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NEW DENVER AIRPORT

Safety, Construction, Capacity, and Financing Considerations

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The Honorable Frank R. Wolf
House of Representatives

The Honorable Bob Carr
House of Representatives

The City of Denver is building a new airport, scheduled to open in 1993, to replace its existing airport, Stapleton International. The new airport has been under construction since 1989 and is nearly 20 percent complete. This facility will be the first major new airport constructed in the United States since the Dallas-Fort Worth airport in 1974. The Federal Aviation Administration (FAA) plans to provide—from the Airport and Airway Trust Fund—about $615 million of the nearly $4 billion needed to build the new airport. Most of the remaining construction costs would be financed by revenue bonds issued by the Denver Airport System, the entity responsible for developing the new airport.

In response to your April 25 and May 20, 1991, requests, this report addresses four basic issues raised regarding the new Denver airport. You wanted to know whether (1) the new airport site is more prone to adverse weather than Stapleton and therefore to greater flight safety hazards; (2) adequate design and construction methods are being used to protect airport runways and other structures from soils that expand when wet; (3) the new airport would reduce air traffic delays at Denver or systemwide; and (4) the project is financially viable, given current budgeted costs and revenue projections.

Results in Brief

Weather conditions at the site of the new Denver airport are similar to those at Stapleton. Potentially dangerous storms have not been shown to occur more frequently at the new airport site than elsewhere in the Denver area or to increase aircraft safety hazards. According to pilots, slightly higher average wind speeds at the new site are not significant and will not affect flight safety.

Expansive soils—soils that expand when wet—like those at the new airport site are common throughout the Denver region. Airport officials are using proven design and construction methods to prevent problems from occurring when dealing with such soils. To help ensure that construction plans and specifications are followed, project managers have implemented a comprehensive, two-tiered quality assurance program.

The quality assurance program uses independent contractors to check the work of the construction contractors. Nearly 70,000 field and laboratory tests have been conducted to ensure that quality standards are met.

The new airport should significantly reduce flight delays at Denver because, unlike Stapleton's runway layout, the configuration of the runways at the new airport will allow simultaneous operations on parallel runways even in bad weather. FAA has reported, on the basis of a computer simulation of traffic and weather conditions on 3 days in 1989, that the new airport will reduce air transportation system delays by almost 5 percent. We were unable to confirm FAA's estimate because FAA did not have an underlying analysis to support whether conditions on the 3 days were typical of conditions throughout the year.

The financial viability of the new airport is the most problematic of the four issues raised. There are a number of uncertainties, such as the future level of United Airlines flight operations at Denver and the success of the plan to bring Continental Airlines out of bankruptcy, that will affect the financial viability of the new airport. Although uncertainties exist, our analyses suggest that (1) the City's financial assumptions for the new airport are reasonable and (2) the probability is low that the airport will be unable to generate sufficient revenues to meet operating expenses and service its debt. Nevertheless, the possibility of default always exists and would become more likely if several adverse conditions, such as cost overruns, schedule slippages, the loss of a hubbing carrier, and traffic shortfalls, were to occur.

Background

To assist FAA in ensuring a safe and efficient air transportation system, the Congress established the Airport and Airway Trust Fund in 1970. FAA is responsible for administering disbursements from the Trust Fund. Financed by excise taxes levied on passenger tickets, air cargo, and general aviation fuel, the Trust Fund pays for air traffic control facilities and equipment, research and development, and a portion of FAA's operations expenses, and it makes grants to airport operators for improvement projects and new airports through the Airport Improvement Program.

FAA has committed about $615 million in federal funds for the new Denver airport. Of this total, about $435 million would be provided in Airport Improvement Program grants to the City of Denver for construction of eligible portions of the airport. Through fiscal year 1991, the Congress had appropriated $175 million for grants to the City for airport construction and FAA had given the City a letter of intent citing its commitment to provide the remaining grant funds by 1999. Ultimately, however, any additional disbursements from the Trust Fund must be approved by the Congress.

In addition to the $435 million for construction of the new airport, another $180 million in federal funds is earmarked for FAA to procure and install air traffic control facilities and equipment, such as the control tower, radars, computers, and communications equipment. Through fiscal year 1991, the Congress had appropriated for FAA's use about $103 million for facilities and equipment at the project.

Weather at the New Site Appears to Pose No Added Safety Hazards

Adverse weather conditions occur frequently in the Front Range of the Rocky Mountains where Denver is located. However, these conditions do not appear to be significantly more severe at the new airport site than at Stapleton or to pose any added flight safety hazards. According to scientists from the National Oceanic and Atmospheric Administration (NOAA) and the National Center for Atmospheric Research (NCAR) and our analysis of available data, potentially dangerous storms do not appear to be more prevalent at the new airport site than elsewhere in the Denver area.

According to NOAA and NCAR scientists who have studied the convergence zone—where west winds near the Rocky Mountains collide with southeast winds and often spawn tornadoes and other storms—this zone does not always form in the same location but moves throughout the Denver area. Similarly, data on the incidence of microbursts (strong downdrafts of wind), which NCAR has tracked since 1987 using special radar, show random distribution—no concentration at the new airport site or anywhere else in the Denver area. NOAA scientists said that current data suggest no discernable differences in the occurrence of severe storms between the two airport sites. They are continuing to monitor weather in the area to identify conclusively any long-term climatological patterns for severe storms in the Denver area.

Wind speeds at the new airport site are slightly higher on average and wind gusts are somewhat more frequent than at Stapleton, but scientists and pilots with whom we met believe that the differences are insignificant and will not increase safety hazards at the new airport. (See app. II.)

Expansive Soils Have Been Considered in Constructing the New Airport

Expansive soils like those at the new airport site are common throughout the Denver region. These soils will expand when wet and, if not properly treated, can lead to premature replacement or high maintenance costs for structures built on them. Engineers designing runways and other structures at the new airport have extensive experience constructing airports on such soils. Our review showed that design engineers have included proven methods for controlling and minimizing soil expansion. Runways and structures are being built on a 6-foot fill material conditioned and treated to control soil expansion, a standard practice in such conditions. Tests conducted on the treated material have shown that soil expansion is within predicted and acceptable limits.

The City of Denver has implemented a quality assurance program to monitor construction at the site to help ensure adherence to plans and specifications. Contractors are required to use independent firms to perform quality control inspections. To oversee these inspectors, the City has its own quality assurance team selected from various firms having expertise in the areas being monitored, and it has employed an independent laboratory to verify contractor soil test results. As of July 1991, nearly 70,000 field and laboratory tests had been conducted to ensure that construction was meeting quality standards. FAA has also approved the City's quality assurance program. Our first-hand observations of this program in operation indicate that the program is functioning as intended. (See app. III.)

Local Delays Should Be Reduced, but Reductions in Systemwide Delays Are Unclear

Since the mid-1980s, Stapleton has encountered substantial air traffic delays. Delays are especially prevalent during poor weather conditions and peak traffic periods. To alleviate the delays, the City, with FAA's concurrence, chose in the mid-1980s to build a new airport rather than expand Stapleton. Factors affecting this decision were limitations to expanding runways onto potentially contaminated areas of the Rocky Mountain Arsenal, now controlled by the U.S. Army, and continuing noise problems around Stapleton.

The new airport has design advantages over Stapleton that should reduce air traffic delays at Denver. For example, runways at the new airport, unlike those at Stapleton, are spaced far enough apart to allow for simultaneous landings in poor weather. Computer simulations show that aircraft flying to and from the new airport can experience significantly fewer delays. However, the new airport's effect on reducing delays at other major airports with connecting flights to and from Denver is unclear. FAA has reported that the new airport will reduce delays throughout the system by almost 5 percent, basing this estimate on a computer simulation of systemwide delay reductions. The simulation results are based on three national daily weather scenarios and air traffic conditions in 1989, which may not be representative of average actual conditions throughout the year. FAA could not provide data on the frequency of occurrence of these conditions systemwide to support the simulation results. Without these data, we cannot confirm FAA's estimate. (See app. IV.)

Airport Revenues Should Cover Costs

The new Denver airport will cost nearly $4 billion, including costs for land, design, construction, financing, and additional expenses related to the City's agreement with United Airlines. Most of these costs will be financed using revenue bonds, which are paid off using the revenues of the airport. To repay these bonds successfully, the City must (1) control its costs so as to minimize the amount of money it must borrow and (2) generate enough revenues to pay the costs both of operating and maintaining the airport and of meeting the debt service on the bonds. Concerns about the financial viability of the new airport have been raised because substantial cost overruns have occurred at other large construction projects and because traffic levels at Denver, which affect airport revenue, have in the past fallen short of projections.

To date, with only 19 percent of construction complete, construction costs for the new airport have remained within budget. Through August 1991, 27 construction contracts, valued at about $732 million, had been awarded, and 5 of these had been completed. However, it is too early to determine whether the entire project will be completed within budget. In line with the airport construction schedule, about 40 percent of the construction contracts have been awarded, and such factors as higher-than-expected bids, delays, and overruns could adversely affect budgeted costs. Moreover, the airport has experienced some schedule slippage; actual construction fell 4 percent behind what had been planned as of July 1991.

Airport revenues come from payments made by airlines, such as lease payments and landing fees, and from nonairline revenues, such as rental income from airport parking and food concessions. The volume of traffic at the airport affects these revenues. Traffic levels depend, in turn, on the health of the Denver economy, the level of national economic activity, and the overall demand for airline travel.

The effect of traffic levels on revenues is reduced, however, by the airport's cost-recovery rate-setting system. This system, mandated by the City's bond ordinance, requires that the airport set rates and charges for the use of each part of the airport so as to recover the costs of constructing, operating, and maintaining each part of the airport. If revenues decrease because of declines in traffic levels, rates must be increased so as to generate the needed revenue.

Revenues could also be affected by airport use agreements between the City and the airlines. These agreements provide that if costs to the airlines exceed $20 per passenger, the airlines are free to renegotiate their lease agreements with the City. Airlines may choose not to exercise their option to renegotiate their leases. Current costs at Stapleton are about $6 per passenger, and the financial plan for the new airport calls for these costs to be about $13 per passenger. Continental Airlines, a major tenant at the new airport, is currently in bankruptcy, and its future use of the new airport remains uncertain. If Continental were to cease operations, traffic levels at the airport would probably decline and costs per passenger would increase. We found, however, that although many unknowns remain that could affect the airport's future revenues, air traffic at Denver is not likely to decline so much that the airport would be unable fully to service its debt.

