Air Traffic Control Performance Measurement in the Federal Aviation Administration

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The Federal Aviation Administration uses two manual systems to measure air traffic control system performance and is now in the process of developing a third, which uses its recently installed computer equipment to collect performance data. Our objective is to obtain insight and understanding about the utilization of capacity, the causes of air traffic delays, the magnitude of delays, and the the locations at which they occur so that air traffic control can be performed more efficiently. The first system, started in 1968, identifies aircraft delays of 30 min and where, when, and why they occur. The second system, implemented in late 1975 at major airports where delays occur, utilizes hourly airport runway capacity standards to assess performance when demand reaches or exceeds capacity. Performance is indicated by an index comparing actual aircraft services to a standard. The system also provides data on delays of 15 min or more, causes for delays, and substandard performance as measured by the performance index, runway utilization, and weather data. The third system, now in early stages of development and testing, will collect accurate delay data on aircraft flying into major airports. This delay data base will be the most comprehensive and accurate of the three systems and will provide total information on aircraft delay. Coupled with the data provided by the second system, it will give a sophisticated and accurate performance data base that will indicate system performance and areas for improving the air traffic control system.

The Federal Aviation Administration (FAA) uses two manual systems to measure air traffic control system performance. It is now in the process of developing a third system. The earliest measurement, the national airspace system communication (NASCOM), was started in 1968. It identifies all aircraft delayed over 30 min. In 1975 a second system, the performance measurement system (PMS), was implemented. It uses comparisons of deviations from runway capacity standards to measure performance. A third technique, automated delay measurement system (ADMS), using computers, is now being developed and tested.

NATIONAL AIRSPACE SYSTEM COMMUNICATION

NASCOM was established to provide timely performance data on several aspects of the air navigation system. One aspect studied was the amount of delay incurred at airports, in the surrounding airport areas, and in the en route airspace. Specifically, NASCOM

1. Measures the number of aircraft delays of 30 min or more,
2. Identifies the airport at which the delays occur,
3. Indicates whether the delays are experienced by departing or arriving aircraft,
4. Records the time period in which the delays occur, and
5. Pinpoints the cause of the delays.

Air traffic controllers collect the data manually as delays occur and transmit their findings daily to the FAA for review. The results over the years indicate that approximately 70 percent of delays occur at four major airports: Chicago O'Hare, John F. Kennedy, Atlanta International, and LaGuardia. The major cause of delays and fluctuation in the number of delays is adverse weather. Based on annual statistics, weather causes approximately 73 percent of delays. Other causes identified are such things as equipment failures, airport disruptions, and airport emergencies. NASCOM also shows that the majority of delays occur to arriving aircraft in the airspace surrounding busy airports. The NASCOM system serves as a good indicator of trends in delays and causes of delays.

PERFORMANCE MEASUREMENT SYSTEM

The PMS is based on standards for the hourly traffic throughput capacity of the airport defined for various runway configurations, weather conditions, and traffic mixes. Performance is measured by comparing the actual amount of traffic serviced to the engineered performance standards (EPSs). Many factors were considered in the development of EPS. First, a throughput capacity standard was defined as the number of aircraft that can be serviced in 1 h under specified conditions, assuming a continuous supply of aircraft without regard to the delay encountered. It does not indicate a specific amount of delay because delays are influenced highly by factors that are only partially controlled by the FAA, such as scheduling. This standard combines observed aircraft operating characteristics and air traffic control procedures over which the FAA has control.

The next step in developing EPSs was an identification of all of the major runway configurations used, the relevant physical characteristics of the runway layouts, and runway taxiway locations. Then, runway operating strategies were identified. These include such considerations as (a) Are the runways used for both arrivals and departures, or are they segregated by arrivals and departures? (b) Are there any restrictions on runway use dictated by type of aircraft or noise abatement? and (c) Does the weather influence runway usage? EPS development also reflects air traffic control operating procedures that influence arrival and departure separation aircraft under visual flight rules and instrument flight rules.

