airports the runways are not independent of one another because of actual intersections or intersecting paths. The capacity of various runway pairs is dependent on the intersection distances, ranging from 12 to 55 departures/h, as the intersection changes from a far distance to a near distance.

The O'Hare Delay Task Force determined by a series of detailed simulation analyses (subsequently verified by actual operations) that the effective capacity of O'Hare ranges from fewer than 130 to more than 170 movements/h, depending on the runway configurations used. The average delay can be reduced from more than 10 min to 2 min or less with the increased capacity available from the better runway configurations. One of the best runway configurations utilizes parallel runways 27L and 27R for landing and parallel runways 32L and 32R and runway 22L for takeoffs. This is one of several triple departure configurations.

Because the capacity of a runway or an airfield varies inversely with the average in-trail separation, during recent years the dominant cause of reduced capacity and increased congestion delays has been the increase in separations required to avoid the turbulence of wake vortexes. According to FAA estimates, the average separation at O'Hare could be reduced by 12 s on approach and 8 s on departure when no wake vortex is detected in the approach and departure paths, for an overall increase in

Table 1. Congestion delays at airports.

| Critical Factors | Potential Improvements |
|---|---|
| Demand during peak period | |
| Limit | Instituting quota period during day, 1-h or 30-min periods, and arrival and departure limits |
| Control | Reporting of movements and delays, enforcing quota rules, and controlling flow during major disruptions |
| Effective capacity | |
| Runways, configuration, and usage | Selecting best (low delay) configuration for wind and weather conditions |
| Average in-trail separation | Installing wake vortex system and making other improvements (e.g., metering and spacing) |

Figure 1. Average congestion delays versus ratio of demand to capacity.

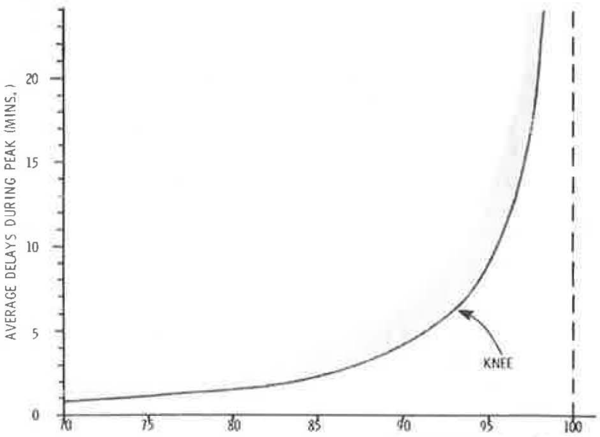
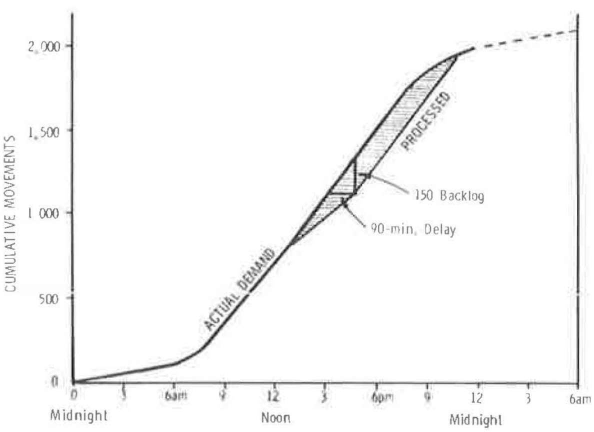
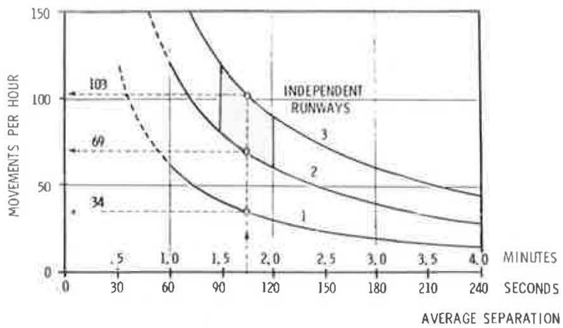



Figure 2. Cumulative traffic movement demand at O'Hare Airport.




capacity of approximately 15 percent. Because of the extreme sensitivity of delays to relatively small changes in capacity under peak demand conditions, the 15 percent increase in capacity could reduce the average delay at

Figure 3. Capacity dependent upon separation and runways.




O'Hare by over 50 percent under instrument flight rules (IFR) conditions. For this reason, the airlines are hopeful that the wake vortex detection system installed at O'Hare in 1976 on a test basis will be proved, expanded, and made operational during 1977.

Table 1 summarizes the findings of the O'Hare Delay Task Force—the critical factors affecting congestion delays and the areas for potential improvements. The greatest near-term payoffs can be realized by

1. Selecting the best (lowest delay) runway configurations for the existing wind and weather conditions;
2. Installing wake vortex detection systems similar to those installed at O'Hare for use with a manual system for reducing in-trail separations when wake vortexes are not a problem; and
3. Improving the systems for controlling traffic demand during the peak periods of the day by (a) more complete and detailed real-time reporting systems covering movements by runway and delays by hour, (b) enforcing the quota rules and not accommodating additional traffic when incremental delay costs would exceed a certain dollar value (e.g., $100), and (c) an effective and equitable system of flow control when disruptions are anticipated, including improved predictions of capacity for the coming period.

*Publication of this paper sponsored by Special Committee on Air Transport Activities of the Transportation Research Board.*