We contracted with a consultant to analyze the probability of default, taking into account the probabilities of cost overruns, low traffic levels, and other adverse events. This analysis found that the probability was very low that the airport would even have to dip into the reserve account that is maintained to ensure debt coverage.

The bond analysts we talked to have concluded that, although the new Denver airport is subject to more uncertainty than most airport projects, the risk associated with the bonds is still acceptable for most investors. Therefore, while it is impossible to be certain about the future financial viability of the new airport, the available evidence suggests it should be viable. (See app. V.)

We conducted our work between May and September 1991. During that time, we interviewed officials from federal agencies, the City of Denver, and other organizations, and we reviewed and analyzed pertinent data and studies. Further details of our objectives, scope, and methodology are provided in appendix I. We discussed the information in this report with federal and Denver officials, and we incorporated their comments as appropriate. These officials generally agreed with the facts in the report. However, as you requested, we did not obtain official written agency comments on this report. We performed our work in accordance with generally accepted government auditing standards.

As arranged with your offices, we plan no further distribution of this report until 7 days from the date of this letter. At that time, we will send copies to other interested congressional committees; the Secretary of Transportation; the Administrator, FAA; and the City of Denver. We will also make copies available to others upon request.

Major contributors to this report are listed in appendix VI. If I can be of any further assistance, please contact me at (202) 275-1000.

John H. Anderson, Jr.

for Kenneth M. Mead
Director, Transportation Issues

Contents

Abbreviations

ALPA	Air Line Pilots Association
FAA	Federal Aviation Administration
GAO	General Accounting Office
NASPAC	National Airspace System Performance Analysis Capability
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
O&M	operation and maintenance
PFC	passenger facility charge
S&P	Standard and Poor's

Objectives, Scope, and Methodology

In letters dated April 25 and May 20, 1991, and in subsequent discussions with their offices, Representatives Frank R. Wolf and Bob Carr, Members of the Subcommittee on Transportation, House Committee on Appropriations, asked us to examine the following issues regarding the new Denver airport:

- Is the new airport site more prone to adverse weather than Stapleton, thus increasing flight safety hazards?
- Are adequate design and construction methods being used to protect airport runways and other structures from soils that expand when wet?
- Will the new airport likely reduce air traffic delays at Denver or enhance the capacity of the national air traffic system?
- Is the project financially viable, considering the assumptions used to budget costs and project revenues?

To address the first objective, we contacted numerous officials from federal agencies, the City of Denver, and other organizations with expertise on weather-related issues. At the National Oceanic and Atmospheric Administration's (NOAA) Environmental Research Laboratory in Boulder, Colorado, and its National Weather Service Area Office in Denver, we obtained information on safety-related weather phenomena in the Denver area, such as the convergence zone, microbursts, tornadoes, and mountain air waves. We discussed these weather phenomena and their potential effects on flight safety with officials at the National Center for Atmospheric Research (NCAR) in Boulder and reviewed pertinent NCAR data and studies. Woodward-Clyde Consultants, the City's consultant responsible for gathering and analyzing data from weather monitoring stations located in the vicinity of the new airport site, provided us with data collected from these stations. Finally, to gain first-hand perspectives on potential flight safety hazards posed by adverse weather at the new airport site, we interviewed the Chairman of the Aviation Weather Committee for the Air Line Pilots Association, and officials from the Air Carrier International Flight Academy at Front Range Airport, located 2.5 miles from the new airport.

To address the issue of expansive soils, we discussed with members of the Denver airport management team—including City consultants and contractors—steps being taken to prevent soils from expanding and potentially damaging airport runways and other structures. To verify the management team's approach, we reviewed geotechnical reports on the soils at the new site prepared by City contractors and geological maps obtained from the U.S. Geological Survey and the State of Colorado Geological Survey. We obtained information about standard building practices for expansive soils in the Denver area through discussions with officials from the Department of Public Works, City and County of Denver, who are responsible for issuing building permits. We also inspected the runways at Front Range Airport to contrast the effects of soil expansion, given different design and construction methods, and assessed the quality assurance program for monitoring construction at the new airport by documenting the process with the manager of quality assurance for the City's consultants, the Greiner, Inc./Morrison-Knudsen Engineering team.

In addition to verifying the validity of the management team's approach, we made several unannounced visits to the new airport site to observe quality control and quality assurance inspectors monitoring construction and testing soil samples. While at the site, we reviewed quality assurance records to better understand the overall process and to assess methods used to resolve deviations from design standards and specifications. We also met with officials from the Federal Aviation Administration's (FAA) Denver District Office to discuss their role in approving and monitoring the quality assurance process.

To assess the impact of the new airport on reducing local and systemwide delays, we contacted FAA officials at headquarters in Washington, D.C.; the Northwest Mountain Region in Seattle, Washington; and the Denver District Office. We obtained from them aviation delay data, air traffic forecasts for Denver, and results of three computer simulation models used to measure the impact of the new airport on reducing local and systemwide delays. Denver airport officials provided us with the results of two computer simulation models, studies, maps, photographs, and other information on the configuration of runways, taxiways, and gates at both Stapleton and the new airport. They also provided us with alternative proposals considered in the decision to build a new airport. Finally, we spoke with officials from the Air Transport Association and United Airlines to obtain their views on the impact of the new Denver airport on reducing local and systemwide delays.

We did not verify the assumptions used or the accuracy of the results for four computer simulation models—the Airport and Airspace Simulation Model; Airspace Simulation Model; Runway Delay Simulation Model; and Airport Machine—that measured local aircraft delay reductions only. Because of time constraints or access restrictions, we compared the results only in terms of consistency. We reviewed documentation for the National Airspace System Performance Analysis Capability (NASPAC) computer simulation model, which simulates both local and systemwide delay reductions, to enhance our understanding of the model results. Although we observed no major problems with the model, we cannot attest to the model's validity. We did not attempt to validate the NASPAC model. Because of the nature of policy-assisting models such as NASPAC, their outputs cannot be relied upon as exact predictors of the future.

To address the financial viability of the new Denver airport project, we discussed the methodology used to develop the financial projections for the new airport with Denver airport officials; the airport consultant, KPMG Peat Marwick; and the financial advisor, Lehman Brothers. We also obtained pertinent studies and other documentation relating to air traffic, revenue, and cost assumptions and projections for the new airport. We discussed with officials from credit-rating agencies and with bond analysts their views on the financial viability of the new airport. We contacted the two major air carriers at Denver—United and Continental—for their views on the proposed fees and charges.

To test the financial assumptions and projections for the new airport, we contracted with Hickling Corporation, an airport consulting firm, to perform a risk analysis to assess the financial viability of the new airport. The assessment focused on revenue and cost assumptions. In evaluating cost and revenue assumptions associated with these analyses, we reviewed the airport use agreements between the City and United and Continental Airlines.

Our evaluation of the financial viability of the project involved the use of a computer model developed by Peat Marwick. Since this model was proprietary, we did not have access to it. We presented a number of scenarios and assumptions—such as levels of airport usage and fees—to Peat Marwick staff. They then provided us with the model results based on these scenarios. The main output of Peat Marwick's model was a determination of whether revenues from the new airport would cover costs and what airline fees would be necessary to generate this revenue. Because the model was proprietary, we did not monitor the data input to the model or review documentation regarding the model's internal logic. We reviewed the model outputs provided by Peat Marwick staff. Because of access restrictions, we did not attempt to verify the model and cannot attest to the model's validity. Like the outputs of other policy-assisting models, the outputs of the Peat Marwick model cannot be relied upon as exact predictors of the future.

The Hickling Corporation staff's assessment of the financial viability of the new Denver airport followed their established risk analysis process. The process as applied in this case involves the following:

- Linking six independent forecasting modules to portray different aspects of the new Denver airport. The modules represented are listed below; their key components are noted in parentheses:

  1. Traffic (including domestic routes involving Denver as an endpoint, hubbing operations at Denver, international travel, and cargo)

  2. Operations and maintenance costs (including personnel services, parking structures, repairs and maintenance, shuttle bus services, utilities, and supplies and materials)

  3. Other revenues (including nonairline revenues from terminal business concessions, parking and rental cars, and cargo rental areas)

  4. Project costs (projected completion cost based on a planned monthly construction rate, and projections for project cost variations, interest rates, and the costs of delay)

  5. Debt service requirements (estimated on an annual basis for total debt service, debt service attributable to the project, and debt service attributable to land acquisition)

  6. User fees and debt coverage (calculates cost components for operations and maintenance expenses; equipment, other capital outlays, cargo taxiway costs; project debt service; and land debt service, and then allocates these costs to cost centers [terminal complex, tenant-related costs, baggage handling and facilities, international facilities, airfield area, ramp area, and fueling system])

- Convening panels to assign the ranges of uncertainty about key analysis variables. The initial values for variables and assumptions entering into Hickling's independent projections for the project included financial and bond documents related to the new Denver airport, FAA forecasts for both Denver and national air traffic, Department of Commerce projections for the Denver-Boulder metropolitan area and the state of Colorado, and reports from the Congressional Budget Office and the President's Council of Economic Advisors of economic projections for the U.S. economy. The forecasting modules and the values assigned to various inputs and assumptions were widely discussed with knowledgeable individuals as well as with panel participants. Panel participants included airport representatives from Denver and elsewhere, bond-rating analysts, Denver citizens, and our staff.

- Using their proprietary Risk Analysis Process (RAP) software, modified to represent the proposed new Denver airport. The Hickling RAP model is a Monte Carlo simulation that uses the uncertainty ranges for key variables assigned by the panels to make repeated estimates of forecast outcomes in the form of probability distributions. The results of the Hickling analyses provided to us were based on 500 simulations for each of the six modules listed above. These six modules were sequentially solved 500 times in preparing the final probability distributions for the key variables of airline cost-per-passenger and debt service coverage ratio. The probability distribution for overall airport traffic, against which revenue sensitivities were estimated, was based on 500 runs of the traffic module. The probability distributions for revenue and cost elements, in turn, were estimated for independent samples of 500 runs of each of the component-estimating modules. Finally, the distribution reflecting uncertainty in each of the revenue and cost components, along with the estimated traffic distribution, was used to estimate the overall sensitivity of user fees and debt service coverage.

