# Analysis and Simulation of Regional Airspace

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The Chicago-region airspace system analysis conducted as part of the site selection phase of the Illinois-Indiana Regional Airport study is described. The analysis provided data on performance measures used to evaluate the five proposed alternative sites, from the airspace feasibility standpoint. A comparative analysis approach considering alternatives and scenarios was conducted using data generated from SIMMOD simulation. The region, nature of study, structure and characteristics of the region's airspace, elements of the analysis methodology, input data requirements and collection, simulation procedure, and interpretation of simulation output data are described and discussed. The performance measures used as criteria to assess the feasibility of the alternative airport sites from regional airspace system are discussed. Results of the analysis are presented, evaluation of performance measures on the airport and system levels are discussed, and the operational characteristics of the regional airspace system with each of the five alternative sites included are described.

The Chicago region defined by the study consists of nine counties in northeastern Illinois (Cook, Kane, Lake, McHenry, DuPage, Will, and Kankakee) and northwestern Indiana (Lake and Porter) (*1*). According to the National Plan for Integrated Airport System (*2*), the Chicago region (air traffic hub) consists of two primary airports (O'Hare and Midway), nine reliever airports, and five general aviation airports (see Table 1). Several of the region's public airports are included in the FAA Terminal Area and Hub Forecasts for Chicago (*3*).

The air traffic activity in and around the Chicago area is extensive. O'Hare is the busiest airport in the world and is a major U.S. hub for the United States' two largest airlines—American and United. The regional air traffic system is the crossroads of the east-west air traffic of North America. The sheer number of flights into and out of the airspace system dictates and limits the options available in the designing of necessary airspace modifications and the procedures required to accommodate a new major airport in the area. Table 2 lists aviation activities at some of the Chicago-area airspace air traffic control (ATC) facilities, the daily average, and their ranking in the United States. Chicago Air Route Traffic Control Center (ARTCC) and O'Hare Air Traffic Control Tower (ATCT) are the busiest in the United States, with daily average aircraft operations of 6,847 and 2,163, respectively (*4*). O'Hare Terminal Radar Area Control center (TRACON) is the second most active in the U.S. National Airspace System (NAS) with 3,233 average daily aircraft operations during 1989.

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## STUDY

The Illinois-Indiana Regional, or the Chicago Region Supplemental, Airport is the largest new airport development planning effort since Dallas–Fort Worth Regional Airport. The main objective of the site selection phase of the study, sponsored by the states of Illinois and Indiana and the city of Chicago, is to research factors relevant to selecting the site for a new major air carrier airport in the southern part of the greater Chicago area. The sites the study investigated are

- Gary Regional Airport, Gary, Lake County, Indiana;
- Lake Calumet site, Chicago, Cook County, Illinois;
- Peotone Site, near Peotone, Will County, Illinois;
- BiState Site, between Beecher, Will County, Illinois, and Cedar Lake, Lake County, Indiana; and
- Kankakee site, North of Kankakee, Kankakee County, Illinois.

The location of these five sites in the Chicago region and in relation to O'Hare International Airport is shown in Figure 1.

From an airspace standpoint, the feasibility of establishing another major airport in the Chicago area is largely dependent on the ability of the ATC system to accommodate the increased demand that a new airport's activity will impose on available airspace. The determination of feasibility must therefore be based on quantitative data that support the premise that an additional airport can fit harmoniously within the greater Chicago area and can coexist with other airports without compromising air safety, operational efficiency, and existing capabilities of the region's airport system. However, with the region's aviation demand forecast likely to exceed available capacity soon, this objective may be difficult to attain. Some of the conditions stipulated in the study require the new proposed airport to augment existing capabilities and not introduce an airspace environment that compromises the existing level of safety. Furthermore, air safety cannot be addressed independent of considerations of operational efficiency. If a proposed site dictates maintaining safety through the inordinate application of various techniques for accommodating the increased demand on the region (such as airborne and ground holding, delay or diversion routing, and increased separation intervals), the site's candidacy as a new major airport is suspect. In considering these criteria, the predicted activity of each existing airport within the greater Chicago area must be considered as well as that of the proposed airport. From an airspace perspective, the proposed airport should serve to ameliorate the capacity problems at Chicago's major airports without unduly diminishing the ca-

**TABLE 1 Chicago Region System Airports (1989) (2)**

| Airport | Classification[1] | Based GA Aircraft | Demand, Aircraft Operations | Nominal Capacity (ASV[2]) |
|---|---|---|---|---|
| Chicago O'Hare International[3] | PR_L | 2 | 797,000 | 841,000 |
| Chicago Midway[3] | PR_L | 292 | 257,000 | 330,000 |
| Lake in the Hills[3] | RL_BU | 136 | 94,000 | 108,000 |
| Waukeegan Regional[3] | RL_TR | 261 | 131,000 | 220,000 |
| Palwaukee[3] | RL_TR | 460 | 207,000 | 275,000 |
| Aurora Municipal[3] | RL_TR | 276 | 146,000 | 160,000 |
| DuPage County[3] | RL_GU | 470 | 217,000 | 160,000 |
| Lewis University (Romeoville)[3] | RL_BU | 243 | 74,000 | 155,000 |
| Lansing Municipal | RL_BU | 158 | 39,000 | 155,000 |
| Gary Regional[3] | RL_TR | 115 | 106,000 | 220,000 |
| Chicago Meigs Field[3] | CR_S | 4 | 6,000 | 240,000 |
| Clow (Plainfield) | GA_BU | 141 | 37,000 | 150,000 |
| Schaumburg[3] | GA_BU | 141 | 83,000 | 215,000 |
| Campbell (Round Lake Park)[3] | GA_GU | 90 | 18,000 | 220,000 |
| Joliet Park[3] | GA_BU | 81 | 59,000 | 215,000 |
| Frankfort | GA_BU | 162 | 38,000 | 150,000 |

Notes: (1) P= Commercial Service-Primary (L=Long-Haul, M=Medium-Haul, S=Short-Haul), CM= Commercial Service-Other, CR= Reliever Airport with Commercial Service, RL=Reliever (GU=general utility, TR=transport, BU= Basic Utility), GA= General Aviation.
(2) Annual Service Volume, in terms of aircraft operations
(3) Airports included in FAA Terminal Area Forecasts

pability of an existing facility. The proposed airport must therefore provide the capability to meet or exceed the increased demand forecast.

