# Charlotte/Douglas International Airport

## *Capacity Enhancement Plan*

## *April 1991*

⇐ *About the Cover: An aerial view from Concourse A looking west to Charlotte's center city, located seven miles by road from the airport.*

PREPARED JOINTLY BY THE U.S. DEPARTMENT OF TRANSPORTATION, FEDERAL AVIATION ADMINISTRATION, CITY OF CHARLOTTE AVIATION DEPARTMENT, AIR TRANSPORT ASSOCIATION, AND THE AIRLINES SERVING CHARLOTTE.

## FIGURE 1 Charlotte/Douglas International Airport

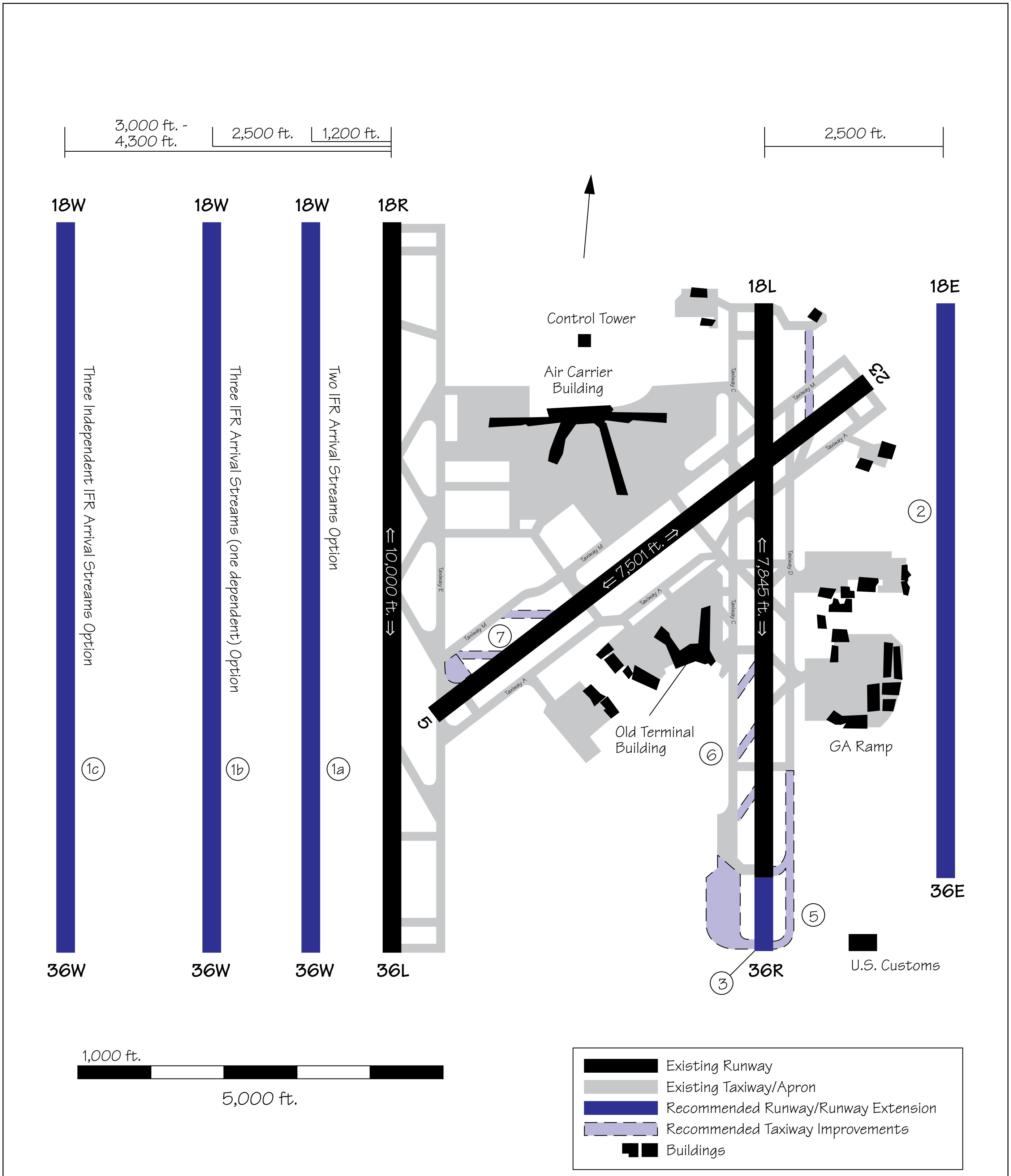


**Figure 1 Charlotte/Douglas International Airport**

## Figure 2 Recommended Delay Reduction Alternatives

| | Annual Benefits* | | | | | |
|---|---|---|---|---|---|---|
| | Baseline (430,000) | | Future 1 (520,000) | | Future 2 (600,000) | |
| **Airfield Improvements** | Hours | Dollars | Hours | Dollars | Hours | Dollars |
| 1. Build a Third Parallel Runway 18W/36W [1] | | | | | | |
| a) Two IFR arrival streams | 6,642 | $9.3 | 12,357 | $17.3 | 24,500 | $34.3 |
| b) Three IFR arrival streams (one dependent) | 7,357 | $10.3 | 14,714 | $20.6 | 29,286 | $41.0 |
| c) Three independent IFR arrival streams | 7,500 | $10.5 | 15,071 | $21.1 | 30,143 | $42.2 |
| 2. Build a Fourth Parallel Runway 18E/36E [2] | — | — | — | — | 8,714‡ | $12.2‡ |
| 3. Extend Runway 36R Further South [3] | 857 | $1.2 | 3,286 | $4.6 | 9,214 | $12.9 |
| 5. Extend Taxiway D Full Runway 18L/36R Length | | | | Narrated† | | |
| 6. Build Angled Exits Off Runway 18L | | | | Narrated† | | |
| 7. Build Angled Exits Off Runway 23 | 177 | $0.2 | 229 | $0.3 | 271 | $0.4 |
| 8. Construct Departure Sequencing Pads at Runway Ends | | | | Narrated† | | |
| 9. Install Centerline Lights on Runway 5 | | | | Narrated† | | |
| **Facilities and Equipment Improvements** | | | | | | |
| 11. Install Category I ILS on Runway 23 | | | | Narrated† | | |
| 12. Install Category II/III ILS on Runway 18R | 950 | $1.3 | 1,130 | $1.6 | 1,280 | $1.8 |
| 13. Install Category II/III ILS on Runway 18L | | | | Narrated† | | |
| 14. Install Category II/III ILS on Runway 36R | 143 | $0.2 | 357 | $0.5 | 857 | $1.2 |
| 15. Install Airport Surface Detection Equipment Radar | | | | Narrated† | | |
| 17. Expand the CLT TRACON and ARTS IIIA | | | | Narrated† | | |
| 18. Acquire the Aircraft Situation Display | | | | Narrated† | | |
| 19. Install Precision Runway Monitor | | | | Narrated† | | |
| 20. Install Approach Light System on Runway 18L and Runway 23 | | | | Narrated† | | |
| **Operations Improvements** | | | | | | |
| 21. Waiver to Conduct Intersecting Runway Operations with Wet Runways | | | | Narrated† | | |
| 22. Increase CLT Tower Satellite Positions for Departures | | | | Narrated† | | |
| 24. Identify Departure Restrictions | | | | Narrated† | | |
| **Other Improvements** | | | | | | |
| 27. Improve Reliever Airports (reduce GA 50%) | 4,032 | $5.6 | 10,030 | $14.0 | 20,000 | $28.0 |

*Note: Benefits are not necessarily additive.*

* Annual Delay Hours and Millions of 1989 Dollars

† These improvements were not simulated, therefore, no dollar figures are available. However, there is a description of each of these items in Section 3 — Delay Reduction Alternatives

‡ Delay savings depend upon the location of the third parallel runway, 18W/36W. With a third runway location supporting dependent IFR operations, savings for the fourth runway are greater. With a location supporting fully independent operations, savings are less.

1. Category II ILS on Runway 36R and Taxiway Support; three VFR arrival streams
2. Category II ILS on Runway 36R and Taxiway Support
3. Includes Runway 36R Holding Pad and Taxiway C and D Extensions

# Summary

The number of flight operations at Charlotte/Douglas International Airport (CLT) has grown 30%, from 330,000 in 1985 to 430,000 operations in 1990. By 1990, Charlotte Airport was ranked the 8th busiest air carrier airport in the country based upon aircraft operations. By the year 2000, the number of aircraft operations is forecast to grow to 520,000, a 21% increase in less than a decade.

Growth trends at airports throughout the United States have resulted in increased delays to the travelling public and have raised concerns about the current and future capacity and efficiency of the air transportation system.

In response to these concerns, the Federal Aviation Administration (FAA), airport operators, and air transportation system users have initiated joint industry and government task force studies for airport capacity enhancements at most major airports throughout the United States. The objective of these Airport Capacity Design Team studies is to identify and evaluate methods of safely increasing capacity and efficiency and reducing current and forecast flight delays.