Since standards can be developed for a wide range of arrival and departure mixes, we selected a representative mix. An analysis of arrival and departure mixes during busy hours at the major airports included in the PMS showed that a 50:50 mix is representative. This, therefore, was used to develop the standard for all airports. We also needed to categorize aircraft by type and figure the percentage of each type of aircraft using the airport. We were interested in the size and performance characteristics of aircraft. The aircraft size (gross weight) indicates runway-use capabilities and dictates required aircraft arrival and departure radar separation distances, which must be maintained by an air traffic controller. Aircraft performance refers to landing and takeoff speed, which translates into times and corresponding longitudinal distances. Initial EPS focused on four categories of aircraft. Field investigation later indicated some generalizations could be made about aircraft size and performance characteristics; however, an individual mix by aircraft category was developed for each airport. An aircraft weighing over 136 054 kg (300 000 lb) has the most significant influence on capacity. These aircraft are called heavies and normally require extended separation distances for following aircraft because of wake vortex hazards.

Once the major factors that influence capacity were identified, we began development of the standards. First we quantified the probabilities of event occurrences and event restraint times for the various arrival and departure phases of flight. A probability of occurrence matrix of all possible arrival and departure sequences for the various categories of aircraft was developed for each configuration. Then for each possible combination an event restraint time, measured in seconds, was developed based on actual field measurement under peak traffic conditions. Restraint times are the times required for aircraft to perform an event that restrains the next aircraft from performing an event. For example, if a nonheavy aircraft is to depart after another nonheavy aircraft, the restraint time would be the time it takes the first aircraft to start its departure roll, lift off the runway, and fly a distance of 3.2 km (2 miles). The trailing aircraft is restrained from beginning its departure roll until the leading aircraft attains this distance.

A summation of the related probabilities multiplied by the appropriate restraint times divided into 1 h (3600 s) yields the capacity for a particular runway. If more than one runway is used, which generally is the case, and there are interdependent conditions (i.e., the operations on the one runway are influenced by the operations on the other, as in crossing runways), we follow the same process of using probabilities and restraint times to arrive at a standard.

The aircraft separation criteria used for developing EPSs were those required during radar conditions of 4.8, 6.4, or 8 km (3, 4, or 5 miles), depending on the size and sequence of the arriving and departing aircraft. However, on-site measurements indicate that 5.6 km (3.5 miles) is more realistic than the 4.8-km (3-mile) separation standard. The increased separation required behind heavy aircraft has made modification of the standard necessary. Capacity determination is based on the assumption that the demand is always ready to be served when there is time available to service the aircraft.

At the present time, capacity standards have been developed for 24 of the largest domestic airports. Approximately 160 sets of capacity standards have been developed for the various airport configurations. These sets include variations for four different weather conditions and reflect variations in runway use based on these conditions.

Although airports are unique with respect to airspace, runway, and taxiway design, most airports are developed from a basic set of components. Examples of these are single runways, parallel runways, intersecting runways, and high-speed turnoffs. Several patterns obviously emerged, and many of the standards at the various airports are similar for similar runway configurations when the type of traffic serviced is also similar.

The concept used to develop the standards is quite simple. Analysis showed that many of the factors analyzed and initially thought to have significant impact on capacity were later found to have little impact when the type of performance system being developed was considered. The major advantage of the approach is that it can accommodate changes in operating procedures quite readily without extensive data collection. The approach also reflects the practical aspects of measurement—only those factors that could be ultimately identified on an hourly basis during performance measurement were considered. A comparison of these PMS standards with those developed by more sophisticated techniques shows only minor differences.

Once we developed the EPS values, we could evaluate actual performance at the 24 selected airports. The airports were divided into three groups based on the level of traffic and NASCOM delays experienced.

Group 1 airports include Chicago O'Hare, LaGuardia, John F. Kennedy, Washington National, and Atlanta International. These airports have the most detailed performance reporting requirements. Each reports detailed operational, traffic, and weather information covering approximately 10 h/d. This time period includes the busiest hours of the day.

Group 2 airports include Boston Logan International, Cleveland Hopkins, Dallas-Ft. Worth Regional, Newark International, Los Angeles International, Miami International, Philadelphia International, Greater Pittsburgh, San Francisco International, and Lambert-St. Louis International. These airports report only delay data on a daily basis. On a quarterly basis they report detailed operational, traffic, and weather data for a 7-d period. The quarterly data yield traffic pattern, runway usage, and capacity data. These data are used for general analysis and to determine whether a group 2 airport should be moved into group 1.

Group 3 airports include Baltimore-Washington International, Port Columbus International, Detroit Metropolitan-Wayne County, Houston Intercontinental, Minneapolis-St. Paul International, Phoenix Sky Harbor International, San Antonio International, and Tampa International. These airports are not required to report any data. The standards are used for local operational evaluations and for planning. The airports are potential candidates for group 2 airport classification.