In establishing the ground rules for an airspace study of the magnitude of the Illinois-Indiana Regional Airport Study, considerable thought was given to past studies, the results expected, and a means of quantifying and measuring the outcome against known and established facts. The study team determined that to arrive at reasonable and valid conclusions regarding the impact of an additional major airport in the Chicago area, as much as possible of the total Chicago ARTCC airspace should be included in the study (*5*). It is also determined that a distance of 150 nautical miles (NM) from O'Hare airport would encompass most of the airspace pertinent to the study objectives. Problems involved with the integration of arrival and departure operations to and from the Chicago airports with high-altitude en route traffic are resolved outside this 150 NM airspace radius or resolved through traffic man-

**TABLE 2 Air Traffic Operations in Chicago Airspace (Total Aircraft Operations) (*4*)**

| Facility | Annual Operations | NAS Rank 1989 | Daily Average Operations |
|---|---|---|---|
| Chicago ARTCC | 2,499,252 | 1 (ARTCC) | 6,847 |
| Chicago O'Hare TRACON | 1,179,889 | 2 (TRACON) | 3,233 |
| O'Hare ATCT | 789,384 | 1 (ATCT) | 2,163 |
| Chicago Midway | 316,041 | 34 (ATCT) | 866 |
| Chicago Palwaukee | 250,101 | 53 (ATCT) | 685 |
| Chicago DuPage | 217,515 | 74 (ATCT) | 596 |
| Aurora | 140,567 | 179 (ATCT) | 385 |

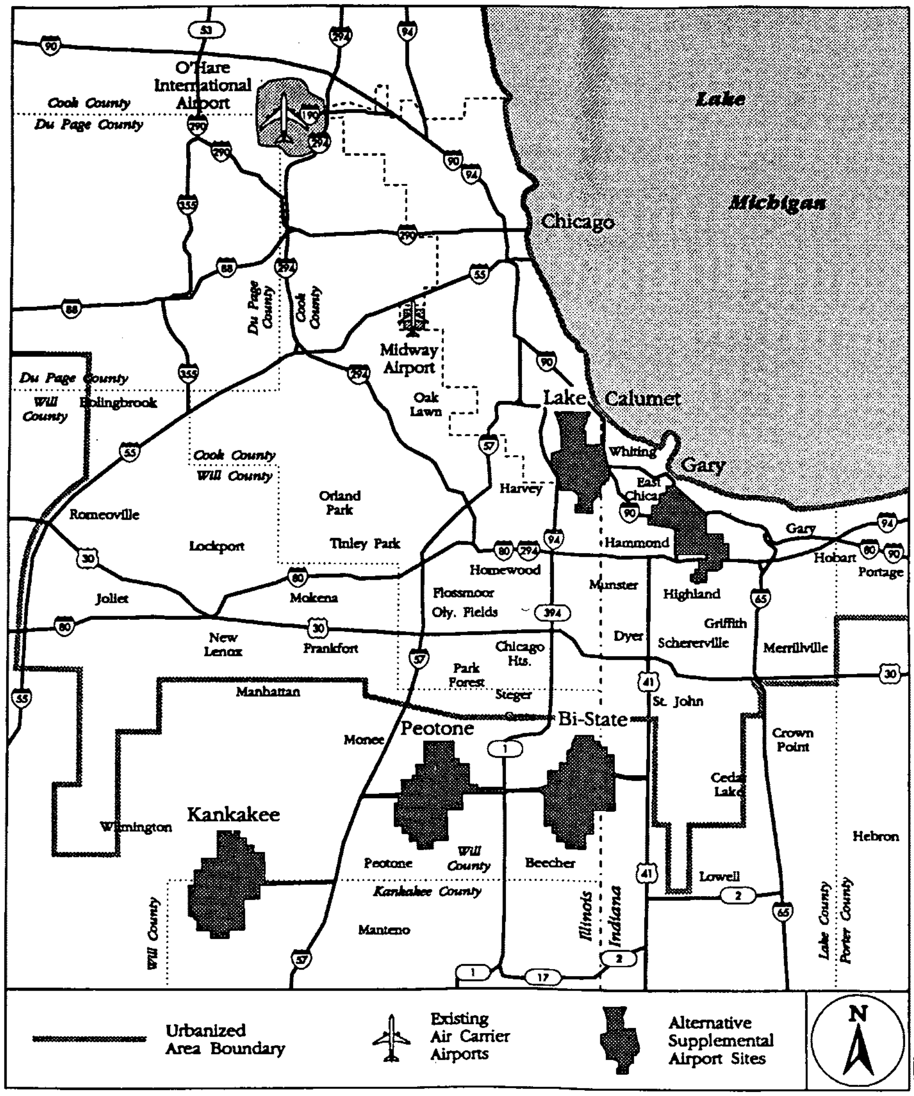


**FIGURE 1 Chicago region airports (5).**

agement restrictions applied by either the departure or arrival ATC facilities. It is conceivable that full integration of regional airspace and resolution of conflicts may extend beyond the 150 NM range, but given the scope of the study, the study team, in consultation with FAA ATC personnel, determined the 150 NM range to be a reasonable assumption. Because of Chicago's pivotal role, whatever happens in the Chicago airspace affects NAS.