Key aspects of the Peat Marwick model were incorporated into the Hickling modeling process (including the forecasting modules and the RAP model). Although the Hickling staff did not have direct access to the Peat Marwick model, they held numerous discussions with the Peat Marwick staff and requested several runs of the Peat Marwick model under differing assumptions and scenarios. Reviews of these model results and discussions with Peat Marwick staff then formed the basis for combining the Peat Marwick model with Hickling's RAP model.

Hickling staff briefed us on the results of their analysis and also provided us with written results, which included a summary of data sources, the panel meetings, input variable value ranges, and descriptions of the six independent forecasting modules. Hickling's RAP model is proprietary.

We did not review the documentation of the RAP model's internal logic or attempt to verify the RAP model. Therefore, we cannot attest to its validity. Like the output of other policy-assisting tools, its outputs cannot be relied upon as exact predictors of the future.

In addition to the steps described above, we discussed the four issues addressed in this report with 15 people who had expressed concerns about one or more aspects of the new airport, either directly to us or during the May 1991 Subcommittee hearings.

Weather Conditions at the New Site Not Significantly Different From Those at Stapleton

Adverse weather, such as thunderstorms or high winds, frequently disrupts flight operations in the Denver area. According to a study done for the City and County of Denver, weather conditions adversely affect operations at Stapleton at some time during the day on about 140 days each year. Some people have raised concerns that weather at the new airport—whose perimeter is only 12 miles northeast of Stapleton—is worse than at Stapleton and could more severely affect flight safety. Specific concerns were that

- storm frequency is greater at the new site because the "line of convergence," or convergence zone, where the northwesterly winds near the Rockies meet the prevailing southeasterly winds, is over the new airport;
- windshear, a recognized threat to flight safety characterized by rapid changes in wind direction or speed, is more prevalent at the new site;
- the effect of a mountain "air wave" coming downslope from the Rockies is more intense at the new airport site; and
- average wind speed is greater at the new site.

Our discussions with scientists at NOAA and NCAR and our analysis of available weather data have identified no significant differences in weather between Stapleton and the new airport. According to NOAA and NCAR scientists, storm frequency for the two airports is basically the same. Wind speeds, while slightly higher at the new airport, should not increase risks to flight safety, according to pilots with whom we spoke.

The Denver Convergence Zone

From May through August, a convergence zone often forms in the Denver area. This phenomenon occurs when two air masses meet and often spawns thunderstorms that may produce tornadoes and microbursts—small but strong downdrafts of wind that may be virtually impossible to detect without specialized radar. Some expressed concern that this convergence zone is located directly over the new site, but available data suggest otherwise. In part, the concern stemmed from a 1988 NCAR study stating that the zone forms more frequently or intensely over the new airport than over Stapleton. However, study conclusions on the convergence zone were based on observations relating to only seven severe weather incidents.

Our review of available data on convergence zones in the Denver area shows that the zone is not stationary. Scientists at both NCAR and NOAA who have studied the convergence zone in the Denver area for 10 years said that its exact position is highly variable and that available data are not sufficient to determine if this phenomenon occurs more frequently at the new airport than at Stapleton. Data compiled to date for the Denver area on the occurrence of the convergence zone and the severe storms it often creates show no significant differences between Stapleton and the new airport. NOAA officials said that additional weather monitoring is needed to establish conclusively whether any long-term climatological pattern exists.

Windshear

Forms of windshear include tornadoes and microbursts. Weather experts told us that weather systems typically intensify as they move east from the Rockies, but limited meteorological data from NOAA and NCAR on the incidence of tornadoes and microbursts have not indicated any difference between Stapleton and the new airport.

Data from the University of Chicago—where scientists have studied tornadoes for more than 20 years—show that tornadoes occur throughout the Plains states but tend to be more frequent and more severe east of the Colorado-Kansas border. NCAR and NOAA, which have collected and analyzed tornado data for almost a decade, say the data on tornadoes are insufficient to conclude that these severe storms occur more frequently in any particular location in the Denver area. Our review of tornado data for the period from 1981 to 1989 showed that tornadoes are scattered more or less randomly east of the Denver area, where both Stapleton and the new airport site are located.

We also examined whether the new airport site has more windshear and microbursts than Stapleton, which critics of the new airport have portrayed as already the worst windshear airport in aviation. Scientists from NCAR and the Lincoln Laboratory at the Massachusetts Institute of Technology have studied the occurrence of microbursts around four cities—Orlando, Florida; Denver, Colorado; Kansas City, Missouri; and Huntsville, Alabama--where they are frequent. According to a Lincoln Laboratory official, Orlando had the highest incidence of microbursts, although the differences in numbers and intensity of microbursts among the four locations are quite small.

NCAR scientists have been studying microbursts in the Denver area since 1987, using the Terminal Doppler Weather Radar system. From their data, which were available only for 1987 and 1988, we identified no notable concentrations of microbursts in the area. After reviewing the same data—and drawing on 10 years of experience with microbursts—

NCAR scientists said that the current Doppler radar data contradict the notion that microbursts are more frequent at the new airport site.

The chairman of the Aviation Weather Committee for the Air Line Pilots Association (ALPA) said that the physical size of the new airport would provide "greater operational flexibility in dealing with microburst events and tornado activity." He also said that the new facility, being farther from the mountains than Stapleton, "actually removes some of the maneuvering risks" associated with flying in the Denver area. He said that planes landing at Stapleton routinely fly over or near the new airport site at low altitudes with no adverse effects. The president of the Air Transport Association of America echoed many of the ALPA official's comments. He said that the

> marginally different weather conditions that could occur at the new facility should not pose a problem because of the unconstrained maneuvering area around the new site and the anticipated runway configuration. The deployment of state-of-the-art weather and air traffic control equipment will serve to further enhance the operation of the new airport.

FAA recognizes that microbursts can be dangerous to aircraft and should be avoided. Hence, the agency plans to install Doppler radar systems not only at the new Denver airport but also at 46 other microburst-prone airports in the nation.

Mountain Air Waves

During winter months in the Denver area, winds coming down the eastern slope of the Rockies gain speed and form waves, which cause turbulence. Some people contend that a mountain wave "node"—where the effect of the wave is particularly severe—is located directly over the new airport site. This contention is based largely on a 1956 United Airlines meteorology circular that describes mountain wave features in the Denver area.

According to NOAA and NCAR scientists, mountain wave nodes are not fixed and do not appear to be located over the new airport site any more frequently than elsewhere in the area. Furthermore, they said that the turbulence from mountain waves is most severe next to the foothills and lessens as the waves move eastward. A NOAA scientist noted that the effects of mountain waves may actually be less severe at the new airport, which is located east of Stapleton.

Wind Speed Differences

We found that wind speeds are higher at the new site than at Stapleton and that not all monitoring stations are within the boundaries of the site. However, the effect of higher wind speeds appears minimal. For example, for the year ending August 31, 1990, the wind-monitoring station located between two runways at the new airport recorded an average wind speed of 7.6 knots, as compared with about 7 knots at Stapleton during 1990. Also, Stapleton recorded calm winds more frequently—about 7 percent more often than the new airport. NOAA and NCAR scientists consider this difference to be insignificant. Similarly, airline pilots with whom we talked and the head of a flight training academy at Front Range Airport, which is 2.5 miles east of the perimeter of the new airport, said that the increased wind speeds at the new airport are not an issue and do not pose a problem for aircraft, since they are relatively constant from one direction. Also, we noted that wind speeds at other airport locations, such as San Francisco and Honolulu, are greater than at the new Denver airport. Average wind speeds at these two airports were 9.5 and 9.7 knots, respectively, during 1990, as compared with 7.6 knots at the new airport site.

The City's rationale for locating its wind-monitoring stations at or near the new airport site appears reasonable. Measurements of wind speed and direction have been collected since 1985 from monitoring stations at different locations in the vicinity of the new airport. These measurements began before the final airport site was selected, but they were taken in the general area under consideration. When the final site was determined, only one of three stations was located on the selected site. Later, another station, which had been located off-site, was moved between two planned runways. The third station is located just outside the new airport boundaries on the highest point in the area. This station has not been moved because it is used to track unobstructed wind conditions.

Design and Construction of Buildings and Runways Are Taking Expansive Soils Into Account

In designing and constructing buildings, roads, airport runways, and other structures in Colorado and other states in the region, geotechnical engineers must take into account the characteristics of expansive soils—soils that swell when wet. If not properly considered in construction projects, expansive soils can cause heaving and cracking of structures, which, in turn, can lead to premature replacement or high maintenance costs.

Some people have raised concerns about the suitability of soils underlying buildings and runways at the site, specifically, that

- soils at the site are highly expansive and unsuitable to build on;
- in designing and constructing runways and buildings, proper measures are not being taken to control the effects of expansive soils; and
- contractors are not conditioning and treating soil under runways according to design specifications.

Although the soils at the new airport site are expansive, engineers responsible for designing and building the airport have taken soil conditions into account in designing the runways and buildings. Also, a comprehensive quality assurance program has been implemented—with built-in checks and balances—to oversee construction and verify soil test results.

Soil Expansiveness

Geological maps produced by the U.S. Geological Survey and the State of Colorado Geological Survey and results of test borings of soils at the site show that the soils at the new site are indeed expansive. However, they are typical of soils throughout the Denver area where airport runways and other structures have been built.

The soils at the new airport are similar to soils underlying the two runways at Front Range Airport and a portion of one runway at Stapleton. The same engineering firm responsible for preliminary design of runways at the new airport designed the runways at Front Range Airport. We verified the conditions of these runways by physically inspecting both of them. We found that the main runway at Front Range, built in 1983, is similar in design to runways at the new Denver airport, and it is in excellent condition. Conversely, we found that the other runway--constructed in 1985 as a temporary runway until a larger replacement runway could be built—was constructed without the same design measures to control expansion. This newer runway is showing signs of cracking and heaving due to soil expansion.

Runway and Building Design

According to geotechnical engineers, expansive soils do not preclude construction, but rather require the use of proven techniques to correct and compensate for the expansiveness. To determine the techniques that should be used at the new airport site, contractors have extensively investigated subsurface conditions, analyzing several thousand soil samples. The analyses, which show that the soils are expansive to varying degrees, have been used to design the foundations for buildings and runways.