In the case of Charlotte/Douglas International Airport, a number of capacity enhancement alternatives were considered, and recommendations were developed by the Charlotte/Douglas Airport Capacity Design Team. This effort was supported by extensive modeling and simulation performed by the Federal Aviation Administration Technical Center.

The Team addressed airfield, facilities and equipment, operations, and other areas which could affect overall efficiency and capacity of the Charlotte/Douglas International Airport.

To assess the delay impact of the current and projected growth, analyses of demand and capacity were performed at three levels of traffic demand to project associated aircraft delay. These are representative of the current *Baseline* demand of 430,000 annual aircraft operations at CLT; a forecast demand called *Future 1*, which represents a future demand level of 520,000 annual operations; and a forecast level designated *Future 2*, which is identified as 600,000 annual operations.

Given the aircraft demand and airport capacity over a wide range of yearly operational conditions, the Baseline annual delay has been calculated at 19,071 hours. This equates to an annual cost of $26.7 million for aircraft delays. The results of the analysis reveal that current yearly Baseline delay costs will escalate to $53.1 million at the Future 1 demand level and $99.9 million at the Future 2 demand level without airport improvements.

In the context of this analysis, 27 delay reduction alternatives were identified and evaluated. Of these, 21 initiatives were recommended.

**Major Recommendations with Future 2 Annual Delay Savings**

| Alternatives | Hours | Millions of 1989 Dollars |
|---|---|---|
| • Build a third parallel Runway 18W/36W | 30,143 | 42.2 |
| • Build a fourth parallel Runway 18E/36E | 8,714‡ | 12.2‡ |
| • Extend Runway 36R further south | 9,214 | 12.9 |
| • Install Category II/III ILS on Runway 36R | 857 | 1.2 |

An illustration of one possible implementation scenario of capacity enhancements is addressed in Figure 3.

This chart represents the delay cost implications of growth forecast for the Charlotte/Douglas Airport if nothing were done to control aircraft delays. Additionally, a scenario of delay reduction enhancements is depicted consistent with the recommendations of the Capacity Team.

The results in terms of cost are dramatic. At the highest demand level, over $60 million per year could be saved by implementing the enhancements recommended.

Depending upon actual growth rates and the timing of implementing the enhancements, projected cumulative savings could also be substantial. For example, with a 5.5% annual growth in operations between Baseline and Future 2 demand levels, the cumulative benefit of the enhancement projects could exceed $375 million.

Figure 4 illustrates the capacity and delay curves for the current airfield configuration at Charlotte. It shows that aircraft delays will begin to rapidly escalate as hourly demand exceeds 100 operations per hour. Figure 5 illustrates that, while hourly demand rarely exceeds 100 operations at Baseline demand levels, 100 operations per hour is frequently exceeded at forecast Future 2 demand levels.

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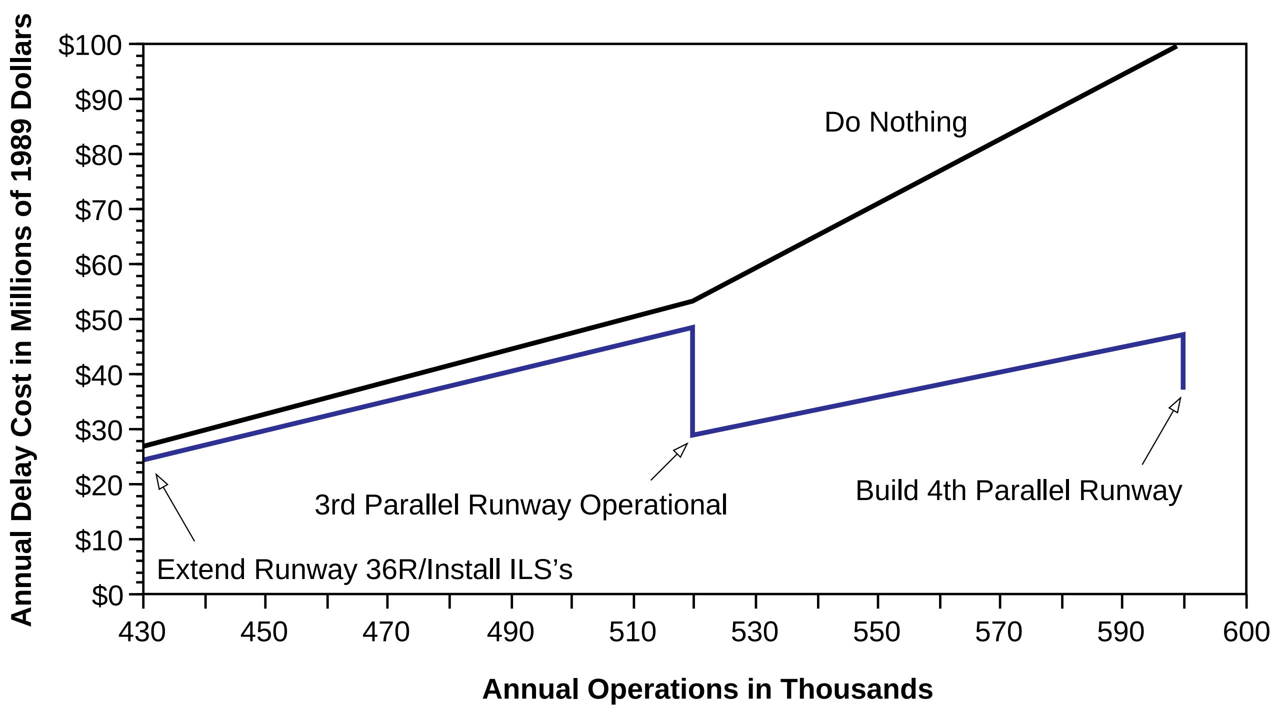
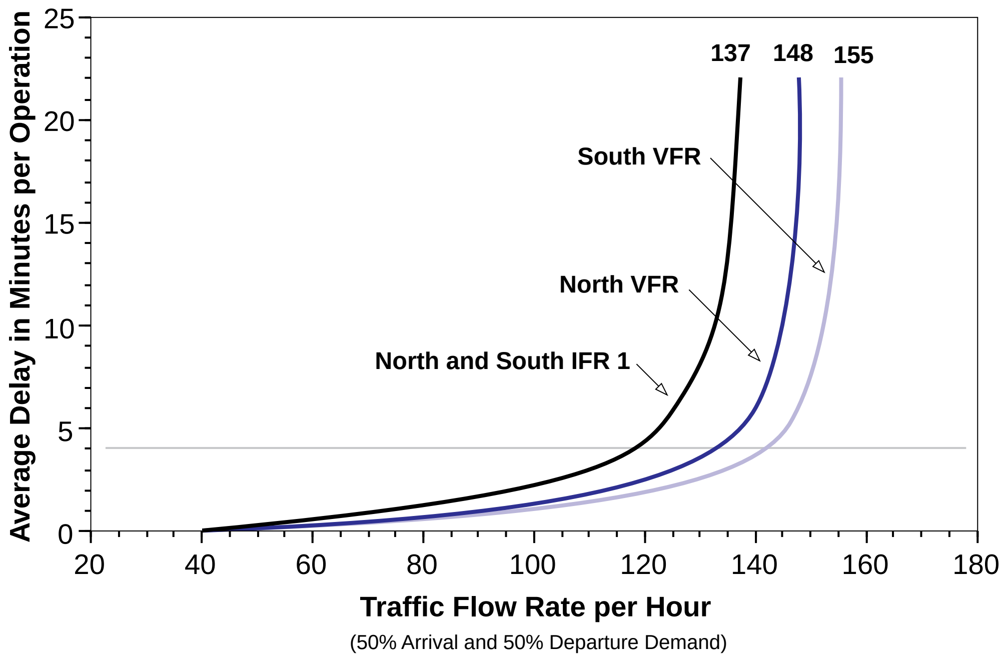
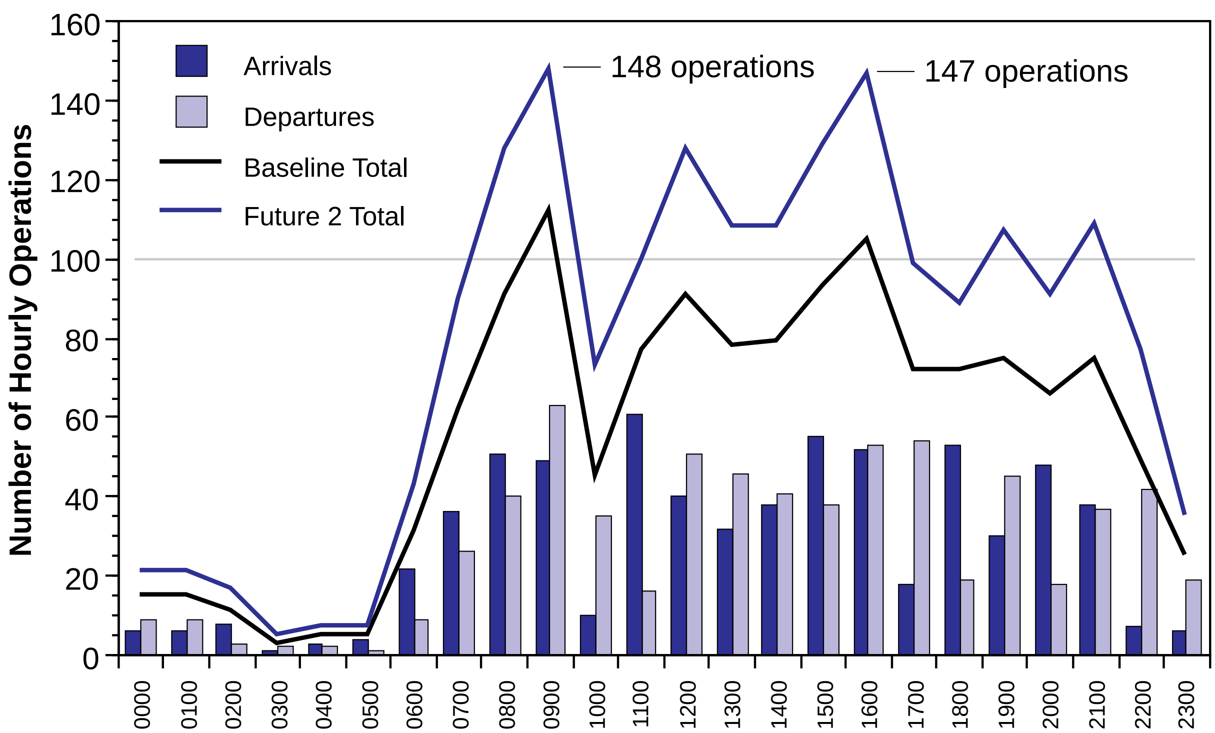
## Figure 3 Delay Costs/Benefits Scenario



