Measuring Airport Landside Capacity

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At the request of the Federal Aviation Administration (FAA), the Transportation Research Board (TRB) undertook to develop guidelines for assessing the landside capacity of individual airports. A special 18-member committee, representing airport operators, airlines, and airport planning and design professionals, directed and participated in this study. This paper reviews the study's principal findings and recommendations, presented in the final report published in September 1987. An airport's landside capacity is its capability to accommodate passengers, visitors, air cargo, ground access vehicles, and parked or parking aircraft. Of these, the broad demands of air passengers traveling between their homes, offices, and other points of departure to the aircraft—or in the opposite direction when their aircraft arrives and they deplane—are most important to judging capacity at most commercial service airports; and they are the focus of the study. Airport passengers, then, are in most cases the basis for measuring landside capacity. Nevertheless, at some airports employee access and parking, cargo operations, or aircraft servicing may become constraining. While airport operators, airlines, and passengers may often recognize when an airport's landside facilities and services are approaching the limits of their ability to accommodate additional demand, there are no generally accepted procedures and standards for judging airport landside capacity. Current FAA forecasts of more than 70 percent growth over the next decade in the annual number of airline passengers in the United States indicate that consistent bases for making decisions about operation and development of airport landside facilities will continue to be needed. Research to collect data on service conditions over the wide variety of airports, passenger markets, and airline operations should be undertaken to support development of landside service-level measures that can be used by airport operators, airlines, and the FAA to make consistent decisions about needs for airport facilities.

The Federal Aviation Administration (FAA) forecasts that the number of annual commercial air carrier enplanements will increase from their 1986 level of 409.6 million to 696.8 million by 1998, an average growth rate of more than 4.7 percent annually. Passenger enplanements by commuter and regional airlines are expected to grow even more rapidly—6.7 percent annually—from their 1986 level of 26.1 million to 56.9 million in 1998. While continuing trends toward higher aircraft passenger load factors and the use of aircraft with greater seating capacities may lead toward more modest growth in the number of aircraft operations, these forecasts presage greater demands than ever on the nation's commercial service airports.

To meet these demands, many airports must add new facilities or make better use of existing facilities, or do both. Airport management and local officials will be faced with tough decisions about airport use and expansion, decisions that must be made within a context of community concerns about airport-related noise and the broader economic consequences of jobs and commerce related to good air transportation. Airlines, operating in an often fiercely competitive postderegulation environment, want to maintain their freedom to operate their systems efficiently and economically. Air passengers are pleased with lower air fares but at the same time are increasingly vocal in their objections to delays and other perceived evidence of declining service standards. The FAA, responsible for assuring both the high quality of the nation's air transport system and free competition within the airline industry, must operate under broad policies intended to control government spending.

NEED FOR GUIDELINES

Regardless of their different perspectives, each of these groups needs an understanding of airport capacity. Reliable capacity estimates are essential to making informed judgments about how existing facilities can be used, when new facilities are needed, and what it may cost to take action on these judgments.

Unfortunately, airport capacity is a particularly complex problem, and there is no generally agreed-upon meaning of capacity. Even when operating at what many people might intuitively feel is a capacity limit, most parts of an airport could accommodate a few more cars or people or aircraft if some measure of speed, comfort, or safety were sacrificed. Demands fluctuate and are typically concentrated at certain times of day or in certain parts of the airport. Airport professionals have tried for years and with some success to come to grips with these problems (*1*).

An airport may be described in two parts: runways, taxiways, and air traffic control systems used by aircraft and their pilots make up the *airside*. Extensive research and practical experience have produced widely accepted procedures for assessing airside capacity in terms of numbers of takeoffs and landings that a particular airport's airside can safely and effectively handle in an hour (although adverse weather conditions can sharply reduce

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these numbers). The FAA sanctions these procedures, and they are used throughout the United States and in many other countries (*2*). Even so, airlines responding to traveler preferences and competitive pressures may schedule more flight operations during peak hours than some airports can accommodate under the best of conditions. The delays that may result from an airport's airside capacity problems can spread through each airline's system, to be felt far beyond the one busy airport, with consequences for the airlines' public image as well as their corporate profits.