## METHODOLOGY

Analysis of Chicago airspace within the site selection framework requires, as a first stage, establishment of a realistic baseline on which the whole airspace design is based. Developing the baseline simulation involves definition of air routes within predefined sectors, existence of air traffic procedures used in Chicago ATC, and determination of the air traffic loading and aviation activities in a representative period. This entailed the following:

- Study and review the airspace and air traffic environment applicable to activity during the baseline period (late 1989 and early 1990) within a certain range that would represent Chicago airspace,
- Evaluate air traffic operations at the Chicago area airports, which includes site observation and data collection at certain airports,
- Verify and validate data collected from various sources, and
- Develop the baseline simulation.

To accommodate an additional major regional airport for the Chicago area, various scenarios are simulated. Scenarios by site, year, and other assumptions considered in the analysis are simulated and include

- Considering planned enhancements for the Chicago airspace in consultation with FAA;
- Applying future regional aviation demand, forecasted in a separate process, to the established baseline and enhanced airspace; and
- Evaluating simulation and interpreting results for various scenarios (alternative sites and demand forecast).

**Baseline Data Collection**

To establish a realistic baseline for a third major airport in the Chicago area, considerable data is acquired, studied, and reviewed. Documentation studied includes FAA Facility Directives and Letters of Agreement; published flight procedures; terminal and en route sectorization; various related charts, including controller, Coast and Geodetic, terminal control area (TCA), en route high or low airway, and sectional and area navigation charts; a terminal and en route flight progress strip survey; and alternative sites location and layout plans. The most pertinent data collected include Standard Terminal Arrival Procedures; Standard Instrument Departures (SIDs); Instrument Approach Procedures for Chicago airports (O'Hare, Midway, and other selected airports); U.S. Standard for Terminal Instrument Procedures; FAA Great Lakes Region Air Traffic Division Letters of Agreement, directives, and operational manuals; and current arrival or departure route use and volume. Data collection is augmented by visits to ATC facilities and contacting individuals involved in this effort to observe air traffic in progress, collect or verify data on traffic flows, or both, and to document the altitudes of actual arrival and departure aircraft at navigational fixes and along the routes serving the Chicago region.

Flight progress strips, which are used in the ATC system to augment the automatically displayed data as the controllers' tool to manually keep track of flights and their progress, are collected for 7 days (November 5–11, 1989). A total of about 80,000 flight strips is compiled from the Chicago ARTCC and the Chicago O'Hare TRACON facilities. These strips are sorted into arrival, departure, and over-flight categories and become the baseline for the study and airspace model development. One representative day is selected and a detailed analysis of these strips conducted.Computer files from the Official Airlines Guide (OAG) (*6*), which are also used to augment the data collected during the early phases of the inventory preparation process, cover the same period of time as the flight progress strips used. OAG data are entered into the SIMMOD event file to provide airline flight schedules and to verify the data input from the flight progress strips.

The input data base required to develop the basic airspace structure includes location and configuration of existing and proposed airports and airport runways; existing and planned arrival, departure, and over-flight tracks; airways and jet routes within the Chicago ARTCC airspace; and traffic volumes for the study target years for all airports and tower en route operations. Moreover, the FAA NAS Plan (*7*) is scrutinized to examine system improvements planned on a national and regional basis that might affect the Chicago area.

To validate the data, the SIMMOD postprocessor animation capability is used to compare the model logic with real-world air traffic control observed data vis-à-vis airspace issues. Simulation input and logic are adjusted to incorporate controller-type decisions into how the traffic would flow within the airspace system and to and from airports.

**Regional Airspace Organization**

The U.S. ATC system consists of 23 air route traffic control centers, some 400 airport control towers, more than 200 flight service stations, and more than 1,500 navigational aids (*6*). In the Chicago region, the structure of the airspace system includes the following elements:

- ARTCC airspace: The Chicago-designated ARTCC airspace is described as an area approximately 400 × 300 mi, (120,000 $mi^2$) (Chicago ARTCC data are based on information from FAA Facility Directives, Letters of Agreement, published flight procedures, documentation on terminal and en route sectorization, and other sources) that is divided into 44 sectors: 26 low altitude sectors with nominal jurisdiction from ground level to 23,000 ft mean sea level (MSL), 11 high altitude sectors controlling air traffic from 24,000 to 33,000 ft MSL, and 7 super-high altitude sectors controlling air traffic above 34,000 ft MSL.
- TRACON: Similar to the ARTCC, terminal ATC facilities control air traffic operations within a defined airspace around one or more airports. Generally, the approach control area is a 30 or 40 mi radius of the radar serving the primary airport up to 10,000 ft MSL from ground. O'Hare TRACON designated airspace includes an area approximately 35 × 40 mi (1,400 $mi^2$) and is divided into 13 areas of control: 4 for arrival control, 4 for departure control, and 5 for satellite airport operations. The Chicago terminal airspace extends to 13,000 ft MSL, and within this airspace control zones with more stringent operational and weather criteria enhance safety and facilitate the movement of air traffic within the terminal airspace (e.g., TCA and airport radar service area).
- Milwaukee over-flights: Milwaukee flights to or from the south normally overfly the Chicago terminal airspace at or above 15,000 ft MSL and do not directly contribute to O'Hare TRACON operational considerations or workload. Milwaukee air carrier operations rarely exceed 25/hr and only a portion of these arrive or depart to or from the south over Chicago terminal airspace. These flights are generally segregated from the Chicago terminal operations, but they affect the Chicago ARTCC sector workload in specific areas.
- Satellite airports in the Chicago region: There are several reliever and general aviation airports in the Chicago area, referred to in this study as satellite airports. Operations for the activity generated by those airports in the existing Chicago O'Hare terminal area, mainly general aviation traffic, are included in the airspace model for the target years. The location of these airports, the arrival and departure routes used to serve each satellite airport, and the interaction with both O'Hare and Midway traffic flows need to be accurately determined. However, no unusual flow restrictions were placed in the simulation on flights to or from the satellite facilities and sectors.