## Figure 4 Flow Rate vs. Average Delay




## Figure 5 Hourly Airport Demand



⇑ *A people–connecting place centered around the Queen Charlotte sculpture (© 1990 by Raymond Kaskey).*

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# 1.0 — Introduction

## 1.1 Background

North Carolina is the nation's greatest producer of furniture, tobacco, brick, and textiles. It is second in the Southeast in population and first in the value of industrial and agricultural production. Tourism accounts for more than $1 billion of revenue annually.

Charlotte, the largest city in the state, has experienced development in recent years as a financial and trade center. Its metropolitan statistical area is estimated to contain in excess of 1 million persons and ranks as the 35th largest metropolitan area in the United States.

The Charlotte area is projected to continue its strong growth rate through the end of the century due to the recreational appeal of the area and its strong and diverse economic base.

Charlotte/Douglas International Airport (CLT), which was built in 1934, is a national resource critical to local and regional transportation needs to support continuing economic vitality and growth.

Further, as the largest airline hub operated by USAir, Inc., Charlotte/Douglas International Airport is a significant component of the national air transportation system linking hundreds of towns, cities, and major metropolitan areas throughout the East from Boston to Miami. Charlotte also serves as an aviation transportation gateway to the Western United States, as well as Europe and the Caribbean.

By 1986, Charlotte was ranked as the 23rd busiest airport in the United States on the basis of 5.9 million passenger enplanements. By 1988, the number of enplanements had grown more than 29% to 7.6 million. By the year 2000, enplanements are forecast to grow another 54% to a total of 11.7 million enplaned passengers annually.

The number of flight operations at Charlotte has grown 30%, from 330,000 in 1985 to 430,000 operations in 1990. By 1990, Charlotte Airport was ranked the 8th busiest air carrier airport in the country based upon aircraft operations. By the year 2000, the number of aircraft operations are forecast to grow to 520,000, a 21% projected increase in less than a decade.

These figures emphasize major challenges facing the air transportation industry to enhance existing airport capacity and develop new facilities to handle this future demand.

⇐ *Night view of the Queen Charlotte sculpture, Queen Charlotte Square.*

The Federal Aviation Administration (FAA), airport operators, and the users of the national air transportation system have initiated Airport Capacity Design Teams to identify, develop, and evaluate means of reducing delays at high activity air carrier airports in the United States. The Charlotte Capacity Team was formed to help accomplish this objective.

## 1.2 Objectives

The major objective of the study was to develop recommendations which, if implemented, would increase airport capacity, improve airport efficiency, and reduce aircraft delays.

In addition to achieving this objective, the Design Team accomplished the following:

- Assessed current airport capacity.
- Examined the causes of delays associated with the airfield and its immediate airspace.
- Evaluated capacity and delay benefits of alternative air traffic control (ATC) procedures, navigational improvements, airfield changes, and user options.
- Examined the relationship between air traffic demand and delay to aid in establishing acceptable air traffic levels.

## 1.3 Scope

The Charlotte Capacity Team limited its analyses to aircraft activity on the airfield and within the immediate airspace, comprising the common approach and departure corridors. It considered alternatives that could increase capacity and reduce delays.

The Capacity Team did not examine detailed landside or environmental issues, which are beyond the scope of the study. They will be addressed in future airport planning studies. The data developed in this study will provide important inputs to future studies.

## 1.4 Methodology

Based upon historical and projected demand, the Charlotte Capacity Team established three levels of annual demand to assess delay against projected growth and to evaluate the efficacy of improvement alternatives.

The Capacity Team developed a list of alternatives for increasing capacity and reducing delays at the Charlotte Airport. This list was refined during the study. Several improvements were eliminated because they were not feasible. Some delay reduction options were narrated because they were underway, completed, or better suited to a verbal description than a computer simulation. The remainder were simulated and their potential annual delay savings calculated.

Model simulations included present and future air traffic control procedures, various airfield improvements, and three traffic demand levels. To assess projected airfield improvements, the FAA used different airfield configurations for present and future airport layouts. The time frame for improvements and ATC procedures determined the appropriate aircraft separations used to simulate VFR and IFR weather conditions. One improvement involving new runways was simulated only for the highest demand level.

For the delay analysis, the FAA developed traffic demands based on the *Official Airline Guide*, historical data, and airport forecasts. Aircraft volume, mix, and peaking characteristics were used to generate a demand profile for each of the three demand levels.

Annual delay estimates for the proposed improvement options were extrapolated from the simulation results. The estimates took into account the yearly variations in runway configurations, weather, and demand based on historical data. They did not reflect exceptional circumstances, such as closing a runway for snow removal. The technical details of the simulation methodology are described in the Technical Studies Section.

The Capacity Team then compared the annual delay estimates and assessed the potential delay reductions. Based on the annual delay savings and marketplace considerations, the Capacity Team developed a set of recommendations which are presented in the Summary (Figure 2).

Appendix A describes RDSIM, the Runway Delay Simulation Model used in this study.

## 1.5 Participants

At the start of this study, the Capacity Team Chairman invited every group interested in reducing delays, increasing capacity, and improving efficiency at the Charlotte Airport to provide a representative to work on this effort. Appendix B lists the active participants.

⇐ *The mix of land use in the airport area is varied. Presently, 33% of the air carrier fleet serving Charlotte is composed of Stage III aircraft capable of Category III operations.*

⇒ *Charlotte/Douglas International Airport is a large hub operation for USAir, one of 11 airlines serving regional air travelers.*

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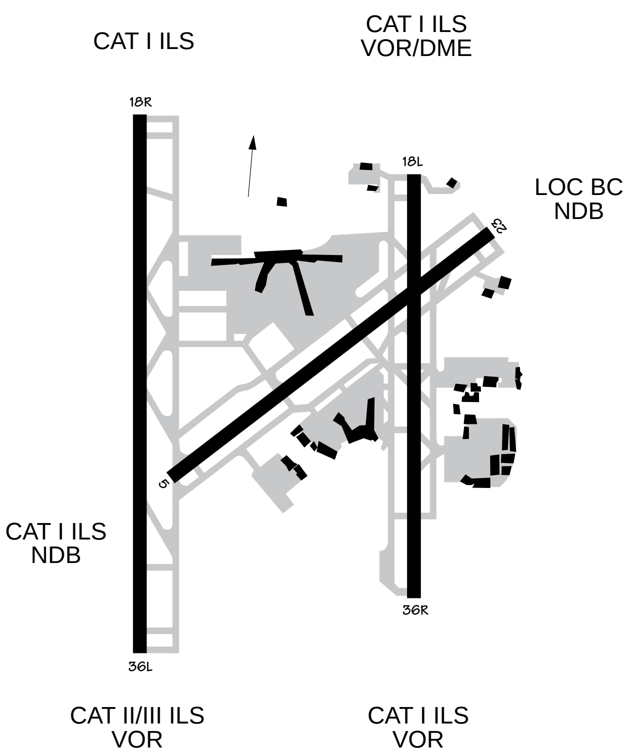
## FIGURE 6 CHARLOTTE APPROACH CAPABILITY



# 2.0 — Existing Conditions

As with most major airports, Charlotte/Douglas International Airport is in a noise sensitive environment. Low–density population areas of scattered home development and agriculture lie west and south of the airport. Warehousing and light industry predominate in the immediate vicinity of the airport.