No such generally accepted guidelines exist for measuring capacity of an airport's *landside*—the aircraft gates, terminal buildings, baggage services, parking structures, and ground access facilities used by passengers and cargo traveling by air, and by the businesses and employees seeking to offer air transport services. Crowded terminal waiting areas, queues at check-in and baggage claim areas, filled parking lots, and congested roadways may be among the more visible symptoms that demands on the landside are more than the airport can accommodate. When such symptoms influence airlines' ability to operate effectively and their customers' choices about travel and business, the consequences of landside capacity problems may be felt throughout the metropolitan area an airport serves.

The FAA requested that the Transportation Research Board (TRB) take a first step toward developing guidelines for landside capacity assessment. The TRB assigned staff and convened a special 18-member committee representing airport operators, airlines, and airport planning and design professionals to review current practice and recommend procedures for measuring an airport's landside capacity. The study, scheduled for approximately one year's duration, began in November 1985 (*3*).

The committee quickly found that even among experienced professionals in the field, there was often disagreement as to the precise meanings of many of the terms and concepts that underlie landside capacity measurement. They also found that the diverse interests involved in an airport's development, operation, and use make it difficult to reach agreement quickly.

Each airline schedules its own flights and chooses the types of aircraft to be used. However, a substantial degree of centralized management of airside operations is provided by the federal government's air traffic controllers. In many cases these controllers can act when they spot a capacity problem and thereby reduce or avoid serious consequences. Aircraft may, for example, be required to wait at their parked positions or on taxiways until congestion in the airside system is reduced to acceptable levels. Yet even with this centralized management and generally accepted ways of measuring airside capacity, many of the nation's busiest airports have recurring problems of passenger and aircraft delay because demand exceeds capacity during those periods when people want to travel.

Efforts to adjust demands to fit capacity require greater cooperation among competing airlines, airport operators, government agencies, and the public than can usually be achieved within the context of continuing and often intense political debate about free enterprise and local control. (Allocation of operations "slots" and coordination of competing airlines' schedules, two of the ways of that have been considered for avoiding excess delay, have possibly serious implications for the relative competitive advantage of the companies involved. The federal government is unable or reluctant to make decisions that affect local communities' prerogatives.)

The landside presents an even more difficult situation: The airport operator's ability to respond to landside problems is often restricted by long-term airline leases on terminal building space. There are large numbers of small operaters of services who also have leases and may not all hold similar opinions about how they would like the airport to operate. Individual consumers who are the users of a typical airport's landside present a wide variety of needs and concerns related to their ages, social and economic backgrounds, and reasons for travel. The local community may express mixed feelings about the airport, reflecting both the concerns of neighbors about aircraft noise and safety and the desire by the community for better air service and airport access. The federal government, responsible for the safe and effective overall operation of the air transport system, has very limited authority to deal directly with landside concerns.

When an airline wants to offer new or expanded service at an airport, federal interstate commerce laws generally require that the airport provide space for aircraft and passenger services. While a few communities have attempted to restrict airport use and airline operations (John Wayne Airport in Orange County, California, and Westchester County in New York are outstanding cases), airlines, the FAA, and these communities have avoided testing the legal validity of capacity restrictions by reaching out-of-court settlements about facilities' expansion and use. (Local noise control plans, prepared under FAA-administered programs, are considered an acceptable basis for limiting airline operations at an airport, an action that the FAA otherwise views as a probable violation of laws to protect interstate commerce and free enterprise.)

Some airport operators have seen the levels of activity at their airports explode as airlines establish new hub-and-spoke route structures. The revenues and jobs generated by such increased airline activity can be very attractive to the airport operator and local government, although needs for new facilities and complaints by the airport's neighbors who are exposed to increased noise may cause political problems.

Reflecting on the likely continuing growth of air passenger volumes and changes of airline route structures, the study committee quickly concluded that landside capacity measurement guidelines would indeed be useful. Appropriately crafted guidelines would give users the basis for measuring the landside capacity of an existing airport in a reliable and consistent manner so that airport operators and airlines could use results to discuss short-range solutions to problems as well as longer-range needs for facilities and operating policies, and airport planners and operations

professionals could use them to discuss facility construction and use decisions in the public forum. Developing such guidelines was the goal of the study.