In designing the airfield, engineers plan to minimize expansion by preventing infiltration of moisture into the subgrade. Their process includes

- excavating all soil under buildings and runways to a depth of 6 feet;
- mixing, wetting, and compacting this excavated soil according to a predetermined specification to form a "select" subgrade of reasonable uniformity and composition;
- applying a 6-foot layer of select subgrade under runways and some buildings and stabilizing the top 12 inches of this layer with lime to form a less permeable moisture barrier; and
- applying over this select base an 8-inch layer of thinly mixed concrete followed by 17 inches of Portland cement concrete to form the runway surface.

Some have expressed concern that adding lime to soils containing gypsum could worsen soil expansion. City consulting geotechnical engineers are aware of this possibility, but their analysis of the lime-treated soil at the new airport shows that it contains insufficient gypsum or other material to cause an expansive reaction with lime. To further test the expansiveness of the lime-stabilized soil, City consulting engineers prepared test fills of select soil at the site, let the soil sit for more than 6 months, and then measured the degree of soil expansion. Soil analyses of these fills performed by a soils expert in lime stabilization at Texas A&M University showed that expansion of the select soil was well within design limits.

Concerns were also raised about the adequacy of water run-off ponds constructed between the runways to ensure drainage. A drainage system has been designed that will carry away water within 24 hours from the worst rain storm expected in a century. According to an official from the FAA's Denver District Office, FAA concurs with the design of the drainage ponds. Analyses performed by hydraulic engineers on the project show that 5 to 15 hours, on average, would be required to drain the ponds of the water volumes estimated to be generated by a 100-year storm. Even if water remained in the ponds for some unforeseen reason, project engineers do not believe that it would seep into the soil beneath the runways because the ponds would be lined with a heavy clay soil that allows water to permeate only a few inches a year.

As recommended by experts who specialize in construction on expansive soils in the Denver area, buildings and other structures at the new airport are being erected on drilled piers, which in some cases extend 50 feet below the surface. Also, to better control the effects of soil expansion, a void of at least 6 inches is being left between the ground and the building floors in case any expansion occurs, according to officials from the City of Denver's Building Inspection Division. They said that structures at the new airport are being built in accordance with standard building practices for the Denver area.

Quality Assurance Program to Monitor Construction

A two-tiered quality assurance program is in place at the new Denver airport to ensure that construction proceeds according to design plans and specifications. First, contractors must hire quality control inspectors from independent firms to provide construction oversight. Second, the City has assembled a separate team of quality assurance inspectors from engineering consulting firms not involved in construction at the site. Team members, including geotechnical engineers and other experts, oversee construction at the site. Also, the City has hired a geotechnical firm to collect test samples necessary to verify the contractors' quality control tests. As of July 31, 1991, over 60,000 quality control field and laboratory tests and about 8,000 additional quality assurance tests had been performed as part of overseeing construction at the site.

FAA has approved the City's quality assurance program, and, according to FAA officials at the Denver District Office, the City's program surpasses FAA's criteria for quality assurance. In addition to approving the City's program, FAA reviews test results at the site monthly to ensure that any deviations from specifications are properly resolved, according to FAA officials.

To obtain first-hand knowledge of the quality assurance program, we made several unannounced visits to the site and observed runway construction activities. We observed contractor quality control inspectors and City quality assurance inspectors overseeing construction activities. In addition, we reviewed selected quality assurance and quality control test results at the site and found no evidence or indication that construction procedures deviated from established specifications.

The New Airport Can Reduce Local Delays, but Its Effects on System Delays Are Unclear

Reducing local and systemwide air traffic delays was a major objective underlying the City's decision in the mid-1980s to build a new Denver airport. According to FAA data, Stapleton has been among the most congested airports in the nation. Long-term forecasts at the time the decision was made to build a new airport predicted substantial increases in air traffic, which would have worsened delays. To alleviate air traffic delays and avoid obstacles to expansion at Stapleton, the City decided to build a larger, more efficient airport that would meet air traffic needs well into the next century.

Several people have raised concerns about the need for a new airport and the impact of this airport on reducing local and systemwide delays. Those expressing concerns say that

- since air traffic at Denver has not grown as much as the City and FAA projected, Stapleton can accommodate growth in air traffic until at least the year 2000;
- if additional capacity is needed at Stapleton after the year 2000, current runways could be expanded or new ones could be built on the grounds of the adjacent Rocky Mountain Arsenal;
- the new Denver airport, as currently planned, will open with fewer or with the same number of runways and gates as Stapleton; and
- the new airport will have little or no effect on reducing local and systemwide delays.

When the new airport opens, local air traffic delays should decrease significantly. Reduced delays are possible because the layout of runways, taxiways, and gates at the new airport is more efficient than at Stapleton. However, the impact of the new airport on systemwide delays is unclear.

Stapleton Can Accommodate Current Air Traffic Levels but Not Without Delays

Since the mid-1980s, FAA has ranked Stapleton as one of the most congested airports in the country, with annual air traffic delays of at least 38,000 hours. FAA considers an airport congested if it experiences at least 20,000 hours of airline flight delays annually. At the time the decision was made to build a new airport, long-term forecasts predicted substantial increases in air traffic for the Denver area. In the 1986 master plan for the new Denver airport, Peat Marwick forecast that air traffic would grow from 17.4 million enplaned passengers in 1986 to 25.8 million in 1995. In 1988, the 1995 estimate was lowered to 23.6 million.

Instead of growing in the late 1980s, air traffic at Stapleton fell, in part because Frontier Airlines ceased operations in 1986 and a recession adversely affected the Denver economy. In 1990, enplaned passenger traffic leveled off at 13.8 million. Despite the decline in air traffic, FAA data show that Stapleton continued to experience congestion, with over 46,000 hours of flight delays in 1990.

Problems Cited With Expanding Stapleton

To alleviate delays, the City could have chosen either to expand Stapleton airport or to build a new airport. Since at least the mid-1970s, expansion of Stapleton airport has been studied as an alternative to building a new airport. Some studies offered options that called for expanding Stapleton onto the Rocky Mountain Arsenal at costs ranging between $875 million (in 1979 dollars) and $1.5 billion (in 1981 dollars). However, these studies may not have included substantial costs for improving existing runways, taxiways, and access roads. Costs for decontamination and the demolition of the Arsenal facilities also were not included in these estimates. The City chose to build a new airport because, in expanding Stapleton, the City would have faced several problems, including obstacles to building on the Arsenal grounds and excessive aircraft noise around Stapleton.

Because the amount of land available to build additional runways at Stapleton is inadequate to meet runway spacing criteria, expanding there would require using portions of the adjacent Arsenal currently controlled by the U.S. Army. City officials believe that expanding onto the Arsenal is not feasible because parts of the Arsenal are contaminated with a variety of chemicals that were used formerly to produce nerve warfare agents and pesticides on the site. These officials said that if the airport were expanded onto the Arsenal, the City might be held liable for undetermined amounts required to clean up contamination at the site. In addition, no portion of the Arsenal could be made available to Stapleton before completion of the cleanup program, according to the Arsenal official in charge of the cleanup. He said the construction of airport facilities on the Arsenal could drastically alter the characteristics of the underground water and thereby potentially spread the contamination. Cleanup of the Arsenal will continue through at least the turn of the century.

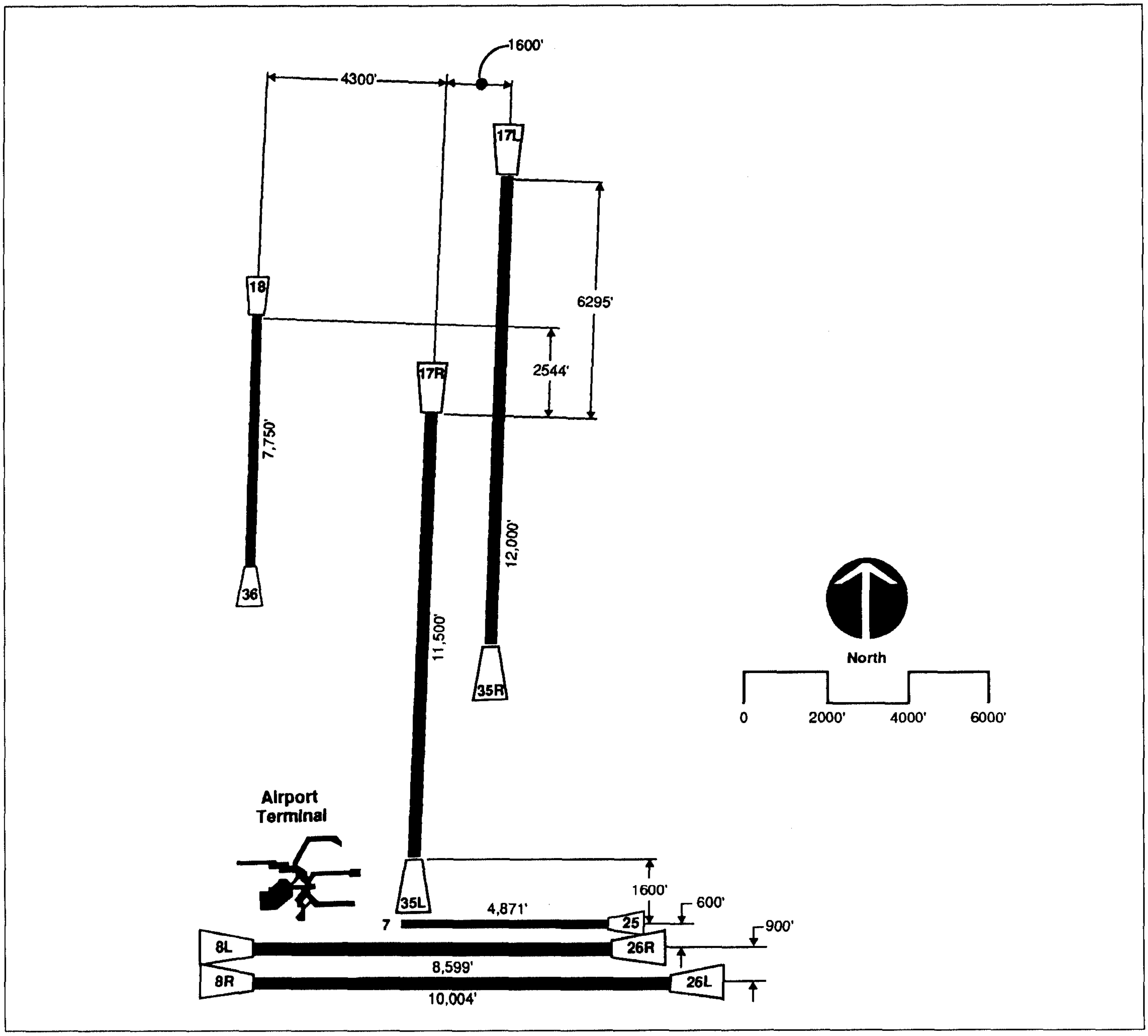
Aircraft noise at Stapleton has been a continuing problem. In 1981, members of communities adjacent to Stapleton sought injunctive relief against the City and County of Denver because of excessive noise problems in their neighborhoods. In the 1985 settlement of the lawsuit, the City agreed not to construct any additional runways at Stapleton for the use of turbo-jet aircraft and to close Stapleton and move its operations to a new airport by the year 2000 or as soon as possible.[1] To expand or build additional runways at Stapleton, the City would have to negotiate a new agreement with these same plaintiffs. In contrast, the City believes aircraft noise at the new airport, which is located in a sparsely populated area away from downtown Denver, will not be a significant problem. The City has purchased land 2 miles off the ends of runways to prevent construction of residential developments within close range of aircraft noise.