Land to the east and northeast consists of densely populated areas of single–family and multi–family homes. Additionally, the mix of land use in this area is varied, including commercial and industrial land use along a major road and railway corridor.

The area north of the airport contains scattered residential developments, some commercial development, and recreational land. However, residential areas, schools, and churches immediately to the north of the airport pose significant environmental concerns which have resulted in noise restrictions to aircraft operations at Charlotte.

Airport demand is characterized by a mixed aircraft fleet of both older and newer aircraft. Presently, 33% of the air carrier fleet serving Charlotte is composed of Stage III aircraft capable of Category III operations.

## 2.1 Airport

The Charlotte/Douglas International Airport is located in Charlotte, North Carolina, approximately 5 miles west of the city center. The current airport facilities (Figure 6) consist of two active north-south parallel runways, Runway 18L/36R and Runway 18R/36L separated by 5,000 feet. A third runway, Runway 5/23, lies in a northeast-southwest direction intersecting Runway 18L/36R.

Runway 18L/36R is 7,845 feet in length and 150 feet wide. Runway 18L is supported by CAT I ILS, VOR/DME and ASR instrument approaches. Runway 36R is supported CAT I ILS, VOR, and ASR Standard Instrument Approach Procedures (SIAP).

Runway 18R/36L is 10,000 feet in length and 150 feet wide. Runway 18R is supported by CAT I ILS, VOR/DME, and ASR SIAPs. Runway 36L is served by CAT II/III ILS, VOR, and ASR SIAPs.

Runway 5/23 is 7,501 feet long and 150 feet wide. Runway 5 is supported by CAT I ILS, NDB, and ASR Standard Instrument Approach Procedures. Runway 23 is supported by back–course ILS, NDB, and ASR Instrument Approach Procedures.

## 2.2 Operations

Charlotte Airport is served by 7 major airlines and 4 commuter carriers. For one major carrier, Charlotte is their largest hub, with over 900 operations each day. Some 45 gates, not including commuter hard stands, normally support more than 1,300 operations daily.

The operations at Charlotte are predominantly driven by hourly arrival and departure banks. These banks drive current peak hour demand to over 100 operations per hour during certain hours of the day. In certain hours, arrivals or departures reach 60 per hour.

Heavy jet aircraft represent less than 2% of the current demand at Charlotte. Large aircraft account for 90% of the operational demand. Light twins and small single engine aircraft represent 8% of the demand.

The weather conditions at Charlotte are generally favorable enough to allow optimum runway use about 90% of the time, consistent with wind direction. These conditions are ceilings of 2,100 feet or more and visibilities of 3 miles or greater which permit visual approaches. The remaining 10% of the time, Charlotte operates in weather conditions which reduce airport capacity.

Approximately 7% of the time, CLT has Category I conditions with visibility somewhere between 1,800 feet RVR and 3 miles and ceilings between 200 feet and 2,100 feet. However, about 3% of the year, Charlotte experiences Category II weather with visibility less than 1,800 and ceilings less than 200 feet. A very small percentage of the time, visibility is less than 1,200 feet and ceilings below 100 feet. However, all major passenger airlines and one cargo airline serving Charlotte-Douglas International Airport have special authority approved by the Federal Aviation Administration to conduct Category III operations. All major passenger airlines serving Charlotte Airport can also conduct Category IIIa operations to 700 feet RVR.

Prevailing wind conditions at Charlotte permit an equal balancing of north and south traffic flows on a yearly basis. However, either a north or south flow can be selected and used annually 75% of the time, based upon operational capabilities that permit aircraft operations with minimal tailwind components.

## 2.3 Demand

Current Charlotte-Douglas International Airport demand is keyed to the almost hourly arrival and departure banks of the major air carrier serving the airport.

Operations total more than 1,350 per day, with 675 arrivals and an equivalent number of departures. Some 78% of this demand are airlines and commuters, with 21% general aviation and about 1% military operations.

The number of arrivals peaks with over 50 per hour, five hours of the day, while the number of departures also exceeds 50 per hour, four hours per day. Total operations are in excess of 100, two hours of the day.

Given the aircraft demand and airport capacity over a wide range of yearly operational conditions, the annual delay is 19,071 hours, equating to an annual cost of $26.7 million for aircraft delays.

⇑ *The aviation complex includes the regional terminal, the third terminal since the beginning of the municipal operation in the 1930's. Terminal expansion is underway and when completed in 1993, terminal services will cover over 1,000,000 square feet.*

## FIGURE 7 DELAY REDUCTION ALTERNATIVES

| Alternative | Action | Demand Level |
|---|---|---|
| **Airfield** | | |
| 1. Build a Third Parallel Runway 18W/36W | Recommended | Baseline |
| 2. Build a Fourth Parallel Runway 18E/36E | Study | |
| 3. Extend Runway 36R Further South | Recommended | Baseline |
| 4. Shift Runway 18L/36R South | Not Recommended | |
| 5. Extend Taxiway D Full Runway 18L/36R Length | Recommended | Baseline |
| 6. Build Angled Exits Off Runway 18L | Recommended | Baseline |
| 7. Build Angled Exits Off Runway 23 | Recommended | Baseline |
| 8. Construct Departure Sequencing Pads at Runway Ends | Recommended | Baseline |
| 9. Install Centerline Lights on Runway 5 | Recommended | Baseline |
| **Facilities and Equipment** | | |
| 10. Install Category I ILS on Runway 18L | Completed | Baseline |
| 11. Install Category I ILS on Runway 23 | Recommended | Baseline |
| 12. Install Category II/III ILS on Runway 18R | Recommended | Future 1 |
| 13. Install Category II/III ILS on Runway 18L | Recommended | Future 2 |
| 14. Install Category II/III ILS on Runway 36R | Recommended | Baseline |
| 15. Install Airport Surface Detection Equipment Radar | Recommended | Baseline |
| 16. Locate New VOR at Hickory | Not Recommended | |
| 17. Expand the CLT TRACON and ARTS IIIA | Recommended | Baseline |
| 18. Acquire the Aircraft Situation Display | Recommended | Baseline |
| 19. Install Precision Runway Monitor | Recommended | Baseline |
| 20. Install Approach Light System on Runway 18L and Runway 23 | Recommended | Baseline |
| **Operations** | | |
| 21. Waiver to Conduct Intersecting Runway Operations with Wet Runways | Recommended | Baseline |
| 22. Increase CLT Tower Satellite Control Positions for Departures | Recommended | Baseline |
| 23. Modify/Relax Noise Restrictions | Study | Baseline |
| 24. Identify Departure Restrictions | Recommended | Baseline |
| 25. Implement Use of Runway 5 for Departures | Completed | Baseline |
| **Other** | | |
| 26. Redistribute Traffic More Uniformly within the Hour | Not Recommended | |
| 27. Improve Reliever Airports (reduce GA 50%) | Recommended | Baseline |

# 3.0 — Delay Reduction Alternatives

The delay reduction alternatives, studied by the Charlotte Capacity Team and described in this report, have been evaluated to determine feasibility, costs, and benefits to meet anticipated growth in demand without excessive delays.

Each of the alternatives has been addressed in consideration of the following annual levels of operational demand:

- 430,000 operations
- 520,000 operations
- 600,000 operations

The 430,000 operations reflect the anticipated 1990 activity level. The other demands reflect the forecast levels at some time in the future.

When and where possible, dollar costs have been associated with the delay savings. These are in 1989 dollars and are based upon a $1,400 average hourly operating cost for the aircraft fleet mix serving the Charlotte Airport. It should be noted that the calculated costs are not necessarily additive.

The alternatives for increasing airport capacity and reducing aircraft delays at the Charlotte/Douglas International Airport are categorized and discussed under the following four topics:

- Airfield
- Facilities and Equipment
- Operations
- Other

The following describes the delay alternatives and associated costs and benefits in detail.

⇐ *Delay reduction alternatives are part of the CLT Capacity Team's recommendations in airfield, facilities and equipment, and operations improvements.*

## 3.1 Airfield Improvements

### 1. Build a Third Parallel Runway 18W/36W

Presently, two parallel runways exist at Charlotte/Douglas International Airport (18L/36R and 18R/36L). Although the placement of these two runways allows for independent simultaneous IFR operations, increased capacity could be derived from the addition of a third parallel runway to the west of these existing runways.

The capacity benefits of this proposed runway (18W/36W) are dependent on the lateral distance from the two existing parallel runways. Runway separation distances of less than 2,500 feet require that parallel runways be treated as a single runway during Instrument Meteorological Conditions (IMC).

Runways spaced from 2,500 feet to less than 4,300 feet are considered dependent and require aircraft in IFR to be staggered. Only runways separated by 4,300 feet or more can be operated independently for arrivals and departures in all weather conditions. However, recent technology and procedural developments may reduce the independent runway spacing requirements from 4,300 feet to 3,000 feet.

In order to better assess benefits, the placement of this runway (18W/36W) has been evaluated at a variety of distances from the existing runways in order to ascertain the optimum location to yield the maximum airport capacity. However, consideration of other factors, such as land acquisition costs and noise impacts, will weigh heavily upon any decision to construct any added runways.