LANDSIDE DECISION-MAKING CONTEXT

The context within which an airport's landside is managed is complex. There are multiple decision makers:

- the airport operator, which may operate as a quasi-private enterprise under local or state enabling legislation or as a government agency;
- the airlines;
- the public at large, operating as individual airport users (travelers and businesses using air transport services), airport neighbors, special interest groups, and local and state governments;
- the Federal Aviation Administration.

Each of these groups has concerns that may be immediate or span longer periods, extending as long as the ten- to twenty-year horizon often used in airport master planning and system planning analyses. Such decisions as those regarding facilities development, terminal area leasing, and facilities management are made over progressively shorter time spans, in response to information about the airport's past performance and expectations about future demands. These decision-making groups may not always agree about whether an airport is performing adequately or needs new facilities or operating policies.

Landside capacity measurement is necessarily a short-term activity. Assessment is intended primarily to yield a snapshot view of the airport landside's performance and how that performance may change in response to short-range changes in demand or operating practices. Measures of landside capacity are most meaningful with respect to periods of one to two hours, although the appropriate period may be as short as ten to fifteen minutes or as long as a day. Estimates of landside capacity with respect to longer periods inevitably involve assumptions about distributions of demand and operations—by time of day and from place to place throughout the airport—that limit the validity of the estimate.

Furthermore, landside capacity depends on how facilities are operated, so management action becomes an essential element of landside capacity measurement. Considering these management actions ties the capacity assessment process inseparably into longer-term airport facilities planning. A conclusion that landside capacity is inadequate can imply needs for new facilities, major changes in operating practices for existing facilities, and shifts in policy regarding growth of airport activity. Recognizing these needs and their potential financial, managerial, and community impacts may spur reconsideration of basic goals and expectations about what "adequate" landside capacity means, and may lead eventually to agreement among all parties that problems are well understood and that proposed solutions are reasonable. This is the most important end of airport landside capacity measurement.

DEFINING LANDSIDE AND LANDSIDE CAPACITY

The landside is a complex collection of individual functional components, such as ground access, parking, check-in, baggage claim, aircraft parking, and support systems (e.g., water supply, sewer, and power supply), that interact to serve air passengers and cargo moving between aircraft and origins or destinations within a large area served by the airport (Figure 1). The TRB study defined landside to include the apron parking areas. These areas require land that could otherwise be used for terminal buildings (rather than taxiways and runways), and their geometry directly influences facilities and equipment needed for moving passengers and cargo between aircraft and terminal buildings.

Landside capacity refers to the capability of these functional components (individually and working together as an airport system, including staffing and other operating policies that determine how facilities are used) to accommodate demands of passengers, visitors, cargo, ground access visitors, and aircraft. Demand characteristics include distribution of passenger arrivals over time, modes of travel to and from the airport, number of bags carried and checked, trip purpose, and myriad other factors. In the face of these demands, some components may become bottlenecks and cause crowding, delay, or other symptoms of inadequate capacity.

Because the landside and its capacity are so complex, the TRB study focused on passengers. Although baggage handling, cargo shipment, and aircraft storage and maintenance are important at all airports and may represent limits on landside capacity at some airports, the measurement of their influence on capacity remains a topic for future research.

Factors such as waiting time, processing time, crowding, and availability of passenger amenities for comfort and convenience are indicators of *service level.* Some of these factors are interrelated, and there may be others that are important at a particular airport. For example, the number of passengers waiting in a departure lounge depends on the size of the aircraft being served, when boarding begins, and how quickly boarding proceeds. The rate at which people can move from check-in counters to departure lounges may depend on how many people are in the corridor areas. In either case, conditions in the airport if a substantial fraction of the passengers are vacationers or elderly people may be quite different than if the travelers are mostly business executives or other frequent travelers. Conditions that may be judged acceptable for one situation may be completely inadequate for the other.