Configuration at the New Airport Is More Efficient Than at Stapleton

The overall layout of the new airport is more efficient than that of Stapleton. This increased efficiency is readily apparent when comparing the layout of its runways and gates with Stapleton's layout. Stapleton has six runways, three north-south and three east-west, and 120 gates. (See fig. IV.1.) Two runways are used for commuter carriers. One is 4,871 feet long and the other is 7,750 feet long. These commuter runways are used only sporadically, leaving Stapleton with four air carrier runways—two north-south and two east-west—that range between 8,599 and 12,000 feet long. The separation between the air carrier runways ranges from 900 feet to 1,600 feet. According to airport officials, only 15 gates can accommodate wide-body aircraft without affecting other aircraft. Also, 11 gates at Stapleton are currently unused.

[1] Glenn vs. City and County of Denver, Civ. Action No. 81-CV-2729 (Den. D.Ct. Sept. 19, 1985, as amended by stipulation on Aug. 11, 1986)

Figure IV.1: Stapleton International Airport Runway Configuration



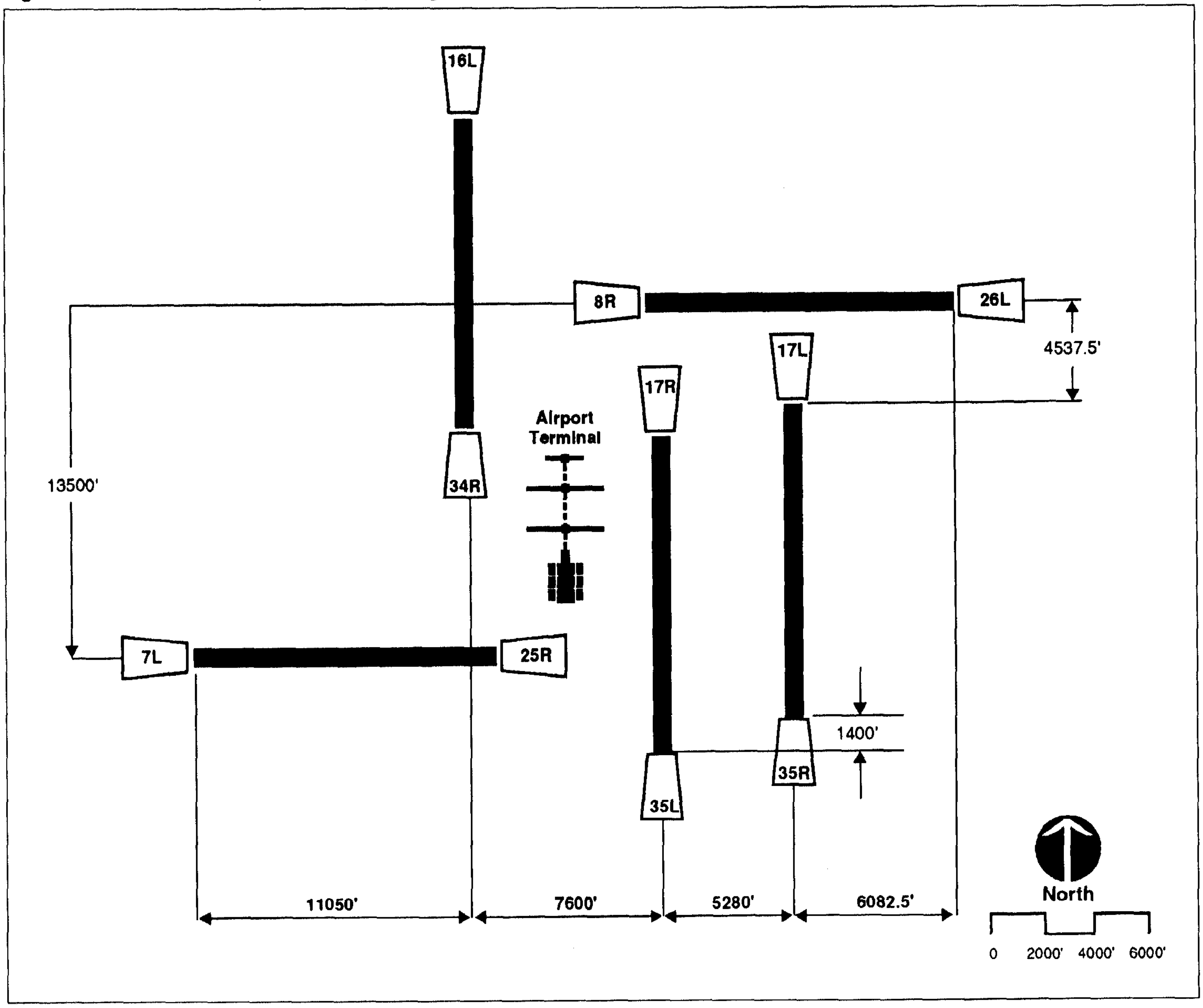
During poor weather conditions, simultaneous aircraft landings are not permitted at Stapleton because its air carrier runways are spaced closer than the 4,300-foot minimum required by FAA for simultaneous take-offs and landings. This close spacing can cause aircraft delays during these periods. Also, ground congestion occurs at Stapleton during peak traffic periods, in part because its runways and taxiways are configured such that aircraft must wait before crossing taxiways and runways to go to and from the gate area.

In contrast, according to the City's plans, the new Denver airport will open in 1993 with approximately 95 gates and five runways. (See fig. IV.2.) A sixth runway is planned to be operational approximately 1 year after the airport opens. (See fig. IV.3.) The first five runways will be 12,000 feet long and the sixth will be 16,000 feet. The runway configuration at the new airport will include high-speed taxiways to allow quick exits from the runways, and aircraft will not have to cross the runways on their way to and from the gate area. Runways will be spaced to allow simultaneous take-offs and landings even in poor weather conditions.[2] The distance between concourse areas will be spacious enough to allow unrestricted movement of aircraft. Also, although the new airport will have fewer gates on opening day than Stapleton, these gates will be sized to handle all types of aircraft. For example, according to City officials, all gates at the new airport, as compared with 15 at Stapleton, can accommodate wide-body aircraft without affecting other aircraft.

In addition to a more efficient airport layout, the new site will have more land than Stapleton—about 48 square miles inside the airport boundary—which will allow for the construction of up to 12 runways and 200 or more gates, depending on the aircraft mix, if needed to accommodate future growth in air traffic.

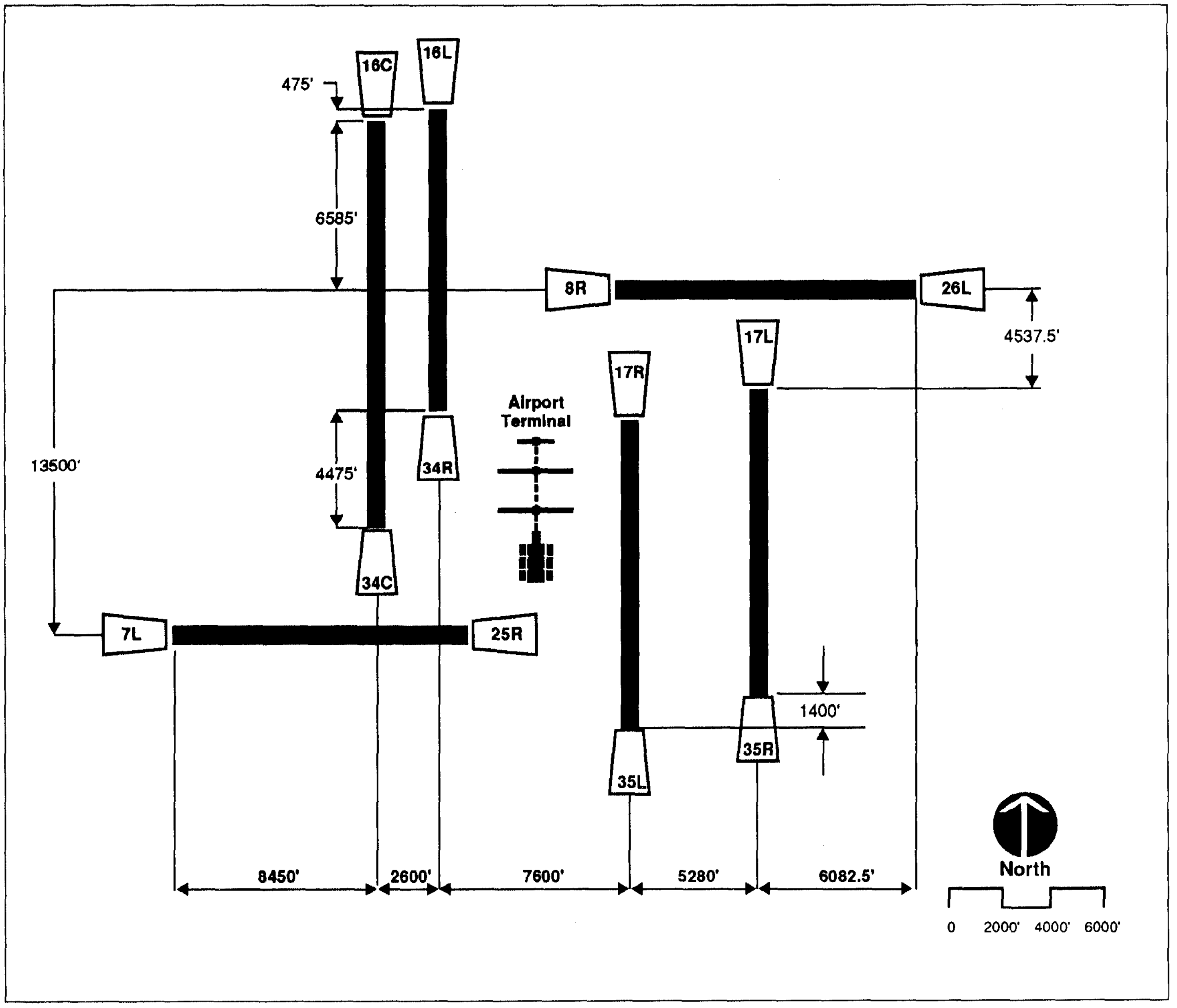
[2]The new Denver airport has the potential to land aircraft simultaneously on three parallel runways in poor weather conditions.