The results of the analyses indicated a delay savings of $9.3 million and 6,642 hours of delay per year could be achieved at today's Baseline demand level with the addition of a third parallel runway that would permit three VFR and two IFR arrival streams. Further, an annual delay savings of $34.3 million and 24,500 hours of delay could be realized at a Future 2 demand level of 600,000 operations per year.

The estimated annual savings for a third parallel runway which would permit dependent approaches in IFR conditions and independent operations in VFR conditions is $10.3 million and 7,357 hours of delay at the Baseline level of demand and $41.0 million and 29,286 hours of delay at Future 2 demand levels. This would permit triple arrivals, with one independent and two dependent approaches.

A third parallel runway placed to permit independent simultaneous approaches in all weather conditions would save

$10.5 million or 7,500 hours of delay at the baseline demand level and $42.2 million and 30,143 hours of delay at Future 2 demand levels.

## 2. Build a Fourth Parallel Runway 18E/36E

Assuming that a third parallel runway is built on the west side of the airfield, the feasibility of a fourth parallel runway should be considered on the east side of the field. However, local roadways already in place on the east side of the airport would require relocation.

The annual delay savings for the fourth parallel runway 2,500 feet east of Runway 18L/36R are dependent upon the location of the third parallel runway, Runway 18W/36W.

With the third parallel runway supporting dependent IFR and VFR operations when used with Runway 18R/36L, the fourth parallel will save $12.2 million and 8,714 hours of delay annually at Future 2 demand levels. However, if the third parallel supports fully independent operations, a fourth parallel will save only $9.3 million and 6,643 hours of delay per year at the highest demand levels.

These savings are based solely on the location of the third parallel. The placement of the third parallel will dictate the demand level which will require a fourth parallel runway, and, potentially, the need for a fourth parallel at all. If the third parallel can be built to allow for triple independent IFR arrival streams, construction of the fourth parallel could be deferred or precluded.

## 3. Extend Runway 36R Further South

Runway 36R is 7,845 feet in length and is intersected by Runway 5/23 5,600 feet beyond the runway threshold. Current air traffic control procedures permit simultaneous use of these runways if certain conditions are met.

For concurrent use of departures on Runway 5 and arrivals on Runway 36R, arriving aircraft must have a suitable distance to land on a dry runway and hold short of the crossing runway. For turbojets to land and hold short requires a minimum of 6,000 feet of usable runway. Extending Runway 36R further south would permit these operations under present air traffic control procedures.

Procedures for landings on wet intersecting runways are limited to a few test sites. If this procedure is approved it is likely that greater runway use distances will be required for wet runways than for dry runways. Future analysis may need to be undertaken to quantify these potential changes in terms of costs and benefits.

An estimated annual delay savings of $1.2 million and 857 hours are estimated at the Baseline demand level, and $12.9 million and 9,214 hours at the highest Future 2 level. These assumptions are based upon an almost equivalent north and south flow operation. Preferential use of a north flow would increase the benefits of the runway extension significantly.

### 4. Shift Runway 18L/36R South

Runway 36R/18L intersects Runway 5/23. The distance from the runway threshold of Runway 36R to the intersection is 5,600 feet. Air traffic procedures for operations conducted on intersecting runways are more restrictive than operations conducted independently on non–intersecting runways.

The benefit to be gained by displacing Runway 36R 2,500 feet to the south to eliminate crossing Runway 5 is marginal. The cost of this effort remains prohibitive in view of the modest capacity benefits which would be achieved.

If Runway 36R were simply extended to permit hold–short operations for turbojet aircraft, the benefits, except for wet operations landing to the north, would be similar to displacing the runway 2,500 feet south.

In addition to the cost of the extension, other associated costs would accrue, including land and additional taxiway construction. Other factors such as noise profile changes and tower visibility must also be considered and argue against this runway displacement.

### 5. Extend Taxiway D Full Runway 18L/36R Length

Presently, general aviation aircraft departing on Runway 18L/36R must cross the runway to taxi to the departure end of 36R. This not only requires extra coordination between the ground controller and the local controller, but also can result in delays between successive departures.

Extending Taxiway D the full length of Runway 18L/36R to the approach end of Runway 18L/36R would enhance air traffic control operations. Ground control would be able to deliver general aviation and Air National Guard aircraft to the departure end without affecting runway activity. Further, this taxiway extension would eliminate any need to sequence general aviation aircraft with the air carrier jets on Taxiway C to achieve a designated departure sequence.

Finally, this would permit an optimized departure sequence selecting departure aircraft from either Taxiway C or Taxiway D, depending upon capability and speed of the aircraft type and the direction of flight.

## 6. Build Angled Exits off Runway 18L

High speed or angled exits reduce runway occupancy times. If average occupancy times of 50 seconds or less can be achieved, longitudinal separation of 2.5 nautical miles can be used in lieu of 3.0 nautical miles for similar non-heavy aircraft arrivals.

Runway exits for Runways 18L and 36R presently exist for aircraft bound for both the Air National Guard and general aviation ramps. However, there are not an adequate number of westerly angled exits for aircraft arriving on Runway 18L to optimize runway occupancy times. The proposed construction of a 1,000 foot runway extension on the south end of Runway 18L will require additional taxiway and runway exits to fully support this investment.

In order to decrease runway occupancy time, additional high speed exits need to be constructed approximately 4,700 feet, 5,500 feet and 6,300 feet from the Runway 18L threshold. These exits are commensurate with normal deceleration rates of the majority of the aircraft which will operate on this extended runway under a variety of runway condition.

## 7. Build Angled Exits off Runway 23

There are no angled exits available for aircraft landing on Runway 23. This runway is the primary runway for aircraft arriving from the north and east when the airport is in a south operation.

Angled exits should be placed approximately 4,700 feet, 5,500 feet, and 6,300 feet from the approach end of Runway 23. Due to the physical layout of the airport, it is not feasible to install new angled exits at these distances.

However, development in the vicinity of Taxiway A-3/B exit, to the north of Runway 23, at 5,000 feet and 5,800 feet from the threshold of Runway 23, would be the best choices. These locations would accommodate the 600 foot runway to taxiway centerline, 1,200 foot taxiway length, and 30° exit angle required to support a high speed angled exit.

These runway exits will not only decrease runway occupancy times for arriving aircraft on Runway 23, but also decrease taxi time to the gate. Ground control will also benefit with a better traffic flow to the gate areas.

If average runway occupancy times of 50 seconds or less can be achieved, longitudinal separation of 2.5 nautical miles can be used in lieu of 3.0 nautical miles for similar classes of non–heavy aircraft.

Annual savings at the Baseline activity level will be 177 hours or $0.25 million and, at Future 2 activity levels, 271 hours or $0.38 million per year.

**8. Construct Departure Sequencing Pads at Runway Ends**

Air traffic flow control often dictates that aircraft hold at the runway thresholds before takeoff because of departure fix restrictions. Expanding the staging areas (departure pads) at the ends of the runways will improve the abilities of departing aircraft to bypass these aircraft waiting for departure clearance.

**9. Install Centerline Lights on Runway 5**

The addition of runway centerline lighting on Runway 5 would reduce current takeoff visibility minimums from 1,800 feet to 600 feet. This will help to maintain capacity during IMC.

## 3.2 Facilities and Equipment

**10. Install Category I ILS on Runway 18L**

An Instrument Landing System (ILS) was installed on Runway 18L in September of 1990, approximately 6 months after the initiation of this study.

In addition to capacity benefits, safety benefits are derived by providing positive runway identification and three–dimensional course guidance in all weather conditions at all times as a result of the precision approach guidance of an ILS.

**11. Install Category I ILS on Runway 23**

A Category I Instrument Landing System installed on Runway 23 can provide enhanced efficiency and capacity for aircraft operations conducted at the Charlotte/Douglas International Airport.

In addition to providing positive runway identification and three dimensional course guidance in all weather conditions, an ILS would lower weather minimums for more efficient runway utilization.

This use includes simultaneous converging instrument approach procedures with concurrent instrument approaches to Runways 23 and 18R to weather conditions as low as a 1,400 foot ceiling and a 3 mile visibility.

**12. Install Category II/III ILS on Runway 18R**

Currently, CLT's capability to support Category II operations is limited to a single north flow runway, Runway 36L. The addition of a capability to land south in Category II/III conditions would enhance the operational flexibility and insure the integrity of operations in response to wind and other limiting conditions.

Although weather conditions restricting operations to Category II occur only 2.9% of the time, the impact of the associated delays can be significant.

Annual savings at the Baseline activity level will be 950 hours or $1.3 million and, at Future 2 activity levels, 1,280 hours or $1.8 million per year.

In calculating delay hours and costs, it was assumed commuter and general aviation aircraft would not operate in IFR 2 conditions. This assumption significantly affects the delay and benefit calculations for multiple runway configuration and use. Therefore, changes in operational capabilities by commuter and general aviation aircraft could measurably affect the justification for new runways if these runways were supported by Category II approaches.