There are no generally accepted standards for describing service levels or judging adequacy of service at U.S. air-

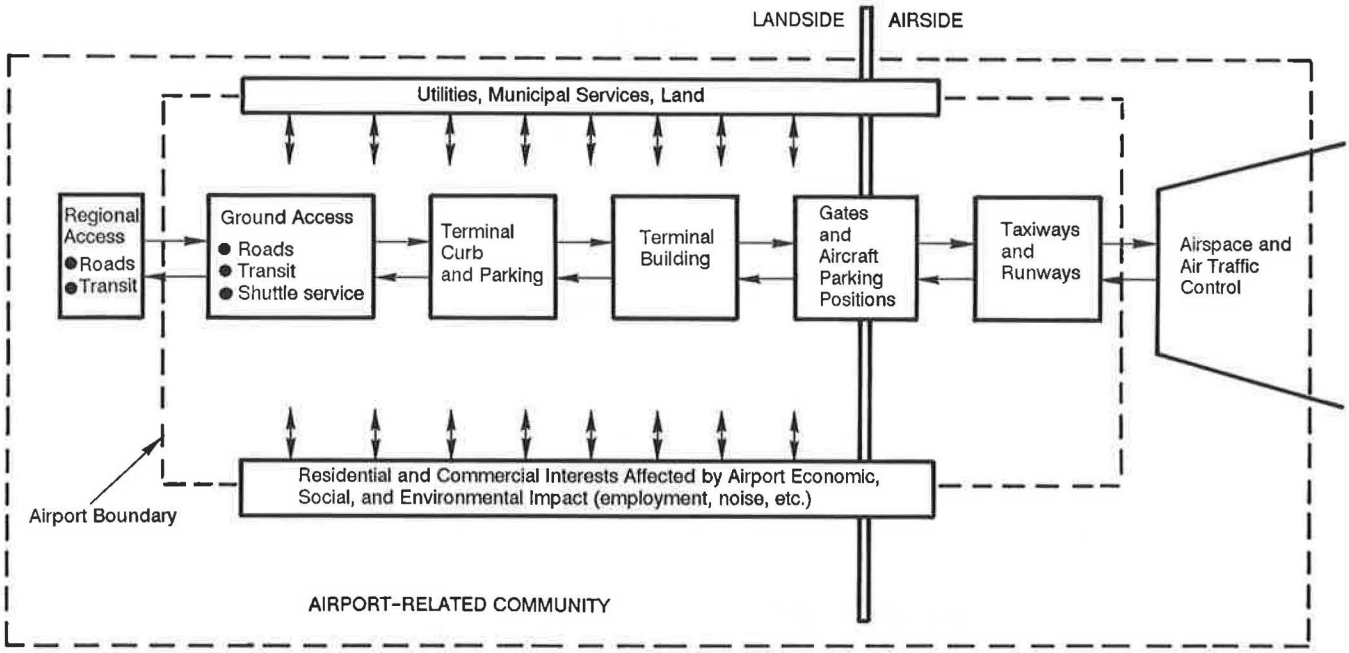

FIGURE 1 Airside and landside: functional view of the airport (*3*).

ports. Further, after extensive review of published reports and personal experience, and despite efforts to assemble field observations and expert opinion, the TRB study committee concluded that available data are inadequate for development of a single set of valid and defensible targets suited to the varied conditions encountered at different airports throughout the United States. Targets for desired or minimally tolerable service levels may be determined case by case, with participation of relevant decision makers at a particular airport; such targets may then become part of the measurement of landside capacity.

Passenger flow through a functional component or group of components is limited in principle by the maximum processing rate at which the component can operate. In practice, however, this maximum throughput is typically sustained for only brief periods of time, because excess passenger demand usually produces significant passenger delays, crowding, or other indications of declining service level that disrupt operations. Capacity is measured by a usually lower *service volume*, the number of passengers who can be accommodated in a given period of time at a given service level, given the pattern of demand placed on the components. Together, service level and service volume represent the "snapshot" view of the airport's landside performance. Whether this performance represents a limit of available capacity depends on the judgments of the various decision makers who are participants in the measurement process, and on the purpose for which the judgment is being made.