The group 1 airports experience most of the delays and have traffic demands that consistently reach or exceed capacity on an hourly basis. At group 2 airports demand only occasionally reaches or exceeds capacity, and at group 3 airports demand comes close to but rarely reaches or exceeds capacity. Below the specific types of data collected hourly.

1. The actual amount of traffic serviced (subcategorized by air taxi, air carrier and military, and general aviation),
2. Scheduled demand,
3. Runway configuration,
4. Weather conditions,
5. EPS,
6. Performance index (PI) when applicable,
7. Number of aircraft delayed 15 min or more, and
8. Causes of delays.

Our primary interest is in assessing the air traffic control system when demand challenges capacity; hence, the PI is calculated for an hour when scheduled demand is near or exceeds the EPS. The PI is the ratio of actual traffic services to the EPS. PIs are not calculated when demand is substantially lower than EPS, since this would not aid in measuring efficiency. When the hourly PI is 95 or less, a cause for the substandard performance index must be identified. This five-point buffer from 100 takes into account the minor deviations for which no perceptible cause can be identified and the approximations made in the EPS calculations. The detailed hourly data also facilitate analysis of the hourly operation.
For example, knowing the actual number of arrivals and departures allows assessment of actual performance regarding the 50 percent arrivals: 50 percent departures assumption used to calculate EPSs. Knowing the traffic mix by type of aircraft also aids in this assessment. In addition to being used for performance measurement, the EPS and hourly performance information is used on

a select basis for national air traffic flow control management on a real time basis.

Of major importance is that this system not only indicates when the system is experiencing delays, but also indicates how well the air traffic control system is operating on a continuous basis when demand is near capacity. Indications to date are that the overall system is very efficient. When airport traffic is near or exceeding capacity, the air traffic control system generally operates close to 100 percent of capacity.

AUTOMATED DELAY MEASUREMENT SYSTEM

The third performance measurement technique uses the computer systems (NAS Stage A) recently implemented in the 20 en route air traffic control centers across the United States and the automated radar terminal system (ARTS) III, which was implemented several years ago at major high traffic density terminals. The ADMS measures the actual airborne delay of aircraft flying into the major airports from the time an aircraft departs one airport to the time it arrives at its destination. In the other systems, the data were collected manually; in this system, the majority of the data will be collected by computer; only a small amount of data will be recorded manually. Off-line computer programs will produce data reduction and report summaries. Since arriving aircraft incur the major amount of delay, present plans are to record delay data only for aircraft arriving at the major airports. The basic initial computer programs for data extraction and reduction have been developed, and Chicago O'Hare has been selected as the first site for implementation, testing, and refinement.

Since initial testing, the system has been sent to several other major high-density airports where implementation is in process. At the present time at Chicago O'Hare, delays are measured for the majority of arrival aircraft from approximately 240 km (150 miles) out to landing. Delay measurement is accumulated in several phases of flight: (a) the en route airspace and (b) the airspace near the airport in a radius of approximately 32 km (20 miles).

In this system delays are calculated by identifying all the possible flight paths of aircraft to the various airport runways along with normal flight speeds for the various phases of flight. Using these data, a matrix of standard flight times is developed for each path. As an aircraft is tracked through the airspace, its actual flying time is accumulated and flight path identified. To indicate delay, the actual time is compared with the appropriate standard time.

Three output reports are now being tested. The most detailed includes data on every aircraft and identifies each aircraft by flight, flight path, landing runway, delay data, and relevant check point crossing times. The second report consists of hourly distributions of delay; it shows the number of aircraft delayed for various 15-min increments of delay through more than 60 min. It also indicates various delay averages and the number of aircraft serviced. The third report gives daily delay summaries.

This system will be refined, improved, and implemented at additional airports over the next year. The data produced will be used to measure delays and serve as a data base for analyzing delay-demand relationships and evaluating runway configuration efficiency, weather impact, and operating efficiency.

SUMMARY

As data collection technology has advanced, the FAA has progressed in its efforts to measure air traffic control system performance. The PMS gave new insight into airport capacity and system performance with regard to this capacity. After the development and refinement of the ADMS is complete, we will be able to obtain detailed and accurate data on delays. This has been made possible through the automated environment of the air traffic control system. Eventually, PMS and ADMS will be merged into one comprehensive data base. The joint ADMS-PMS data base will allow new in-depth analyses that will give additional insight into the air traffic control system and yield a better understanding of the magnitude of delays and their causes. This will allow improvements to the system to reduce delays and improve efficiency.

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