Since many new commuter aircraft have been certified for Category II operations, operational decisions to train aircrews and maintain aircraft to Category II requirements will measurably increase the benefits of additional runways supporting simultaneous instrument approaches to Category II runways.

### 13. Install Category II/III ILS on Runway 18L

The implementation of a Category II/III Instrument Landing System on Runway 18L further expands the operational capacity during all weather operations at the Charlotte Airport.

The upgrade of approach capability to Runway 18L in conjunction with a Category II/III ILS on Runway 18R provides a high degree of operational capability to insure the integrity of operations in all weather conditions for a south traffic flow. This insures minimal delays as a result of conditions which require a south operation in IFR 2 weather.

### 14. Install Category II/III ILS on Runway 36R

A significant near term benefit would accrue as a result of a second Category II/III capability installed on Runway 36R, including the benefits of Runway Visual Range (RVR) equipment, to supplement the current capability on Runway 36L. This would permit simultaneous parallel approaches, effectively doubling airport capacity, during some marginal weather conditions and in periods of high demand.

The benefits estimated from an additional Category II/III capability installed on Runway 36R are at $0.2 million and 143 hours of delay annually at Baseline demand levels and up to $1.2 million and 857 hours of delay for the highest demand level, Future 2.

These estimates do not consider the developing capability of commuters to operate in Category II conditions. Including commuter demand would significantly increase the dollar benefits associated with Category II/III ILS implementation.

## 15. Install Airport Surface Detection Equipment (ASDE) Radar

The ability to independently monitor ground aircraft movement in all weather conditions enables air traffic controllers to use anticipatory clearances to expedite air traffic movements. Further, ASDE allows an air traffic controller to verify aircraft positions and provide definitive control instructions to guide aircraft to and from runways and ramps.

## 16. Locate New VOR at Hickory

A new VOR located at the Hickory Airport could assist in defining air routes to more efficiently overfly the Charlotte terminal airspace. However, a VOR is currently located at Barretts Mountain approximately 8 miles from Hickory.

Since the VOR is predominantly an en–route navigational aid spaced 40 nautical mile or more apart, the cost feasibility of two VORs in this close proximity is doubtful. Additionally, navigational alternatives may permit the circumnavigation of critical portions of the Charlotte Terminal area without requiring a new VOR.

## 17. Expand Charlotte TRACON and ARTS IIIA

The Charlotte TRACON has four arrival radar and four departure radar scopes, and one landing monitor scope. The monitor scope is used by the Traffic Management Coordinator when it is not used to monitor approaches.

To facilitate development of additional air traffic control capability, a minimum of two additional radar positions/scopes are required. One of these would support a dedicated traffic management position. The other scope would serve additional terminal sectors or positions as required, such as a satellite control function.

This initiative assumes an adequate level of staffing and an associated formal training will support any additional equipment installed at the Charlotte Tower and TRACON.

In addition to these initiatives, the upgrade of the ARTS IIIA automation equipment by installation of solid state memory expansion components is important to increase computer capacity and satisfy anticipated increases in traffic demand.

## 18. Acquire the Aircraft Situation Display (ASD)

The acquisition of the Aircraft Situation Display would greatly enhance the ability of Charlotte Tower and TRACON to implement, train, staff, and operate needed traffic management functions.

The ability to have timely information concerning arrivals and departures of aircraft to and from Charlotte is critical to managing runway and airspace resources aggressively. Knowledge of ARTCC demand can result in actions to coordinate re–routes to avoid in-trail or other restrictions imposed by Atlanta, Jacksonville or Washington Air Route Traffic Control Centers.

Further, the ability of Charlotte to aid the ARTCCs in balancing arrival and departure demand would minimize unnecessary delays and improve associated intra–and inter–facility communications and coordination.

### 19. Install Precision Runway Monitor (PRM)

The greatest capacity enhancement benefit at Charlotte Airport would be the addition of a third parallel runway which permits independent parallel approaches in all weather conditions. Currently, this requires 4,300 feet between parallel runway centerlines.

A developmental program known as the Precision Runway Monitor (PRM) has demonstrated the potential for reducing parallel runway spacing to 3,000 feet. This program relies upon improved radar surveillance with higher update rates and a new air traffic controller display system.

Installation of the PRM at Charlotte would significantly reduce the cost associated with the construction of an independent third parallel runway. The ability to construct closely spaced parallel runways reduces siting and construction costs and mitigates potential noise impact to the communities in proximity to the Charlotte Airport.

### 20. Install Approach Light System on Runway 18L and Runway 23

Installing approach lights on Runway 18L and Runway 23 will reduce the visibility minimums for the runways and thereby help to maintain capacity during Instrument Meteorological Conditions (IMC).

## 3.3 Operations

### 21. Waiver to Conduct Intersecting Runway Operations with Wet Runways

Operational experience has demonstrated that the stopping distances for turbojet aircraft are equivalent on well maintained and grooved runways in both wet and dry conditions.

Consequently, the FAA has implemented a limited number of demonstration programs at selected airports around the country to collect data and validate procedures which permit simultaneous operations on intersecting runways, when runway conditions are less than dry.

On the basis of the preliminary success of the program, the Capacity Team recommends Charlotte Airport be included in this program under a wavier of current air traffic control procedures.

## 22. Increase Charlotte Tower Satellite Control Positions for Departures

An expansion of capability to segregate low performance aircraft from high performance aircraft is desirable to enhance operational efficiency and capacity. Additional dedicated control positions in conjunction with airspace, route, and procedural modifications will support this objective.

It is also necessary to insure that equipment and resources are provided to support any increases in the number of control positions at the Charlotte Tower. This includes communication and surveillance equipment as well as personnel.

## 23. Modify/Relax Noise Restrictions

If all aircraft presently operating at Charlotte were allowed to operate free of noise restrictions, there could be a significant reduction in annual delays.

Revised arrival and departure procedures would need to be developed and these revised procedures may not allow the entire savings to be realized.

Currently, approximately 40% of the fleet of aircraft serving Charlotte meet Stage III noise requirements, with higher utilizations forecast for Future 1 and Future 2 demand levels. If Stage III aircraft were allowed to follow relaxed noise abatement procedures at present levels, as well as Future 1 and Future 2, lesser but still significant savings could be realized. Moreover, this may encourage the airlines to utilize more Stage III aircraft in their fleets serving Charlotte.

Considering the significance of the aircraft noise issue, the Capacity Team believes a study should be initiated on the effects of relaxing the noise restrictions for Stage III aircraft in order to reduce delays.

## 24. Identify Departure Restrictions

Restrictions impeding the ingress and egress of traffic to and from the Charlotte Airport are a significant concern. While enroute airspace arrival restrictions are not discernible from the Charlotte Airport perspective, departure restrictions attributable to limitations in the enroute environment are apparent in departure spacings imposed.

Further analysis and study are required to accurately identify and resolve operational constraints in the enroute environment which result in delays affecting the operational integrity of the Charlotte/Douglas International Airport. Unfortunately, these studies are beyond the scope of the Charlotte Capacity Team.

### 25. Implement Use of Runway 5 for Departures

In an effort to expedite identified capacity benefits, the use of Runway 5 for departures was implemented by the FAA on January 2, 1991.

The use of this runway configuration significantly increases airport capacity on a north flow in VFR weather and with dry runway conditions when arrivals can land on Runway 36R and hold short of Runway 5. Depending upon the mix of aircraft arrivals and aircraft types, a rate equal to a three runway south operation has been experienced.

Greater benefit could be obtained from this runway configuration with the recommended south extension of Runway 36R. This would permit turbojet aircraft to land on Runway 36R simultaneous with departures on Runway 5. Currently this operation is limited to commuter and general aviation type aircraft.

The construction of a holding pad for Runway 5 departures and a bypass taxiway for departure aircraft transiting for the ramp to Runway 36L, in conjunction with the construction of the angled exits for Runway 23, would provide additional benefit in aircraft staging and movement.

The addition of runway centerline lighting would reduce current takeoff visibility minimums on Runway 5 from 1,800 feet to 600 feet.

Collectively these benefits would expedite ground movement, speed departures, and reduce delay.

## 3.4 Other

In addition to airfield, facilities and equipment and operations changes there are other issues and factors which may affect airport capacity and efficiency. These other considerations may have implications which are beyond the scope of the Capacity Design Team charter.

### 26. Redistribute Traffic More Uniformly within the Hour

More uniform scheduling for both arrivals and departures will produce more orderly flow of traffic, reduce arrival and departure delays, and reduce ground congestion.

However, Charlotte Airport is a connecting hub for passengers, and a uniform distribution of traffic is not consistent with such an operation. Hubbing creates efficiencies that can't be measured in a delay study. The hub and spoke system provides frequent service between city pairs that could not support frequent direct service. Frequent flights provide an economic benefit to consumers, especially business travellers.

## 27. Improve Reliever Airports

Reducing the number of small-slow aircraft may not impact delays to air carriers in VFR weather because many of the small aircraft may purposely operate out of air carrier scheduling peaks.

However, the full development of reliever airports does encourage all–weather operations for all types of private and business aircraft, from small single engine propeller driven aircraft to multi-engine turbojets.

