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A COMPARATIVE EVALUATION OF AIR AND AUTO TRAVEL BETWEEN URBAN REGIONS

(Quantifying Intercity Modal Accessibility)

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16. Abstract

The economic competitiveness of a region, in addition to the quality of life of its citizens, is dependent upon its accessibility to other regions. As the surface and air transportation systems evolve, it is important to explicitly measure the impact of transportation changes on a region's accessibility. Therefore, the purpose of this research project is to develop a methodology to quantify intercity accessibility by mode, and to use this methodology to investigate the impact of air service changes in a region to its intercity accessibility.

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ABSTRACT

There has been an increased dependence of regional industries on the air transportation system in the recent past. At the same time, financial instability of airlines and development of new aviation technologies has resulted in the potential for significant change in the service levels at small- to medium-sized airports. As the transportation system evolves, it becomes important to explicitly measure the impacts of these changes on a region's mobility; these changes also need to be incorporated in the long-term planning processes of state agencies. Hence this project focuses on quantifying interregional mobility of a region and uses the methodology to assess the affects of changes in air service on the mobility of air passengers in Virginia.

A three-step methodology has been developed in this research effort to analyze the affects of change in air service on the interregional mobility of a region. As the part of the first step, guidelines have been developed to select the region pairs (i.e. the travel destinations) for analysis. Two indices called the "Performance time index" and "Performance cost index", which capture the affects of changes in service on mobility, have been developed.

The project entailed the following tasks: (1) Selection of three urban regions of different sizes in Virginia (to demonstrate the working of the methodology), (2) Identification of travel pairs for the analysis of each region (step 1 of developed methodology), (3) Estimation of travel time and costs under the present circumstances by air and automobile (step 2), (4) Estimation of travel times and costs by air, when there is

a change in service by air service and comparison with automobile travel times (step3).

Change in air service has been presented in the form of introduction of a new service and loss of air service at airports. It was observed that changes in air service would have greater impact on regions connected with airports where annual ridership is less than 0.05% of annual US air ridership. In regions served with airports (where annual ridership is less than 0.25% of annual US air ridership); the governing agencies should focus on retaining existing air service in order to preserve the region's interregional mobility. Air travel time (under reduced service because of loss a major airline) would be comparable to the highway travel times for nearly 45% of the travel pairs.

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CHAPTER 2: INTRODUCTION

2.1 INTRODUCTION

The aviation industry, which is responsible for moving people and products by air, contributes a trillion dollars every year to the United States economy. Nearly two million people travel annually on the domestic airlines in the United States and more than one-third of the goods are transported by air [1]. Recent changes in air transportation because of advances in technology [2] and financial instability of airlines [3] have suggested a reduced availability and access to air travel services for people at some of the passenger airports. This change in the supply of air service induces a change in the demand for air transportation [3] and affects the operations of the aviation system. This research effort develops a methodology to evaluate interregional mobility and uses the methodology to assess the impacts of changes in air services on interregional passenger mobility. The applicability of the methodology has been demonstrated for Richmond, Hampton Roads, and Charlottesville-Albemarle regions of Virginia.

2.2 AIR TRANSPORTATION AND REGIONAL ECONOMIC DEVELOPMENT

There has been an increased dependence of regional industries on air transportation in the recent past. In 2005, it has been reported that 25% of all companies' sales are dependent on air transportation and 70% of the companies use air transportation to expand their markets [1]. This section presents the importance of air transportation for regional economic development and competitiveness.

2.2.1 Regional Connectivity and Economic Development

Although relations between infrastructure, connectivity and regional economic development are complex, researchers believe that good accessibility benefits economic development of the region [4, 5]. Presence of a good transportation infrastructure which enables greater accessibility to a region, plays an important role in the location decisions of companies [6,7]. Nenonen and Littunen[8], in their study of location choice of firms, concluded that business managers regard good transportation connections as very important in the location choice of their businesses. Linneker [9] suggested that regions with better access to the locations of input materials and markets will be more productive, more competitive, and hence more successful than more remote and isolated regions. The studies discussed above illustrate that connectivity to various regions plays a very important role in promoting a competitive business environment, and hence these aspects should not be underestimated. Regional development requires a good transportation infrastructure, and air transportation is part of such infrastructure.