### Airspace Use

The use of the Chicago airspace by all categories of aircraft and the forecasts of aircraft activity to the target years are as follows:

- Air carrier operations at the primary airports: Aircraft operation at each of the alternative sites for the target years is forecasted separately (*8*). For O'Hare and Midway airports, future aircraft operations for the target years are considered to be their predicted capacity. These forecasted activity levels are the basis for the future flight schedules, or the events file, used in the SIMMOD simulation runs. The arrival and departure tracks for air carrier traffic using the primary airports are defined using radar tapes and other information provided by the FAA ATC. To facilitate the handling of 1,179,889 IFR operations in 1989 in the Chicago terminal area, Chicago ARTCC and O'Hare TRACON used four navigational fixes, or posts. This arrival concept feeds arriving aircraft into orderly, expeditious flows to the landing runways at the destination airport. These fixes are oriented to the northeast, southeast, southwest, and northwest of O'Hare. Jet aircraft are spaced and sequenced at altitudes above the slower air taxi and general aviation turboprop and propeller aircraft. Air carriers departing from O'Hare are routed out of the terminal area between the arrival fixes, and flights departing from Midway are initially restricted to lower altitudes (often 4,000 to 5,000 ft MSL) to separate them from O'Hare arrivals and departures before climbing and being integrated into the O'Hare departure flow.
- Noncommercial operation: This category of demand, which includes general aviation and military traffic, constitutes about 5 percent of the baseline 1989 at the primary airports. Dependent on proximity to O'Hare and Midway, purpose of flight, desired direction of flight, and weather conditions, a large proportion of general aviation flights comes within the sphere of influence created by O'Hare and Midway operations. Interaction of general aviation with a large air carrier airport located at any of the five alternative sites in the metropolitan area would also be expected, especially for aircraft operating to and from an airport within 30 mi of a new airport or those overflying the same area. Figure 2 shows the location of all airports within a 30-mi radius from each of the five alternative sites.

## SIMULATION

SIMMOD-generated data from simulation runs representing various scenarios, which investigate variations in the operational performance of the regional airspace system at different situations for the proposed site of the new Chicago Regional Supplemental Airport, are used. SIMMOD is input data-intensive. Required data bases encompass airspace structure, flow and use, airports airfield data, flight schedules (grouping of hubbing activities into flight banks), aircraft characteristics, and lists of events that drive the simulation (*9*). Typically, SIMMOD simulation is conducted in three steps

1. Preprocessing: The simulation first creates the network as defined by the user in the airfield and airspace segments of the input. Data acquisition and compilation are normally integrated in several data files used for the SIMMOD preprocessor element. In this study, the standard arrival and departure procedures and routes developed for each of the alternative sites, the forecasted air traffic for the existing airports in the Chicago area airports, and the five new alternative sites were preprocessed into SIMMOD scenarios.
2. Simulation: The SIMMOD events file, generated either internally within SIMMOD or imported from another data base (e.g., OAG), is used to "drive" the simulation and initiate the aircraft traffic arrivals and departures, both in the air and on the ground.
3. Postprocessing: On the basis of an internal simulation timing routine, the simulation module creates an extensive transaction file representing the progress of the model through time, executing events according to their scheduled time. The postprocessor module uses the simulated events records and other data to generate reports and graphic displays. The postprocessor module can perform several functions, including debugging, validation, formatting, statistical reporting, report generation (tabular and graphic), and graphic animation display (*10*). In terms of air versus ground, route, and node delays, the reporting provides comprehensive data logging and statistical analyses on fuelburn, aircraft operations (takeoffs, landings, and taxiing), and delay. This information can be reported by airline, airspace sector, arrival and departure, airport (or component), type of aircraft and so forth.

The Chicago airspace simulation analysis follows FAA guidelines for the development and generation and interpretation of data for SIMMOD applications (*11*). The SIMMOD reporting system provides extensive and detailed information on various aspects of the system. It is imperative to focus on the type of output data that can provide best coverage of system operational performance measures and avoid unnecessary assimilation of vast amounts of data typically generated.

The following scenarios are used for the development of the Chicago airspace simulation, which included multiple runs identified by case, year, configuration, and other pertinent information.

- Year 1989, 2010, and 2020 baseline simulations included the existing O'Hare, Midway, and satellite airports, which established the baseline for validation and comparison of simulation data resulting from later runs, including the proposed supplemental airport sites.
- Year 2010 simulation runs included the five alternative sites scenarios (Bi-State, Gary, Lake Calumet, Kankakee, and Peotone—each with four runways) and Chicago O'Hare, Midway, and satellite airports, at the 2010 demand forecast levels.
- Year 2020 simulation runs for the scenarios represented each of the five alternative sites (with five runways) and include Chicago O'Hare, Midway, and satellite airports at the operational levels forecasted for 2020.
- Year 2010 scenarios simulated special cases required for various interactive situations involving the Lake Calumet site with Midway airport and the existing Gary Regional Airport. These scenarios include O'Hare, Midway, and the Lake Calumet site, where Midway is considered open, closed, and then