These capabilities coupled with adequate ground services and passenger facilities at a convenient location may redistribute aircraft demand and reduce overall delays at the Charlotte/ Douglas International Airport.

A 50 percent reduction in general aviation operations would save 4,032 hours or $5.6 million per year at the Baseline level of activity, and 20,000 hours or $28.0 million at the Future 2 level.

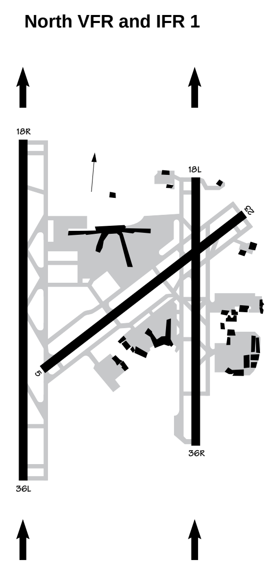



FIGURE 8 NORTH FLOW RUNWAY CONFIGURATION

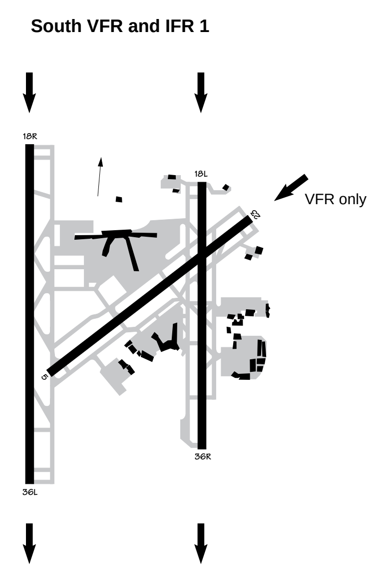



FIGURE 9 SOUTH FLOW RUNWAY CONFIGURATION

# 4.0 — Technical Studies

The Charlotte Design Team evaluated the operation of the existing airfield and the potential benefits of the delay reduction options in terms of airfield capacity, aircraft delays, and aircraft operating costs.

Figures 8 and 9 represent the runway configuration for the north and south flows. Figure 10 illustrates airfield weather and runway use. Weather conditions are defined as VFR when ceilings are 2,100 feet or more and visibilities are 3 miles or greater; IFR 1 in weather conditions less than VFR but ceilings of 200 feet or more and visibilities of 1,800 feet or greater; and IFR 2 when conditions are less than IFR 1 but greater than 100 foot ceilings and 1,200 feet visibilities.

## 4.1 Airfield Capacity

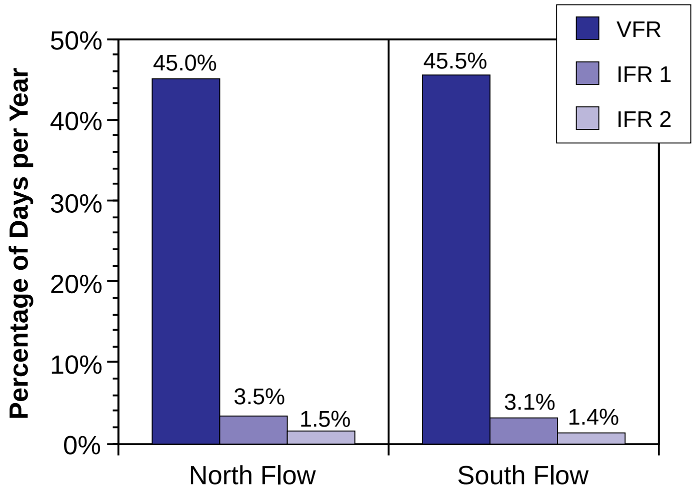
The Charlotte Airport Capacity Design Team recognized that airfield capacity is a very complex problem. Unfortunately, airfield capacity is not a constant value, but varies with runway configuration, weather, aircraft fleet mix, and a host of other factors and conditions. As a result capacity as shown in Figure 12 is represented by a family of curves.

These curves demonstrate the relationship between flows, the number of operations per hour, and the average delay per aircraft for the north and south flows under visual and instrument weather conditions. Both the demand and flow rates are for 50% arrivals and 50% departures.

Priority is given to arrivals unless this would cause an imbalance in the proportion of arrivals. A more detailed description is contained in Appendix A.

It is also important to notice that, as flow increases, average aircraft delay increases moderately until about 4 minutes per aircraft. Once delay reaches this point, an increase in flow can only be realized with significantly increasing delays. Therefore, even when the airport is operating at a relatively low level of delay, a small perturbation in demand can cause a significant increase in delay.

## Figure 10 Airfield Weather and Runway Use



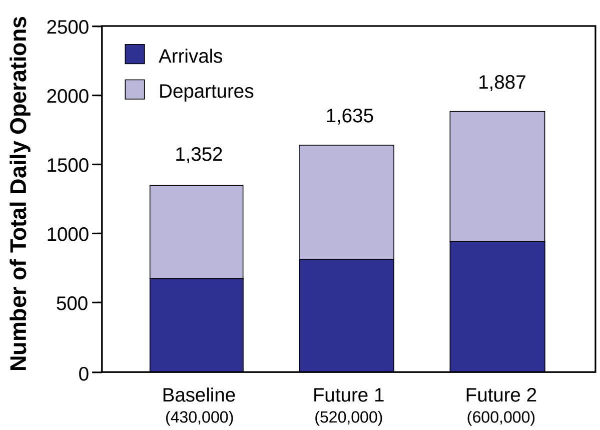

## 4.2 Aircraft Demand

The Design Team used three annual traffic levels as benchmarks: 430,000 operations as a Baseline, 520,000 operations defined as Future 1, and 600,000 operations defined as Future 2. They are associated with 1,352, 1,635, and 1,887 daily operations, respectively (Figure 11).

The number of daily operations for each demand level corresponded to an average busy day in the peak month. The hourly traffic counts were derived from the tower counts for January 31, 1990. The air carrier data were based on the January 31, 1990 *Official Airline Guide.*

At the Baseline level, the current peak hour demand is 112 aircraft operations, 49 arrivals and 63 departures. For Future 1 the total number of hourly operations peak at 132 with 60 arrivals and 72 departures. Peak hour total demand level for Future 2 is 148 operations consisting of 67 arrivals and 81 departures.

## Figure 11 Airfield Demand, Average Busy Day, Peak Month



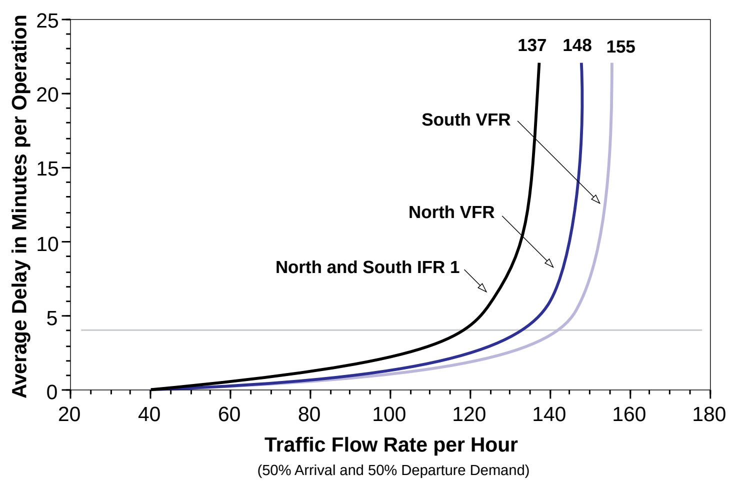
## 4.3 Aircraft Delay

Aircraft delay is the difference between (1) the actual time an aircraft takes to perform an operation and (2) the time it would take to perform that operation without interference from other aircraft in the Charlotte area.

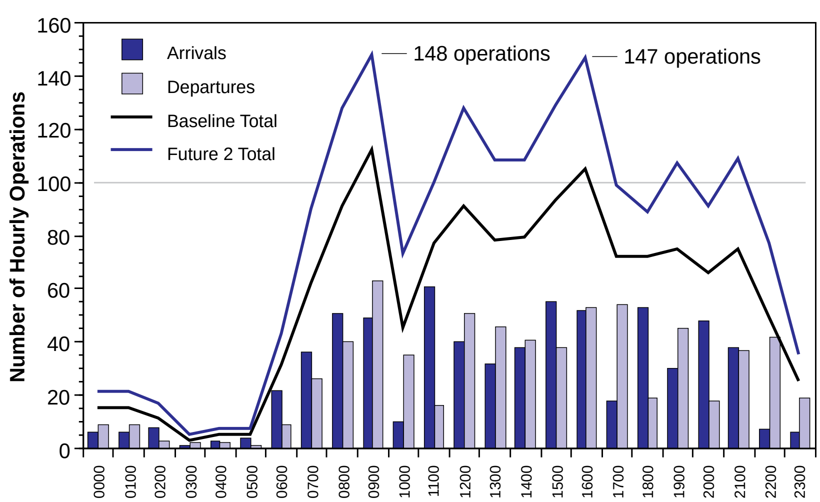
The Runway Delay Simulation Model (RDSIM) determined daily aircraft delays for current and future operations, based on the expected growth in aircraft operations.