2.2.2 Air Transport Services and Economic Development

Airports have been viewed as important economic engines of a region. Butler and Keirnan [10] reported two factors – “Economic impact” and “Transportation benefit”, as being important in measuring the air service’s importance to an area. “Economic impact” is ‘the regional economic activity, employment and payroll that can be attributed directly and indirectly to the operation of a local airport’ and “transportation benefit” is the ‘time saved and cost avoided by travelers’.

Although airports play an important role in the economic development of a region, the method in which it contributes to the economic development is dependent on its size. Larger airports like Washington Dulles International create a large spin-off to the surrounding region and contribute to the economic development through the first factor – “economic impact”. Smaller sized airports are not generators of economic development but they act as facilitators of economic development by influencing the second factor – “transportation benefit”.

Aviation in remote regions itself does not create regional development, but it facilitates other development processes leading to economic development [11]. Work by Graham [12] and Fitzpatrick & Mottram [13] suggests that the importance of air transportation as a part of the regional transport infrastructure is more important in peripheral regions. There has been a sharp distinction between airports that are generating economic activity and those that are facilitating economic activity in a region. In general, the smaller the airport, the less generating and the more facilitating it is [11].

Since air transportation has a significant impact on the regional economic development, it is important to monitor the performance of the aviation system for changes in the level of air service. Hence measurement of various characteristics of the air transportation system becomes important.

2.3 PUBLIC SECTOR

2.3.1 BACKGROUND

The desire to improve the performance of the transportation system and also improve the accountability of governmental performance has resulted in an increase in the transportation community's interest to measure the transportation system's performance. Another important factor contributing to this increased attention towards performance measurement is the growing need to view the transportation system from a multimodal perspective. Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) recognized the importance of viewing the transportation system from an intermodal perspective and also stressed the need to address the efficiency, with which the system meets the transportation needs of its users [14]. This meant that for making investment decisions on an intermodal basis, one needs to be able to measure the performance of each of these modes in a consistent way. This approach was reinforced by the reauthorization of the surface transportation legislation in the Transportation Equity Act for the 21st century (TEA-21), which added concepts of fairness in the distribution of resources to those of the efficiency of the transportation system [15].

Since funding for transportation projects is dependent on the performance of transportation system, measuring performance has become important. Some of the state departments have developed programs to measure the performance of multimodal transportation systems (e.g., California Transportation Commission [16, 17]). The following subsection presents details of the state government's role in aviation planning.

2.3.2 STATE'S ROLE IN AVIATION PLANNING

An aviation agency is typically authorized by state law to engage in the airport system planning. The aviation agency is normally under the state's aviation organization located within the Department of Transportation, or an Aeronautics commission or another state planning agency. (e.g., Commonwealth of Virginia – Department of Aviation, Arizona – Arizona Department of Transportation). The responsibilities of any state aviation department are vested in the agency by the state's legislature.

The majority of the state aviation departments have three critical roles. The first is the preparation of the state aviation plan, which supplements the guidelines [18], set up by the Federal Aviation Administration for an Integrated Airport System. The second role involves issuing airport operating permits & performing related safety inspections, coordinating land-use planning by local governments, establishing & enforcing environmental regulations, and conducting aviation education & awareness programs. The third role is the allocation of funds for aviation infrastructure investments that are under the control of the state.