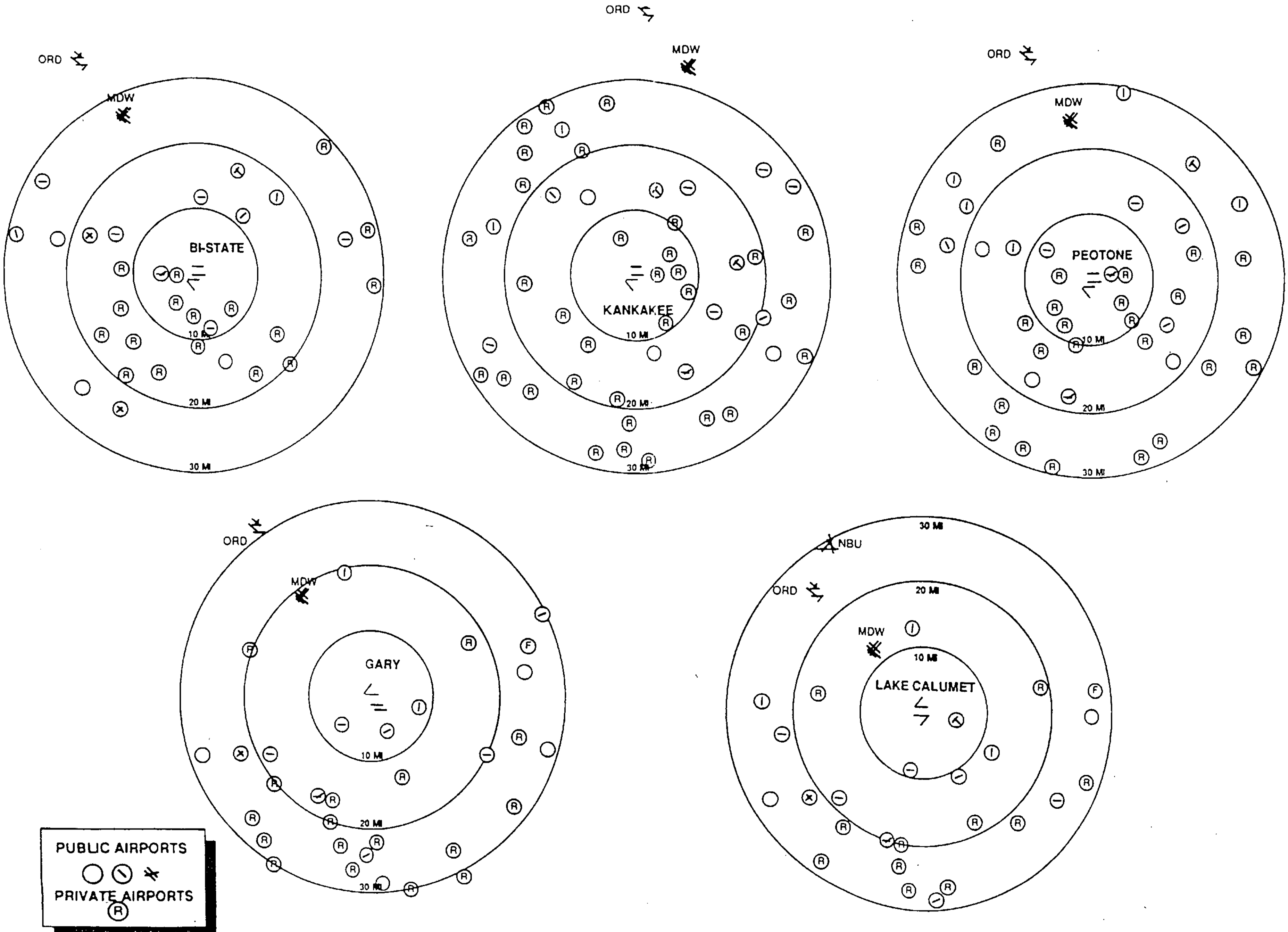


**FIGURE 2 Public and private airports within 30 mi of sites (5).**

restricted to noncommercial operations only, and the existing Gary Regional Airport's traffic included in the satellite airports operations.

- Year 2020 simulation runs included O'Hare, the existing Gary Regional Airport, and the Lake Calumet site with Midway closed.
- Simulation runs and alternative routes that would mitigate some of the delays predicted by the initial SIMMOD results were included.

### Event Data File Development

To establish the data baseline for the SIMMOD Event File, FAA Great Lakes Region Air Traffic Division data are used. Event data for the representative day are independently developed for the airspace simulation model for some specific categories of flight operation. These categories are satellite airport general aviation traffic data, Midway general aviation arrivals and departures, and Milwaukee over-flights. General aviation event data (flights) based on the projection of the 1989 activity levels are added to the events file of the alternative sites. The resulting SIMMOD event file for representative day flight schedule is compared with the actual workload. For O'Hare, the SIMMOD schedule consists of 2,285 flights (2,202 air carrier and 83 noncommercial) compared with the recorded 2,234 flights. For Midway, the SIMMOD schedule consists of 854 flights (665 air carriers and 189 noncommercial) compared with 852 flights recorded on the representative day. For the satellite airports, the SIMMOD schedule includes 540 noncommercial flights with an actual figure of 462.

Total annual operations for the individual airports, including the proposed Chicago supplemental airport, are developed in a separate process (*8*). Conversion factors are then used to convert between representative day activity and annual operations volume. Traffic projections for O'Hare and Midway airports are considered to reflect those facilities reaching capacity by 2010. All traffic growth and delay measurement are compared with the 1989 baseline. For the Lake Calumet site, comparisons are made of the scenarios involving the closing or restricted activity of Midway airport, because the two airports are close. In these cases, the comparisons are made with an average 2010 forecast for the five alternative sites of 530,756 operations. Aircraft groups included in the SIMMOD event file, which is based on FAA categories, are general aviation aircraft (6 models), small (24 models), large (32 models), and heavy (19 models). These include general aviation, commercial air carriers (freighters), and military.

### Airspace Network Development

In the development of the airspace network representation for SIMMOD, the regional airspace structure as discussed earlier is used with some modifications.