Figure IV.2: New Denver Airport Runway Configuration—Opening Day



Source: City of Denver.

Figure IV.3: New Denver Airport Runway Configuration—1 Year After Opening Day



Source: City of Denver.

New Airport May Reduce Local Delays, but Its Effect on Delays Systemwide Is Unclear

A number of different computer simulation models have been used to assess the impact of the new Denver airport on reducing local and systemwide delays.[3] In general, these simulations suggest that the new airport can accommodate growth in air traffic with fewer delays than Stapleton. The only model we found capable of assessing reductions in delays systemwide provides limited evidence that the new airport will reduce these delays.

Projected Reductions in Local Delays

Our review of several computer simulations showed that, in general, fewer delays would be likely to occur at the new airport than at Stapleton, especially during poor weather conditions. For example, the results of one simulation showed that total delays in all weather conditions would decline by about half, from 4 minutes per operation at Stapleton airport to 2 minutes per operation at the new Denver airport. This model suggests that during poor weather conditions, delays would decline about 75 percent, from 28 minutes per operation at Stapleton to 7 minutes at the new airport. The results of another simulation, based on 1990 flight operations levels, showed that local delays at Denver would be reduced substantially, from about 5 minutes at Stapleton to less than 1 minute at the new airport.

Uncertainty of Delay Reductions Systemwide

The only computer simulation model that we found to quantify the impact of the new airport on nationwide delays is the National Airspace System Performance Analysis Capability (NASPAC) model. Results of this model suggest that the new Denver airport would probably have no impact on systemwide arrival delays in "good" weather, but would reduce such delays by about 4 percent in "poor" weather and by 18 percent in "severe" weather.

The NASPAC model uses three national daily weather scenarios that were "selected to represent a range of weather conditions." The weather scenarios portray the weather for the entire system, not just the Denver area. The "good" weather day represents the best-case scenario—good weather at all airports all day. This day provides a lower limit on the delay reduction than might be expected from the new airport. The "poor" weather day uses systemwide weather from February 14, 1989,

[3]We examined selected results produced by five computer simulation models for the Denver area: National Airspace System Performance Analysis Capability developed by MITRE Corporation, Airport and Airspace Simulation Model developed by ATAC, Airspace Simulation Model developed by Landrum and Brown, Airport Machine developed by Dr. Joline, and Runway Delay Simulation Model developed by FAA.

and the "severe" weather day uses weather from March 2, 1989. Because the "poor" and "severe" days represent conditions that occur at fixed points in time, they may not be representative of actual delay reductions occurring throughout the year. FAA was unable to provide any background analysis on how frequently these three sets of weather conditions actually occurred on a systemwide basis to support its choice of these three weather scenarios.

FAA officials have generalized the results of this study, saying that the new Denver airport will reduce systemwide delays by almost 5 percent. Without information on the representativeness of the three weather scenarios, we cannot confirm FAA's estimate or determine the impact of the new Denver airport on systemwide delays.

New Airport Revenues Appear Adequate to Cover Costs

The new airport will cost at least $3.1 billion, including costs for land, design, construction, interest prior to opening, and miscellaneous consulting and financing. This figure does not include the cost of expanding the airport to accommodate United Airlines, which recently agreed to transfer its hub operations from Stapleton to the new airport. These additional costs are expected to be $680 million, which would raise the total costs of the new airport to nearly $4 billion.

Most of the costs of building the airport will be financed with bonds to be repaid from future airport revenues. Some people have raised issues regarding the project's financial viability—the likelihood that the interest and principal on the bonds will be paid when due. These individuals have expressed concern that the state of Colorado or the federal government might have to cover shortfalls in new airport revenues to prevent default.

Specific concerns have been raised about (1) potential revenue shortfalls that may occur because of less-than-expected passenger traffic at Denver, and (2) potential construction cost overruns and schedule delays, which, according to people who have expressed concerns, frequently occur with large projects like the Denver airport. These concerns have stemmed in part from the considerable uncertainties surrounding the project, such as the outcome of the Continental Airlines bankruptcy proceedings and potential construction cost overruns and schedule delays. Concerns about revenues have been heightened by past fluctuations in passenger traffic levels, which in 1990 were 21 percent below 1986 levels.

Ultimately, the financial viability of the project will depend on keeping costs within budgeted levels, opening on schedule, and generating enough revenues from airline fees, airport parking, rental cars, and other sources to cover expenses. Currently, construction costs are slightly below budget and some schedule slippage in construction has occurred. Nevertheless, we cannot say whether the project will be completed within budget or on time because construction was only 19 percent complete through July 1991. While Denver's traffic levels have fluctuated sharply in the past and may do so in the future, revenues are likely to be more stable; at present, revenue assumptions and projections appear reasonable. The airport's fee-setting structure is designed to stabilize revenues by allowing per-passenger fees charged to airlines to rise if passenger traffic declines.

After reviewing the financial plan for the new airport and weighing key uncertainties associated with the project, we believe that the Denver Airport System can probably repay the bonds as planned. However, this repayment capability is subject to several uncertainties, including the possibility of substantial unforeseen cost overruns and schedule slippages, the possibility of Continental Airlines ceasing or curtailing operations at Denver because of its financial problems, and the possible negative effects on traffic of a general nationwide increase in airfares. Our analyses have shown that, even given the loss of a hubbing carrier and substantial traffic shortfalls, the airport should be able to generate sufficient revenue to service its debt. However, the possibility of default always exists, and that possibility would become more likely if a number of the adverse events listed above occurred.

The Financial Plan for the New Denver Airport

The airport's original financial plan (the "original program") assumed that both United Airlines and Continental Airlines would transfer their hub operations from Stapleton to the new airport.[1] Because United delayed committing itself to the new airport, however, the airport developed a revised plan (the "current program") in April 1991, assuming that only Continental would move its hub to the new airport. The current financial plan therefore assumes a $3.1-billion airport—large enough to accommodate Continental, but not both United and Continental. This figure includes about $2.1 billion in actual design and construction costs (including the costs of access roads) and about $1 billion in costs for land, planning and administration, and interest and financing. Costs of air traffic control facilities and equipment to be paid for by the federal government are not included in this amount. (See table V.1.)

This summer United Airlines agreed to transfer its hub operation to the new airport. Since then, the City and its consultants have been revising the airport's financial plan to incorporate the larger airport needed to accommodate both Continental and United. United has asked for more facilities than the airport anticipated, so the new 2-hub plan will be more costly than the original 2-hub plan. The United Airlines expansion will increase total costs by $680 million (above the "current program" 1-

[1] An airline hub operation is an airport connecting complex used by an airline to transfer passengers from one set of incoming planes to another set of outgoing planes. By having a hub operation, the airline can achieve higher load factors, lower costs, and more frequent service between the points connected through the hub. Having a hub operation means that the airline will use a substantial portion of the airport's gates, ticket counters, and baggage facilities and will generate a substantial portion of the airport's revenues.

hub plan) for construction and by an as yet undetermined amount for additional financing.

Table V.1: Initial Costs to Construct and Finance the New Denver Airport

Dollars in millions

Use	Dollar amount
Overall construction costs (including access roads)	$2,085[a]
Capitalized interest[b]	518[a]
Land acquisition	210
Bond reserve requirement/capital fund	210[a]
Issuance expenses/bond discount	61[a]
Pre-1990 planning	21
Total	**$3,103[c]**

Note: These costs include planning, design, construction, and financing costs to be incurred before the opening of the airport. They also include costs to build the fifth runway and Continental's support facilities. Interest charges due after the opening of the airport, as well as operating and maintenance costs of the airport after opening, are not included.

[a]These figures do not include additional costs for expanding the airport to accommodate United Airlines. Construction costs are expected to rise by about $680 million. Increases in financing costs had not yet been calculated at the time we performed our review.

[b]Capitalized interest is the cost of meeting interest payments on outstanding bonds during the construction period, before the airport is generating revenues that can be used to meet interest payments.

[c]Column does not add to total because of rounding.

Source: City of Denver.

About $2.5 billion, or 81 percent, of the funds needed for the new airport will come from revenue bonds, which are bonds that are repaid solely from the revenues of the project for which the money is borrowed. Repayment of revenue bonds is the responsibility of the Denver Airport System; these bonds are not backed by local, state, or federal governments or by the new airport's assets. The remaining funds for constructing the airport, which are required in advance of the airport's opening, are to be obtained from federal grants, passenger facility charges (PFCs) levied at Stapleton,[2] and surplus Stapleton revenues and interest income. (See table V.2.) Some funding sources are not shown in table V.2 because revenues from them will not be received until after the new airport opens. These include Federal Airport Improvement Program grants totaling $156 million, part of the PFC revenues, and the $100-million proceeds anticipated from the sale of Stapleton airport. Funds from these sources will be used to retire bonds issued prior to the opening of the airport.