Figure 12 illustrates the capacity and delay curves for the current airfield configuration at Charlotte. It shows that aircraft delays will begin to rapidly escalate as hourly demand exceeds 100 operations per hour. Figure 13 illustrates that while hourly demand rarely exceeds 100 operations at Baseline demand levels, 100 operations per hour is frequently exceeded at forecast Future 2 demand levels.

### Figure 12 Flow Rate vs. Average Delay




### Figure 13 Hourly Airport Demand



## 4.4 Annual Delay and Cost

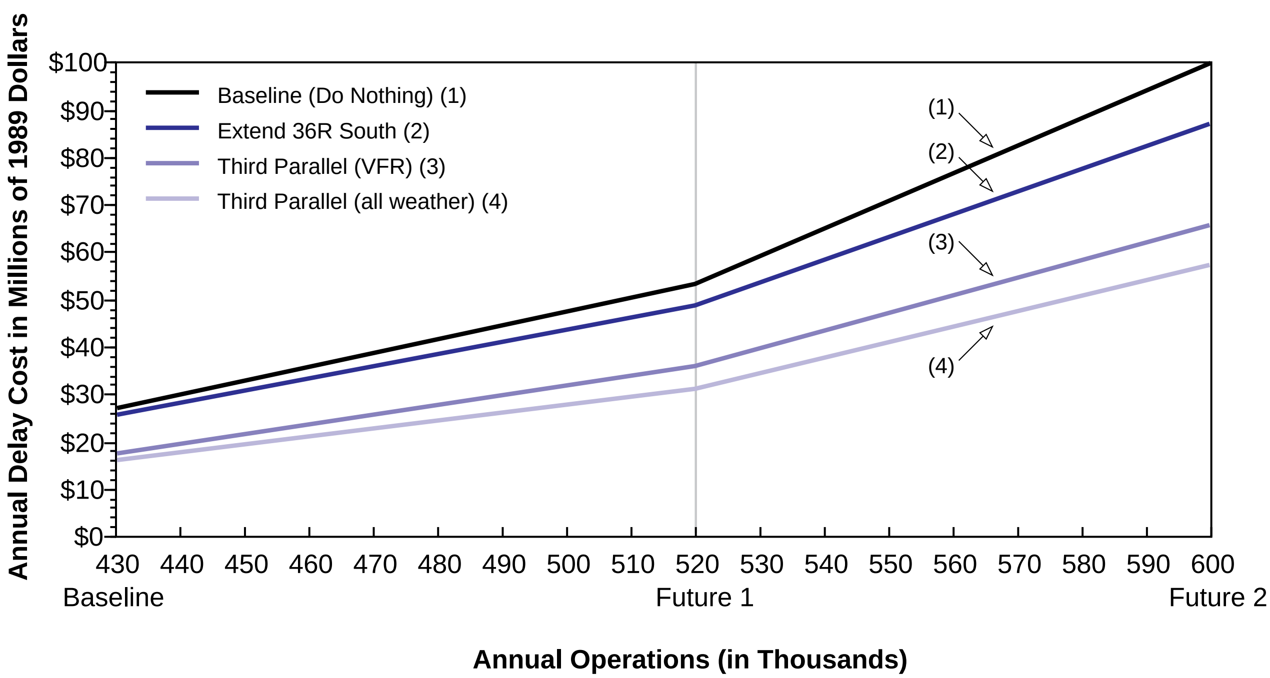
The Charlotte Design Team evaluated the operation of the existing airfield and the potential benefits of the delay reduction options in terms of aircraft delays and aircraft operating costs. Daily delays were annualized to determine the potential economic benefits of the proposed options. The annualized delays provide a measurement for comparing the benefits of the proposed changes.

The dollar value of $23.33 per minute or $1,400.00 per hour was used to compute delay costs at all demand levels, for both present and proposed operations. It was the average direct operating cost for the Charlotte Airport fleet mix in 1989 dollars. It did not consider lost passenger time, disruption to airline schedules, market considerations, or other economic factors.

A comparison of the annual delay savings of the proposed improvements can indicate which are the most effective for a given demand level. For an anticipated increase in demand, an optimum combination of improvements can be implemented in stages so that airfield capacity is increased and aircraft delays are kept to a minimum.

The results of the analysis reveal that current yearly Baseline delay costs of $26.7 million will escalate to $53.1 million at Future 1 demand level and $99.9 million at the Future 2 demand level without airport improvements (Figure 14).

### FIGURE 14 DELAY COST ALTERNATIVES



# Appendix A — Computer Models

The FAA used the Runway Delay Simulation Model (RDSIM) to study the effects of proposed delay reduction and capacity enhancement options at Charlotte.

RDSIM is the short form of ADSIM, the Airfield Delay Simulation Model. ADSIM is a fast-time, discrete event model that employs stochastic processes and Monte Carlo sampling techniques. It describes significant movements by aircraft on the airport and the effect of delay in the immediate airspace. ADSIM was validated in 1978 at Chicago's O'Hare International Airport against actual flow rates and delay data.

Model inputs are empirically derived from the collected field data. The model is calibrated against the field data to insure that the model is site specific.

RDSIM simulates demand only for the runways and does not consider the taxiway network or the terminal complexes. It provides both capacity and delay information.

The experiments were repeated 40 times using Monte Carlo sampling techniques to introduce system variability into each run. The results were then averaged to produce the capacity/delay outputs for a given demand level.

For the delay analyses, RDSIM used actual aircraft schedules based upon the *Official Airline Guide*, historical data, and airport forecasts.

For the capacity analyses, RDSIM creates its own schedule of ever increasing levels of demand based on user specified parameters with randomly assigned arrival and departure times.

⇐ *Lufthansa German Airlines and USAir hold international gates at the newest international and commuter complex placed into service in 1990.*

⇓ *The most recent terminal area forecast anticipates that by the year 2000, the number of aircraft operations will increase 21%.*

⇒ *The airport currently operates with 61 aircraft gates: 41 domestic, 4 international, and 20 commuter gates.*

# Appendix B — Design Team Participants

**Design Team Chairmen**

*FAA Southern Region*
Ed Agnew, Airports Division, Atlanta
Pablo Affant, Airports Division

**FAA Members and Attendees**

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Phil Loftin, Charlotte Tower
Cecil Hall, Charlotte Tower
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Roger Wilke, Charlotte Tower
Jeff Foreman, Charlotte Tower

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Dave Bernier
Mike Dodd

*Air Transport Association of America*
Walt Ferrari
Bill Drew

*Aviation Management Association, Inc.*
Gary R. Church

*Aircraft Owners and Pilots Association*
Ken Medley

*North Carolina Department of Transportation*
Willard G. Pentl

⇑ *The airport's 10,000 foot runway, one of three runways in use, was placed into operation in 1979.*

⇑ *More than 4,000 acres comprise the regional passenger terminal complex, located within easy access to major highways crisscrossing the Carolinas.*

# Appendix C — Glossary

| | |
|---|---|
| ADO | FAA Airport District Office |
| ADSIM | Airfield Delay and Simulation Model |
| ALSF-II | Approach Light System with Sequenced Flashing Lights in ILS CAT-II Configuration |
| AOPA | Aircraft Owners and Pilots Association |
| ARTCC | Air Route Traffic Control Center |
| ARTS | Automated Radar Terminal System |
| ASD | Aircraft Situation Display |
| ASDE | Airport Surface Detection Equipment |
| ASR | Airport Surveillance Radar |
| ATA | Air Transport Association of America |
| ATC | Air Traffic Control |
| ATCT | Air Traffic Control Tower |
| Baseline | 430,000 Annual Aircraft Operations |
| CLT | Charlotte/Douglas International Airport |
| DME | Distance Measuring Equipment |
| FAA | Federal Aviation Administration |
| FSDO | FAA Flight Standards District Office |
| Future 1 | 520,000 Annual Aircraft Operations |
| Future 2 | 600,000 Annual Aircraft Operations |
| GA | General Aviation |
| IFR | Instrument Flight Rules |
| IFR 1 | 200 Foot Ceiling/1,800 Foot Visibility |
| IFR 2 | 100 Foot Ceiling/1,200 Foot Visibility |
| ILS | Instrument Landing System |
| IMC | Instrument Meteorological Conditions |
| MALSR | Medium Intensity Approach Light Lights System with Runway Alignment Indicator Lights |
| NAVAID | Navigational Aid |
| PRM | Parallel Runway Monitor |
| RDSIM | Runway Delay Simulation Model |
| RVR | Runway Visual Range |
| SIAP | Standard Instrument Approach Procedure |
| Stage III | Aircraft Noise Standard |
| TRACON | Terminal Radar Approach Control Facility |
| T/W | Taxiway |
| VASI | Visual Approach Slope Indicator |
| VFR | Visual Flight Rules |
| VMC | Visual Meteorological Conditions |
| VOR | Very High Frequency Omnirange Station |

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DOUGLAS INTERNATIONAL AIRPORT,
LARRY HARRWELL, PHOTOGRAPHER