- Primary jet arrival and departure airspace: Routes within the primary jet arrival and departure airspace (surface to model limit) are included in the SIMMOD airspace network representation on the basis of existing and planned ATC procedures data obtained from FAA during the inventory and data base collection phase.
- En Route low-altitude airspace structure: A separate route structure in the airspace simulation is required for general aviation, air taxi, and other flights using the ARTCC en route low-altitude airway system not included in the tower en route structure. These are flights that are generally handled within the ARTCC low-altitude structure (below 23,000 ft MSL) to and from the Chicago area. Independent routes are established in the model to represent this category of operation.
- Low-altitude tower en route airspace: In situations in which designated terminal airspaces abut, low-altitude en route flights are handled by the terminal air traffic controllers. In the Chicago region, these routes are below 7,000 ft MSL between South Bend, Indiana, Milwaukee, Wisconsin, Rockford, Illinois, and the Chicago O'Hare and Midway terminal area facilities. Although these low level procedures are generally segregated from the majority of the en route air carrier operations, tower en route arrivals and departures must be sequenced with other operations. Independent routes are established in the model to represent this category of operation.
- High-altitude routes: Routes at the high-altitude airspace structure above 24,000 ft MSL are included in the model. Limited over-flight event data are included on these tracks because the interface of this traffic with the Chicago traffic generally occurs beyond 150 NM.
- Over-flights: The volume of Milwaukee over-flights (15,000 ft and above) incorporated into the airspace simulation model is established using the 1989 FAA facility management records for Milwaukee General Mitchell Field along with the city-pair and route use data for O'Hare and Midway.
- General aviation arrivals and departures: Routes are established in the airspace simulation to represent the satellite airports arrival and departure route structure. Flights landing at O'Hare and Midway are integrated with the appropriate traffic flows at the arrival fix and sequenced for the appropriate runways with other traffic, and those destined for satellite airports are segregated on independent routes within south or north satellite sectors of the Chicago terminal area, or both. Departure flights from the satellites are integrated into the existing departure tracks at one of three altitude levels. Departure routes are assigned on the basis of aircraft type, destination airport from 16 city-pair sectors, and existing ATC procedures.

The SIMMOD airspace network structure for the 1989 baseline consists of 290 airspace nodes, 320 airspace links, 240 airspace routes, 44 regional airspace sectors, 16 national airspace sectors, and 11 procedures and plans for airspace only. Composition of SIMMOD model input structure is described in the SIMMOD User Manual (*10*).

### ATC Procedures and Confliction Assumptions

As mentioned earlier, input data used in the SIMMOD Chicago airspace simulation are verified and the model is validated by comparing the model logic with real-world ATC and airspace data. Airspace model animation is used to make adjustments required for the validation process. Major assumptions considered in simulation include the following:

• Baseline and forecast arrival and departure procedures: Data from FAA records, flight progress strip survey, existing and planned ATC procedures, inventory, and observations are used to derive the airspace simulation operational events. Details on the operational activity levels are described in the section on Event Data File Development. Sector and route directional loading data (by volume and percent of total) for the airspace in the baseline event file for the Chicago terminal airspace simulation are shown in Figure 3.

• Modeling of O'Hare TRACON: Initial airspace simulation development plans did not call for extensive modeling of the O'Hare TRACON terminal airspace activity. However, the proximity of the Lake Calumet site to Midway made it necessary to conduct modeling of the air traffic activity within the Chicago terminal airspace. It is clear that the interaction between air traffic operations at Midway and Lake Calumet will be significant, especially for the Lake Calumet site. Assumptions included in the simulation reflect the interdependence of arrival and departure flights between the two airports.

• Weather and meteorological conditions: Because the study objective is to conduct comparative analyses for site selection purposes, a representative day weather condition, not weather extremities and capacity variations, is considered in the simulation. The SIMMOD Windset used is based on a complete wind analysis conducted as part of the study (*5*).

• Runway configurations and traffic patterns for the individual alternative sites: For 2010, each of the proposed sites is planned with two sets of parallel runways meeting the current minimum runway centerline separation criteria for simultaneous instrument approaches, a third parallel runway meeting anticipated reduced runway separation distance criteria, and a fourth parallel east-west runway (*5*). For 2020, a fifth runway is added at the proposed airport sites.

• Obstruction analysis: A preliminary obstruction analysis of each of the areas encompassing the five alternative sites is conducted to support the SIMMOD airspace simulation. This analysis, conducted in accordance with FAA PART-77, evaluates the sites for known obstructions above 200 ft. The results are used in developing the instrument procedures for the site's airspace design.

• IFR procedures potential conflictions: For each site, existing instrument procedures are evaluated in relation to potential conflictions that might require special attention.

• Instrument approaches: Sample instrument approaches are developed for each of the five sites. Aircraft are provided simulated radar vectors from the arrival fixes via the SIMMOD airspace network, separated from other traffic, and sequenced to the instrument approach procedure pattern for landing on the appropriate runway.

• Departures and SIDs: Radar SID procedures are developed for each site.

## RESULTS

The simulation runs are used to investigate the various scenarios related to the structure and operational aspects of the regional airspace system. These scenarios include the baseline (1989), No-Build (Baseline 2010), and the five proposed sites