[2]Passenger facility charges are charges levied on passengers who board flights at an airport. The charges may range up to $3 and were authorized by the Aviation Safety and Capacity Expansion Act of 1990.

Table V.2: Capital Funding Sources for the New Denver Airport

Dollars in millions

Source	Dollar amount
Airport revenue bonds (includes $300 million in short-term bonds)	$2,475[a]
Federal airport improvement grants	279[b]
Interest income from airport funds	199
Nonairline revenues from Stapleton	89
Passenger facility charges	61
Total	**$3,103**

[a]Proceeds from the sale of Stapleton airport are not listed explicitly because they will be received after the new airport opens. The figure for airport revenue bonds includes $75 million in short-term bonds that will be paid off with the anticipated proceeds from the sale of Stapleton.

[b]A total of $435 million in federal Airport Improvement Program grants is anticipated, $279 million of which will be received before the airport opens. The figure for airport revenue bonds includes $156 million in short-term bonds, most of which will be repaid as the remaining federal grants are received. The $435 million does not include $180 million for air traffic control facilities and equipment that will be paid for directly by the federal government.

Source: City of Denver.

Provision for Debt Service Requirements

The revenue bonds will be repaid over various periods; the last bonds will be due to be repaid in 2025. Annual payment of interest and principal on these bonds constitutes "debt service." For the new airport to be financially viable, its total revenues, minus its costs for operation and maintenance (O&M), must exceed its debt service. Debt service for interest on the bonds is expected to vary from $145 million to $177 million per year between 1994 and 2000.[3] Debt service during this period is primarily for interest only; repayment of full principal is deferred until after 2000.

[3]This does not include PFC-backed bonds. Debt service on all bonds, including PFC-backed bonds, will vary from $182 million to $227 million each year from 1994 to 2000.

Table V.3: Projected Annual Revenues and Expenses for the New Denver Airport

Dollars in millions

	Year						
Budget category	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Gross revenues	$280	$296	$308	$314	$317	$321	$341
O&M expenses	105	110	118	123	128	133	138
Net revenues	175	186	189[a]	191	189	188	202[a]
Debt service	145	173	173	168	164	160	177
Surplus after debt service	30	13	16	23	25	28	25

Note: Revenues do not include PFC-generated revenues because total debt service does not include debt service on PFC-backed bonds.

[a]Net revenues and O&M expenses do not add to gross revenues because of rounding.

Source: City of Denver.

The City of Denver operates under a bond ordinance that requires the airport to charge fees sufficient to generate annual revenues that, along with funds remaining from previous years, will cover both the operating and maintenance expenses of the airport and 125 percent of the debt service. The ratio between net revenues (total revenues minus operating and maintenance expenses) and debt service is referred to as the "debt service coverage." Airports commonly operate under bond ordinance requirements that debt service coverage be at least 125 to 140 percent of net revenues. Debt service coverage in excess of 100 percent is typically required by bond ordinances to provide a financial margin of safety to ensure repayment in the event of unforeseen financial needs.

The financial plan makes use of a "coverage account" to meet the bond ordinance requirement. The coverage account is accumulated before the airport opens and is 25 percent of the amount required for debt service each year. As shown in table V.4, the coverage account will have available from $31 million to $42 million in excess of anticipated surpluses from 1994 to 2000. The airport is required to set charges sufficient to maintain debt service coverage at 125 percent of debt service, of which only 25 percent may be in the coverage account. When the amount in the coverage account is included, the total amount available for debt service in any given year varies from 130 percent to 142 percent of debt service requirements. (See table V.4.)

Table V.4: New Denver Airport's Net Revenues, Debt Service Requirements, and Debt Service Coverage

Dollars in millions

	Year						
Budget category	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Net revenues	$175	$186	$189	$191	$189	$188	$202
Debt service	145	173	173	168	164	160	177
Surplus after debt service	30	13	16	23	25	28	25
Coverage account	31	39	39	39	38	38	42
Net revenues plus coverage account	206	225	228	229[a]	227	226	245[a]
Debt service coverage	141%	130%	132%	136%	138%	142%	138%

Note: Revenues do not include PFC-generated revenues because total debt service does not include debt service on PFC-backed bonds.

[a]Net revenues plus the coverage account do not add due to rounding.

Source: City of Denver.

Representatives from Standard & Poor's (S&P), one of the two bond rating agencies that rated the new Denver airport bonds, expressed concern over the large amount of outstanding debt issued by the new airport. While still issuing an investment grade rating (i.e., a rating indicating an acceptable level of risk for most investors), S&P rated the new airport's bonds lower than the revenue bonds issued previously for other major airports. Representatives from the other bond rating agency with whom we spoke, Moody's Investors Service, rated the new airport's bonds slightly higher than did S&P. The two bond rating agencies considered as positive characteristics of the new airport its location (which makes it well-suited to a hub operation) and its capacity for growth. They also emphasized as positive factors the flexibility of the airport plan and the City's assurance that Stapleton would be closed after the new airport opens.

After the new airport begins operations, its annual revenues will be derived from two main sources—airline operations and other operations, such as parking, rental car companies, gift shops, and other concessions on airport property. Revenues from airlines are expected to constitute over 60 percent of the airport's annual revenues. (See table V.5.) Sources of financing other than annual revenues include proceeds from the sale of Stapleton airport, passenger facility charges, and federal grants. Revenues are based on rates and charges assessed according to a cost-recovery rate methodology. This methodology, which sets rates so that costs for each part of the airport are recovered by charges to the users of that part, is required by the City's bond ordinance.

Table V.5: New Denver Airport's Annual Revenue Sources for 1994 Through 2000
(Percentage of Total)

Source	Percentage
Airline rentals, fees, and charges	62
Nonairline revenues	29
Interest income	7
Aviation fuel tax	2
Total	**100**

Source: City of Denver.

The Airport Appears to Have a Strong Commitment to Cost Control

The City appears to have a strong commitment to control costs. The construction bids awarded through August 1991 are under budget, in part because of cost-control procedures used by the City. Some schedule slippage has occurred, although airport officials have indicated that, if necessary, they are prepared to change the scope of the airport—for items not essential to operations—to open the airport as planned. Projections for operating and maintenance costs, which are based on experience at Stapleton, appear to be reasonable.

Initial Construction Bids Are Under Budget

Although only a limited number of contracts have been awarded and completed to date, the airport construction project is currently proceeding under budget. Thus far, 27 construction contracts, valued at $732 million, have been awarded, and 5 of these, valued at $58 million, have been completed. After reviewing cost data on all 27 contracts through August 1991, we found that in aggregate the contracts were under the planned budget. However, we recognize that it is too early to determine whether the entire project will be completed within budget. In the event of cost overruns for construction contracts, the City has provided, in the new airport budget, contingency reserves totaling $202.5 million—equal to 10 percent of the total budget.

The absence of cost overruns through August 1991 appears to be due in part to the City's cost-control procedures. Contractor performance is monitored throughout the design and construction phases. According to airport officials, design contracts include a provision requiring designers to redesign projects at no additional cost if the construction bids exceed established project budgets by 5 percent. For example, the design specifications for one runway initially specified the use of sand as a filler base for grading and drainage. However, because the cost of moving sand was higher than anticipated, the lowest bid received was about 10 percent over the budgeted amount. The designer was requested to revise the design, substituting less costly reworked earth for sand, at no expense to the airport, to bring the project in within budget. The redesigned project resulted in a change order reducing the cost to 11 percent below the budgeted amount while still achieving established construction quality standards.

After the construction contracts have been awarded, contractor performance is monitored continually by the project management team. Airport engineers are responsible for daily monitoring of all contracts to ensure that each contract is progressing on schedule and that the proper materials and equipment are being used. Change orders requested by contractors are closely reviewed and negotiated when changes are necessary, according to airport management. The airport has hired a program management support consultant to recommend design and scope changes to prevent cost overruns. If a contract is about to exceed its budget, the program management support consultant will work with the contractor to minimize costs or reduce the scope of the project.

Some Schedule Slippage Has Occurred

A slippage in the construction schedule for the new airport could delay the opening of the airport, thereby forcing the City to issue additional bonds to cover interest charges until the airport opens and increasing the overall interest costs. The City has allowed for a schedule slippage of as much as 2 months—to January 1994—in its financial plan. Any further slippage would require borrowing additional money to cover debt service.

Although only part of the construction project has been completed, monthly project reports from the airport project management team indicate that the project schedule may be slipping. As of July 1991, work valued at $367 million had been completed, compared with work valued at $382 million that had been planned for completion as of that date, a slippage of about 4 percent. While key milestones have been met, work on the critical $38.6-million subway tunnel and the $27.4-million central portions of the concourses has fallen several weeks behind the projected completion dates. According to airport officials, the schedule slippage should not affect the airport's opening date.

As with contract amounts, the project management team is prepared to revise the scope of the project to ensure that the airport opens on time. The chief of construction stated that the airport would be prepared to defer nonessential items, such as landscaping or the children's play area in the terminal complex, to open on time.

Projections for Operating and Maintenance Expenses Are Based on Experience at Stapleton

O&M expenses at the new airport are expected to increase by 53 percent, from $69 million in 1989 at Stapleton to $105 million in 1994 at the new airport. O&M expenses for the new airport have been extrapolated from the expenses incurred at Stapleton and adjusted for the increases that will be required at the new airport and for inflation. The adjustments for increases in O&M requirements at the new airport were based on judgments of the airport management. For example, after reviewing Stapleton's expenses, the airport management estimated that costs for road and grounds maintenance would increase at the new airport by over 200 percent and costs for snow removal would increase by 60 percent.

The higher O&M expenses at the new airport are primarily due to the increased size of the terminal complex. The financial model used for estimating O&M expenses for the terminal assumes a direct relationship between the size of the terminal complex and the cost of terminal O&M. The other two components of O&M—airfield and administrative—contribute less to the overall increase in total O&M expenses at the new airport. Airfield O&M is estimated to increase nominally at the new airport because, even though there is more concrete in its runways, taxiways, and aprons, the airfield is entirely new and should initially require less maintenance. Finally, administrative O&M expenses are expected to remain about the same at the new airport as at Stapleton. An official at the Dallas/Fort Worth airport—the most recently constructed large new airport (in 1974)—told us that Denver's methodology for projecting O&M expenses appeared reasonable.