Limits are usually encountered only in a part of the airport, and only at particular times of day. Relatively minor changes in staffing practices or facilities utilization may improve service levels and relieve such bottlenecks. Sometimes service levels of components that feed passengers into the bottleneck component may be adjusted to improve the match between demands on these adjacent components and to improve overall service volume. For optimal use of facilities, all components would perform at similar service levels, assuming that such service levels can be defined in a consistent fashion for different types of components; usually, however, there are localized bottlenecks that limit landside capacity. (Determining what is inadequate service is often difficult without reference to specific situations.)

Airport operators may set service-level targets to guide assessment and decision making at their particular airports, taking into consideration the unique combination of passenger demand, airline operations, and community interests they face. Although Canada and some European countries have adopted service-level targets that may be adaptable to some U.S. airports (*4*), substantial research is needed to assemble a suitable database for the range of domestic airports and the airline operations and air travel markets they serve.

CAPACITY ASSESSMENT PROCESS

Measures of landside capacity may be needed to address a variety of airport management, planning, and design problems. The purpose for which a capacity assessment is made will influence the level of detail and focus of the assessment.

In the absence of generally accepted service-level targets, the process for assessing landside capacity must address both service levels and service volumes of landside components (see Figure 2). Passenger demands, as well as

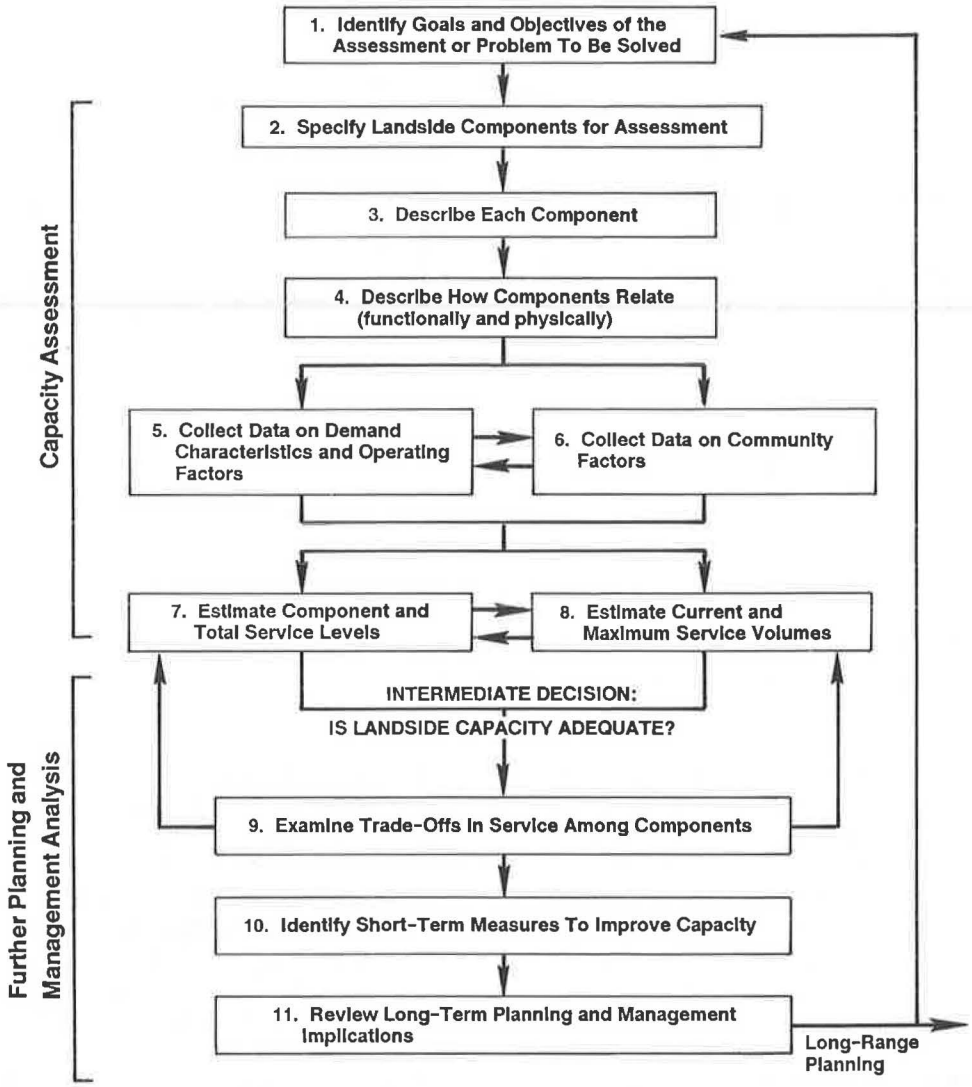

FIGURE 2 Landside capacity assessment, management, and planning process (*3*).