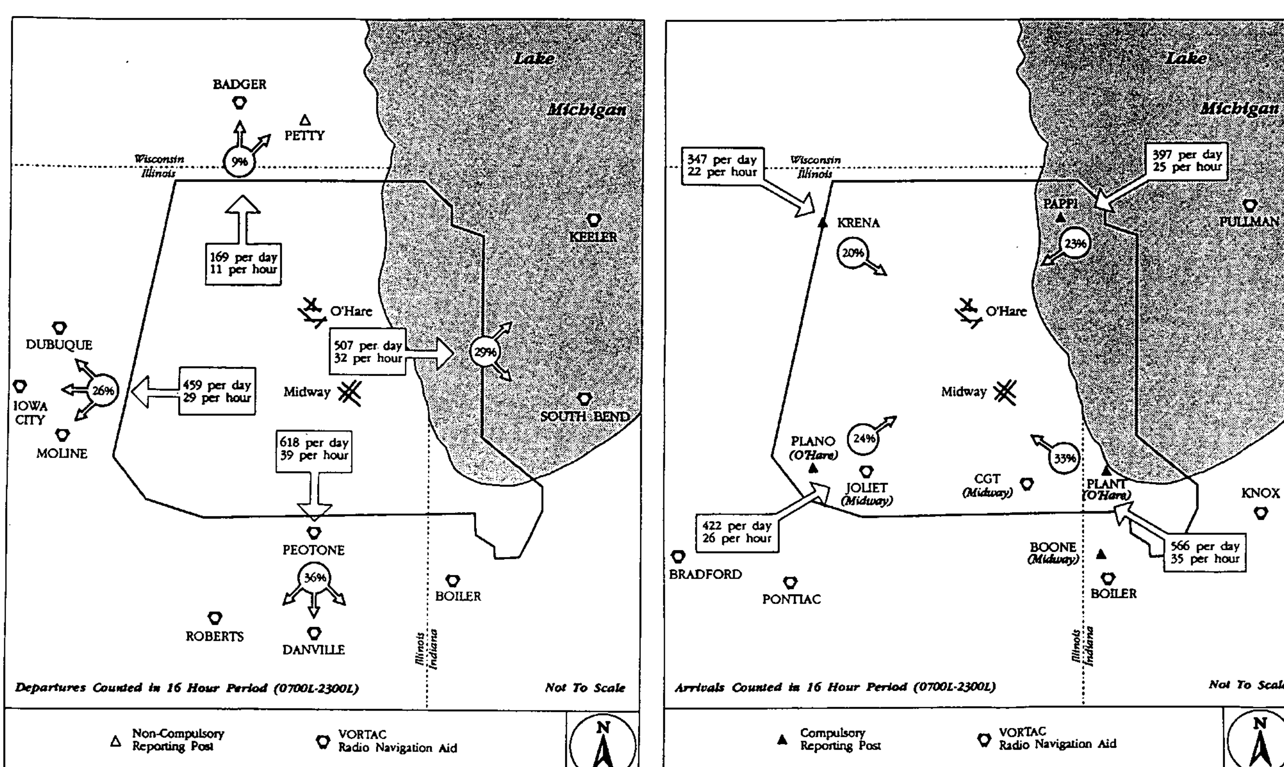


**FIGURE 3 Baseline loading data by sector and direction (*5*).**

for Chicago supplemental airport. The data base from these simulation runs is analyzed and comparison of statistics discussed. The results are shown in Figure 4.

**Baseline (O'Hare and Midway)**

On the basis of the assumption that there will be no expansion at O'Hare or supplemental airports, simulation results indicate a 22 percent increase in annual delays for 2010 and 2020. This level of delay is associated with the forecasted increase in operations for the no-build option. Operations forecasted for the baseline airports are shown to grow at about 8 percent at O'Hare and 11 percent at Midway for 2010, a level maintained for 2020. This level of system activity represents approximately 1,164,000 operations compared with 1,068,000 in the base year 1989. Note that the baseline 2010 projections are supply driven and constrained only by the actual capacities of the primary airports. These projections represent only a modest growth in regional traffic from 1990 to 2010, which is not in line with the demand-driven forecasts of aviation activities in the region (passengers and aircraft operations) determined for the five proposed sites in a separate process (*8*). On the basis of this restricted growth (i.e., the no-build scenario), simulation results for average system delay at O'Hare and Midway per aircraft is 10 min in 2010 compared with 9 min in 1990. For O'Hare, average delay per aircraft for the 2010/2020 baseline is 10 min for arrivals and 15 min for departures.