Airport Revenue Projections Can Be Met, but Risks Remain

Airport revenues are subject to various kinds of uncertainty. Since most revenues are derived, directly or indirectly, from passengers using the airport, the level of passenger traffic volume is a major source of uncertainty. Traffic volume affects revenues derived both from airline operations (e.g., landing fees and rental rates on terminal space) and from nonairline sources (e.g., parking fees and rental car charges). However, the way in which rates are established is designed to compensate for variations in traffic volume.

The Denver airport handles two kinds of traffic—passengers beginning or ending their trips in Denver and those making connections in Denver. The connecting traffic is handled primarily for United Airlines and Continental Airlines, which operate connecting hubs at the airport. Because these connecting hubs generate the majority of the airport's total traffic, changes in hubbing strategies by these two airlines can have a major impact on the airport's traffic.

The uncertainty of revenue estimates for the new airport has been heightened by discrepancies between past airport traffic projections and actual traffic levels. In 1986, airport officials forecast that traffic would grow from 17.4 million passengers per year to 20.1 million in 1990. Instead, traffic fell to 13.8 million, for three major reasons. First, the Denver economy suffered a decline, depressing demand for air travel.[4] Second, air fares in the Denver market, which had been below those of most other markets in 1986, rose by 57 percent between 1986 and 1988, as compared with fares at 38 other airports.[5] This increase in relative fares would be expected to depress traffic volume. Third, Continental Airlines reduced its service levels at the airport.

Future changes in traffic are uncertain because they are affected by uncertainties in future levels of economic activity and airline fares. The Denver economy appears to be recovering now, but it could face renewed vicissitudes during the extended period over which the airport bonds will be repaid.[6] Additional sharp increases in air fares (such as those experienced in the late 1980s) are less likely to occur in the future than in the past because fares are already relatively high at Denver. However, fares at Denver could rise if fares rise nationally. This increase could occur if fuel costs or other costs rise, or if further consolidation among airlines leads to lessened competition and higher fares.

It is also possible that traffic could rise if fares decline. One major airline noted for its low fares is considering entering the Denver market after the new airport opens because reduced congestion at the new airport would make entry easier. Entry of a low-fare competitor would tend to reduce fares for all the airlines at the airport and stimulate traffic. Expanding an airport's capacity is, in fact, likely to encourage new entry and thus keep fares low. This effect is particularly likely to occur at the new Denver airport, where the airport management has stated an intention not to sign restrictive use agreements with major tenant airlines that might discourage entry by other airlines.

[4]For example, employment in the Denver metropolitan area declined by 2 percent between 1985 and 1987.

[5]See our report, Airline Competition: Higher Fares and Reduced Competition at Concentrated Airports (GAO/RCED-90-102, July 11, 1990). In early 1986, Denver was the only airport of the 15 concentrated airports we studied where the fares of the dominant airlines were below the fares at our comparison group of 38 unconcentrated airports. By 1988, fares of the dominant carriers at Denver had risen so that they were above the fares at the 38 comparison airports.

[6]Employment in the Denver metropolitan area rose by 5.2 percent between 1987 and 1990, and the unemployment rate has fallen to 4.5 percent, which is below its 1985 level.

Even if traffic does decline, or grows more slowly than forecast, the rate-setting procedure for airline landing fees at the new airport is designed to compensate for shortfalls in traffic. The airport uses a cost-recovery rate methodology under which airline landing fees recover the airfield's cost of construction, operation, and maintenance. Landing fees charged to airlines are determined so that, regardless of traffic volume, rates will recover costs.

One of the uncertainties in the airport's financial plan is the extent to which it can raise fees and charges without driving away traffic. Airport rates and charges are a small percentage of total airline costs. The airport fees and charges to the airlines at the new airport, per enplaned passenger, are expected to be $13 in 1995, or about 5 percent of average airfares.[7] A 20-percent increase in airport costs would require an increase in such charges of about $2.60, which, if passed through to passengers, would raise airfares by about 1 percent. This increase would depress traffic slightly, probably by about 1 percent also.[8] If charges per passenger rise by 20 percent while the number of passengers falls by only 1 percent, total revenue will rise by almost the full 20 percent.

The new airport can thus raise rates and charges on airlines without being concerned that the reduction in traffic will eliminate the increase in revenue. At some point, rates and charges could become so high that further increases would have a more significant effect on traffic. It is not certain at what point this would occur, but in view of the difficulty in traveling to Denver by surface transportation, it appears that airport costs could rise to a substantially higher level before they would prevent the airport from achieving further increases in revenues.[9]

Of more immediate concern to the City is the provision in its agreement with the two leading airlines at the airport—United and Continental—that releases them from their lease obligations if the airport fees and

[7]The average round-trip fare in the data sample used in our recent report, Airline Competition: Effects of Airline Market Concentration and Barriers to Entry on Airfares (GAO/RCED-91-101, Apr. 26, 1991), was $263.

[8]This estimate is based on a Department of Transportation study, St. Louis Aviation Forecast Study: Final Report (DOT-40176-2, Sept. 1974), which found that when airfares rose by 1 percent, air traffic fell by 0.8 percent. Fare increases would probably be concentrated on traffic originating at or destined for the airport, rather than on connecting traffic.

[9]If per-passenger airport costs rose, for example, to $100 (about seven times their anticipated level, and about one-third of airfares), and the sensitivity of air traffic to airfares shifted so that a 1-percent increase in airfares caused a 3-percent decrease in traffic, then an increase in airport rates and charges, if passed on to passengers in higher airfares and other costs, such as parking fees, would no longer generate an increase in airport revenues.

charges to the airlines rise above $20 per enplaned passenger (in 1990 dollars). Although the airlines would not necessarily exercise this option if costs rose above $20, keeping costs below $20 per passenger is an important financial objective of the airport.

Another revenue risk is the possibility that one of the hubbing carriers could cease operations, leaving the airport with empty, unrented space. While United is financially strong, Continental is in bankruptcy and could cease operations. The airport would then have to pay for having constructed the space for Continental without receiving the corresponding revenues. Although airfield costs would continue to be fully covered by the remaining carriers, terminal costs would not be fully covered beyond the 10-percent allowance for empty space assumed in the revenue projections. Liquidation of Continental Airlines would cause about 25 to 30 percent of the terminal space to be vacant until a new airline entered. The airport could, to some extent, offset this revenue loss by reducing O&M costs on the unused space.[10] However, construction costs could not be reduced once the space was constructed, although airport officials can postpone a decision on the final configuration of the space reserved for Continental until early 1992. Another carrier could possibly enter the Denver market and establish a hub in Continental's place if the latter ceased or reduced its operations.

A final uncertainty in the airport's financial plan is the sale of Stapleton airport. Although the sale is assumed to generate proceeds of $100 million net of any liabilities and maintenance costs incurred before the sale, we were unable to identify any analysis supporting this particular estimate. Both the actual net proceeds to be derived from Stapleton, and the time when they would be received are uncertain.

[10]O&M costs could be reduced by closing up the unused area, thus reducing or eliminating cleaning, heating, and air conditioning costs.

Cost Overruns and Revenue Shortfalls Are Unlikely to Be Large Enough to Result in Default on the Airport's Bonds

One approach to assessing the risk of default is to estimate the probabilities of various adverse events and then calculate the probability of default, given the estimated probabilities of the adverse events. We used a contractor to carry out such an analysis.[11] The contractor assembled representatives of the Denver airport as well as other knowledgeable people in the airport industry, including at least one critic of the Denver airport, to assess the probabilities of cost overruns, traffic shortfalls, and revenue shortfalls. The contractor then calculated the implications of these probabilities for the likelihood of default. The analysis took into account the recent increase in the cost of the airport to accommodate United Airlines.

The analysis indicated that the probability of default was low. There is less than a 20-percent probability that a shortfall in net revenues would require the City to use coverage account monies to meet its debt service requirements at any time before the year 2000. The financial risk is the greatest in 1995, when there is about a 20-percent probability that net revenues will just equal debt service requirements, and a 10-percent probability of revenues falling to about 96 percent of debt service requirements. The amount in the coverage account appears to be ample to meet any such net revenue shortfall. Any revenue shortfall, however, would require the City to increase its airport rates and charges to rebuild the coverage account balance.

Less than a 10-percent probability exists that airport charges to airlines would go above $20 (in 1990 dollars) in any year before 2000, thus allowing airlines to renegotiate their leases. The probability of charges rising over $20 is highest in 1995, with a 10-percent probability of charges rising to $19.30 and a 5-percent probability that charges would reach $20.50.

We also requested the airport consultant for the new Denver airport—KPMG Peat Marwick—to conduct a sensitivity analysis in which we assumed that a hubbing carrier ceased operations and revenues fell

[11] The analytical approach used by the contractor—Hickling Corporation—is described in appendix I. Our staff worked closely with the Hickling staff to refine the assumptions used in their analysis.

short of projections.[12] We assumed that the loss of a hubbing carrier would reduce occupancy of the terminal from 90 percent to 60 percent in 1994 and to 65 percent for 1995 through 2000. We also assumed a decline in traffic from the current 13.8 million passenger enplanements to 11 million enplanements in 1995. The cost figure that was assumed in the analysis was the cost of the "original program," i.e., the original estimate of the cost of building a 2-hub airport. Now that United Airlines has agreed to establish its hub at the airport, it has asked for considerably more facilities than were anticipated in the original program, so that costs for a 2-hub airport will be higher than under the original program.

Under the assumed circumstances, we found that the airport retained its ability to cover its O&M costs and its debt service. We concluded that airline rates and charges would be adjusted upward by $36 million to cover the revenue loss associated with the loss of Continental, resulting in net revenues that were 14 percent greater than debt service in 1995 and 7 percent greater than debt service in 2000. This analysis also found that costs per passenger would stay within the $20 limit. Airline costs per enplaned passenger, in 1990 dollars, were $16.43 in 1995 and $13.49 in 2000.

[12]In a sensitivity analysis, the assumptions underlying a calculation are varied to see how sensitive the results of the calculation are to variations in the assumptions. As noted in appendix I, since the model used by KPMG Peat Marwick for projecting financial results for the airport is proprietary, we did not have access to it. We requested various runs of the model with differing scenarios and assumptions. The KPMG Peat Marwick staff conducted the runs and then provided us with the output from these runs. This process did not enable us to monitor the data input to the model for these runs.

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