relevant airline and airport operating policies and procedures, must be known or assumed. Because service levels and service volumes are interdependent, and because an individual landside component may influence performance of other components and the landside system as a whole, interaction and feedback among steps in the assessment process are critical.

The ability of individual components to accommodate passenger demand is the basis for measuring landside capacity. For an existing or proposed set of facilities and operating characteristics that comprise functional components of the landside, the given patterns of demand determine which individual components may become bottlenecks at particular times of day or for particular parts of the airport. If these patterns of demand remain steady, a bottleneck may represent a limit on total airport activity. However, new demand might still be accommodated at other times or in other parts of the airport.

Assessments of individual components may be used to indicate capacity of the landside system as a whole, by calculating total service volume for the landside system when the capacity-constrained components are operating at their minimally acceptable target service levels. This system capacity measure is much less clearly identifiable than component capacity, however, because shifting the pattern of demand among components can improve service levels and service volumes. Determination of capacity for a group of components involves iteration and feedback to match services levels among the individual components.

All landside components are important to an airport's satisfactory operation, but not all are likely to cause passenger delay and crowding or to become significant in determining the airport's landside capacity. Public telephones, restaurants, restrooms, and newsstands are essential public amenities, yet they are seldom a basis for measuring capacity. The TRB study concentrated on

the following components as the most likely focus of most landside capacity assessments:

- aircraft parking positions
- passenger waiting area
- passenger security screening
- terminal circulation (primarily corridors, stairs)
- check-in (ticket counters and baggage check)
- terminal curb
- ground access
- automobile parking area
- baggage claim
- customs and immigration
- passenger transfer (primarily to connecting flights)

Community factors may influence landside performance and capacity and must be considered in the assessment process. In addition to air passengers, the community includes shippers and other airport users, neighboring residences and businesses, and state and local government. Airport management must work with this community, the airlines, and the FAA to operate and develop the airport to meet demand for aviation services.

When the community appreciates the benefits of the airport, its members may support airport management efforts to promote airport development to attract new users and economic investment in the region. If community members perceive that the benefits of meeting aviation demand are outweighed by such concerns as airport-related noise or highway traffic or the amount of land used for airport activities, however, they may seek to restrict airport operations or limit the airport's ability to invest and alter its facilities. The FAA's noise exposure planning procedures have helped to relieve the conflict among community goals that can become a landside limit on capacity at some airports, but continuing unrestrained land development around other airports threatens to lead to future problems.

If the snapshot assessment of landside capacity results in a decision that capacity is inadequate, analysis may continue within a context of ongoing management and planning. The first line of response to apparent capacity limitations is to search for ways to balance service among components or for other short-term solutions to improve capacity. For example, curbside congestion may be relieved temporarily by stricter enforcement of traffic regulations (recognizing that some airport users may view this as a loss of service quality) while changes in management of taxi dispatching and courier service access are implemented.

Serious capacity problems may require more major changes in facilities management or construction. Such actions cannot be accomplished within the short time frame during which capacity assessment is conducted and take the decision makers into the areas of long-term planning and management. Over the longer term, local and national economics, airline management, and interairline competition may produce changes in patterns of demand that seriously alter the airport's landside performance. The process of landside capacity measurement may then be repeated as part of the airport's ongoing management.

TOOLS AND PROCEDURES OF ANALYSIS

While many of the wide range of analytic procedures, mathematical models, and experience-based rules developed for airport planning and design may be adapted for landside capacity assessment, relatively few such tools are tailored specifically to answer questions about service volumes and service levels. Efforts to characterize landside components and their interaction have frequently applied mathematical queuing and network flow theories, leading to often complex, computer-based models. The declining costs of computers and their increasing availability and sophistication seem to be encouraging the development of newer, more easily used models of landside operations, but data requirements are still extensive and expensive.