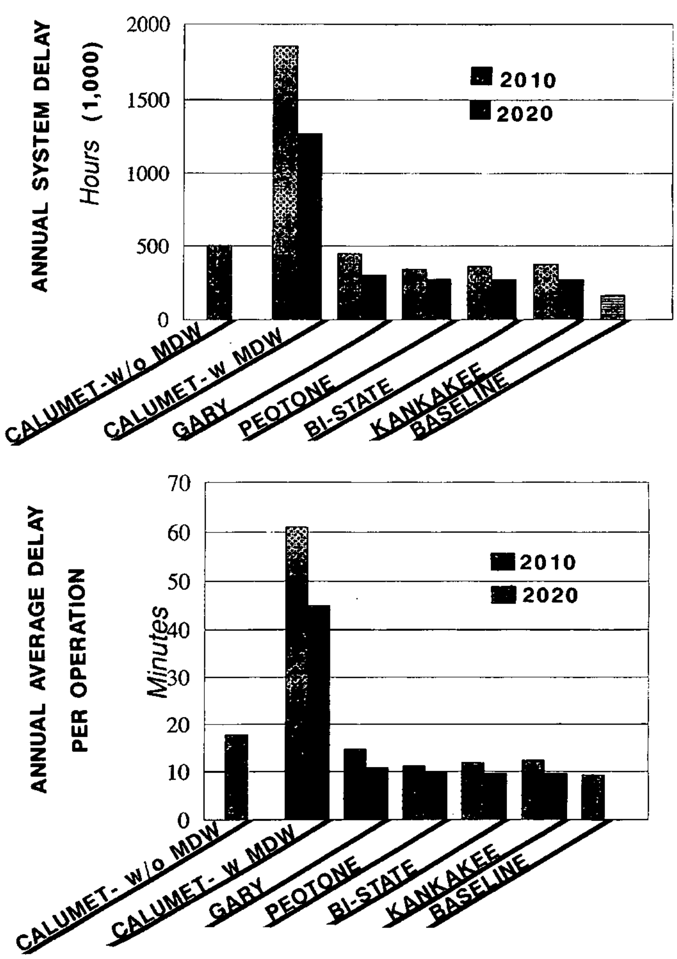


**FIGURE 4 Annual delay for baseline and scenarios: *top*, system delay; *bottom*, average delay per operation.**

**Scenarios for Supplemental Airport Site**

Direct comparison between results of baseline airports with and without the supplemental airport may not be meaningful, because the no-build scenario incorporates only a modest, supply-driven growth in regional aviation activity. The activity is constrained by the physical capacities of airports, not what aviation could possibly reach in a demand-driven environment. With a supplemental airport included, system demand will increase to approximately 1,700,000 operations by 2010 (with supplemental airport average of 530,000), and the system delay would also increase considerably. By 2020, the supplemental airport is forecasted to reach 665,000 annual operations, which would result in more significant increases in delay on the system level. Because of increased levels of interaction between operations in the region, delays at O'Hare are projected to increase by 66 percent, with extensive delays at the Midway and Lake Calumet sites. With Midway airport operating, the interactions between its operations and both Lake Calumet and Gary (the urban sites) are significant. Because the complications for Lake Calumet are severe, a scenario is run to model the system with Lake Calumet site, with Midway closed or restricted in operation. Results indicate that for the two urban sites changes in en route or terminal air traffic procedures will not create more airspace or resolve all the interaction and coordination problems. Airspace is limited and finite, and the close-in interactions of the three airports will continue to be a major problem within the terminal airspace. The interactions between Midway and the two urban sites will significantly increase delay for all primary airports.

The system performance results for each of the five proposed sites are as follows:

- Lake Calumet: Several major restrictions of the regional airspace that includes Lake Calumet and Midway are likely to preclude efficient operation of these two airports in one regional airspace structure for the aviation activity levels projected to 2010 and 2020. On the other hand, aircraft operations forecasted for Lake Calumet with Midway closed or restricted is 700,000 in 2010 and 849,000 in 2020—a figure equivalent to O'Hare's 2010/2020 operational levels. The two scenarios of Lake Calumet with Midway closed and Midway restricted to noncommercial operations clearly indicate (a) the volume of aircraft operations forecasted for Lake Calumet with Midway closed will strain the 2020 Lake Calumet airport capacity and (b) restricting Midway to noncommercial operations still results in serious interaction or conflicts between the two airports with significant levels of delays. Moreover, even with Midway closed, the existing Gary Regional Airport represents a potential problem for the Lake Calumet site. The situation might require Gary Regional to be closed or its operations severely restricted. Therefore, the development of Lake Calumet appears to create a dilemma: if Midway remains open there will be extremely difficult airspace and ATC problems and severe delays. If Midway is closed or restricted to noncommercial operations, the demand forecast with continuing peaking patterns will cause stress to airport capacity to the extent that delays will be significantly higher than other sites. Consequently, this situation becomes a serious constraint on the future growth of Lake Calumet Airport. As shown in Figure 4, the total system annual delay for Lake Calumet with Midway open is 1,280,000 hr in 2010 (equivalent to average delay per operation of 45 min) reaching 1,850,000 hr by 2020 (61 min average delay per operation). With Midway closed, total system annual delay for the Lake Calumet site is 540,000 hr in 2010 (equivalent to 21 min average delay per operation) and 550,000 hr in 2020 (20 min average delay per operation). Three issues are noteworthy. First, in terms of total aircraft operations handled by the system in the context of system performance, closing Midway and relocating its equivalent demand to Lake Calumet will have an entirely different effect on airspace than with Midway open and retaining its demand. Second, the 2020 scenarios include improvements to ATC procedures that will result in increased efficiency of the system. Third, to accommodate the increased long-term demand, an additional runway is used for the 2020 scenarios.

- Gary site: Although anticipated delays associated with the Gary site were slightly higher than those for the Greenfield sites, two factors need to be considered: (a) proximity of Gary to Midway and its departure and arrival tracks would not provide more space for development of new procedures, especially south of the airport, and (b) the altitudes available within the system will be limited and competition for the airspace will therefore be severe. It can be concluded from the simulation results that full potential system capacity will not be achieved under the conditions expected to exist if Gary is developed with Midway fully operational; however, no consideration is given to the Midway-closed scenario for the Gary site. Simulation results show that the total system annual delay for the Gary site, as shown in Figure 4, is 300,000 hr in 2010 (equivalent to 11 min average delay per operation) and 460,000 hr in 2020 (15 min average delay per operation).
- Greenfield sites: The three Greenfield sites (BiState, Kankakee, and Peotone), grouped geographically because of similarity of airspace issues, are located approximately 30 to 35 mi south of Midway. Despite the distance, these three sites are not totally free of airspace and ATC interactions, but they are not as severely or critically affected as are the two urban sites. The most difficult airspace issue for these sites is access to the existing east-west departure tracks, where altitude separation will be required for considerable distances to position departing aircraft onto these tracks. Access to the north tracks is somewhat problematic for departures, and these operations are likely to either be delayed, rerouted, or restricted at low altitudes for extended distances. Simulation results indicate (see Figure 4) that total system annual delay for the Greenfield sites (BiState, Peotone, and Kankakee) is lower than the two urban sites, around 275,000 hr in 2010 (equivalent average delay per operation ranging from 9.6 to 9.8 min) and 350,000 hr in 2020 (average delay per operation ranging from 11.2 to 12.4 min).

## SUMMARY

The Chicago airspace system analysis conducted as part of the Illinois-Indiana (Chicago) Regional Airport study—Phase I: Site Selection is described. This analysis provides the technical information to assist in selecting one of five alternative sites south of Chicago. SIMMOD simulation is used to generate data on performance measures, mainly delay, to enable the evaluation of different scenarios established for the proposed sites on the basis of a scenario development plan devised to conduct this comparative airspace analysis. Results obtained from interpreting simulation output indicates that there are serious airspace conflict problems and excessive system delay levels for the two urban sites at Lake Calumet, Chicago, and at Gary, Indiana. Airspace restrictions and delays are considerably lower at the three Greenfield sites (BiState, Peotone, and Kankakee) further south.

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