The landside capacity analyst choosing procedures typically must strike a balance between simplicity, speed, and ease of use, on one hand, and more detailed and accurate representation of the facilities and services of interest on the other. Greater detail usually means greater need for data, more technically trained analysts, and higher costs. Although methods employing greater detail are generally presumed to yield more reliable results, this may not hold true for forecast data, which are inherently uncertain. Analytic tools and procedures are most useful when they help analysts and decision makers to understand better the sources of current problems and the possible consequences of selecting among alternative solutions to these problems.

Many of the analytic tools are applied to a single component within the landside system, and the level of sophistication in available tools varies substantially among the components the TRB study considered. Gate utilization analyses, for example, can be relatively sophisticated if one of the computerized simulation models now available is used. Analyses of curbside operations and airport road access can use procedures adopted from TRB's *Highway Capacity Manual* (*4*) or the Institute of Transportation Engineers. Passenger security screening, on the other hand, is often handled adequately with simple queuing models that are easily calculated by hand. A number of rules of thumb may be adapted from planning guidelines to yield quick estimates of potential landside capacity.

The great deal of interaction among components composing an airport's landside may be poorly reflected in capacity assessment that depends only on analyses of the individual components. To reflect better the landside's complexity, analysts have tried to develop complete simulations of the landside system as a whole. These models require computers and have had only limited success to date, although some government organizations and private consultants use them regularly. The advent of more pow-

erful, microcomputer-based, general purpose simulation languages and spreadsheet accounting packages that are also easier to use may lead to the development of new capacity assessment tools.

RESEARCH AND DEVELOPMENT NEEDED

TRB's *Highway Capacity Manual* was frequently cited in the TRB landside capacity study as the model for airport landside capacity guidelines. However, the TRB study was at best only a first step toward achieving such guidelines. The manual is a result of three decades and millions of dollars of research and development effort. Much remains to be done to produce a similarly effective guide to measuring airport landside capacity.

Current quantitative knowledge about landside operations and service levels is poorly developed. There are few statistics to support comparisons of landside performance among airports. Airline staffing and operating practices are seldom available. Research is needed to fill these knowledge gaps.

The TRB study highlighted four areas in which research could yield valuable results:

- collecting comparable and detailed data on passenger behavior and facilities utilization at a representative cross section of U.S. airports to provide a sound basis for developing service-level measures;
- collecting data on aircraft delay due to landside problems in a format comparable to that of data already collected on airside delays;
- continuing testing, refinement, and documentation of the procedures and measures for landside capacity analysis;
- testing and validating the overall assessment process presented in the TRB study.

The Canadian Airport System Evaluation (CASE) program (*5*) undertaken by Canada's Ministry of Transport and Communications is a model the TRB study concluded could be adapted to U.S. airports, despite differences in the two countries' regulatory and management environments of airports. Recommendations for the assessment process and needed research were made with this model in mind. The TRB study recognized, however, that there are major barriers to establishing a program of airport landside research and to adopting uniform procedures for landside capacity measurement, because no single agency or organization is responsible for the landside aspects of airports in the United States. In the absence of such a central focus of responsibility, the FAA could take the research lead.

CONCLUSION

Establishing common bases for discussion of airport landside capacity and an explicit process for measuring capacity represents a valuable first step toward definitive guidelines for capacity assessment, but much remains to be done. A database is needed to describe in common terms the operating conditions encountered at various airports throughout the United States. The FAA's records on aircraft delays should be expanded to include all flight delays attributable to landside as well as airside causes and other indicators of passenger service level. The database should represent the full range of different airports' travel markets, airline operations, airport sizes, and airport system roles. Such a database is essential for developing generally acceptable service-level targets for landside capacity assessment. If the United States' high-quality air transport system is to be maintained and future demand met, the means to make rational and consistent judgments about airport landside capacity must be developed.

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The author was project director for the airport landside capacity study, conducted in 1986–1987, and this paper is based on experience gained in that study. The views expressed herein, however, are those of the author and may not reflect those of the Airport Landside Capacity Study Committee or the Transportation Research Board.