2.3.3 AIRPORT PLANNING AND FUNDING FOR AVIATION PROGRAMS IN VIRGINIA

Aviation programs across the United States receive funds from various federal, state, and regional sources. The Virginia Department of Aviation acquires funds for Virginian airports from the following sources:

- State sources

  - Aviation Special Fund – The Aviation Special Fund is generated through the levy of taxes on aviation fuel purchased in the state and the sale and use of aircraft & aviation parts, as well as miscellaneous fees collected by the department for licensing of aircraft & airports.
  - Commonwealth Airport Fund – Commonwealth Airport Fund is generated through taxes from general retail sales, automotive and aviation fuel, and motor vehicles.
- Federal sources
  - Federal airport improvement program

Commonwealth Airport Funds can be used only for purposes of capital improvement programs (programs supporting planning and capital development needs at Virginia's licensed, public-use airports). The Airport Capital Improvement Program (ACIP) as defined in FAA's advisory circular [18] is the compilation of projects for an individual airport for a three- to five year period and includes costs priorities, airport improvement plan (AIP) eligibility and expected funding sources for each element. Virginian ACIP is designed for a six-year period to accomplish the following [20]:

- Provide the aviation board with specific requests for funding,
- Provide the department with specific information to develop an accurate and comprehensive 6-year budgetary program,
- For use by the department to leverage maximum federal funding for eligible sponsors and eligible projects, and
- Establish an accurate assessment of Virginia's long term needs.

Assessment of the existing aviation system is very important because it forms the basis for identifying the long-term aviation needs. The following subsection describes the study undertaken by the Virginia Department of Aviation to accomplish the same.

2.3.3.1 The Virginia Air Transportation System Plan Update

The Virginia Air transportation system plan update (VATSP) [21] was conducted by the Virginia Department of Aviation in January 2000 with the following four objectives:

- Create a strategic management plan,
- Document historic activity at existing facilities,
- Create five, ten and twenty year needs assessments for each airport, based on individual airport forecasts, and
- Identify strengths and weaknesses of the existing system and recommend solutions which increase benefits to system users, enhance the contribution of the Virginia's airport system to Virginia's economy; and minimize adverse environmental impacts.

This study which was conducted in 2002 identified five major industry developments that have had or are likely to have an impact on the future commercial or general aviation air traffic at Virginia airports. They are mentioned below:

- *US Airways financial performance:* US Airways is the dominant carrier at many of Virginia's commercial airports. Increasing competition among full fare carriers and increasing presence of low-fare airlines have placed increasing pressure on US Airways' financial performance. Given the strong presence of US Airways at many commercial airports, a potential bankruptcy could lead to disruption in services.

<u>US Airways' operations during 2002-2006</u>

As the largest carrier at Ronald Regan Washington International Airport, US airways was disproportionately impacted by the airport's extended closure after September 11. The airline was forced to enter bankruptcy in August 2002 but was able to exit bankruptcy in a relatively short period. During the same period, the airline was forced to de-hub Baltimore Washington International Airport. In further attempts to reduce the financial losses the airline de-hubbed Pittsburgh International Airport in early 2004.

High fuel costs and deadlocked negotiations with the Airlines Pilots Association forced US Airways to enter a second round of Chapter 11 bankruptcy in September 2004. In September 2005 US airways merged with Arizona based America west airlines and also emerged from the bankruptcy.

- *Southwest airlines entering Virginian markets:* Southwest airlines announced its intention to start services in Richmond in the future. Improved airfares provide significant levels of passenger traffic stimulation and may result in a redistribution of passenger traffic between individual Virginian airports.

- *Increasing presence of regional jets:* Increasing presence of regional jets has facilitated new nonstop services at many Virginian airports. This can change the passenger's choice of airports and can induce more demand on the aviation system.

- *Growth in general aviation industry:* The 1990s General Aviation Revitalization Act provided product liability protection to aircraft manufacturers. Sustained economic growth in the US Economy, coupled with the recent trend toward fractional aircraft ownership were important contributors to general aviation growth in Virginia and the national.

- *9/11 Terrorist Attacks:* In the months following the September 11 terrorist attacks, commercial passenger traffic levels fell by over 20% nationwide. As the industry was experiencing massive financial losses, airlines implemented substantial capacity reductions. Commercial airports incurred a sharp reduction in revenues, which coupled with requirements for major security upgrades are placed serious strain on airport financial resources.

Table 2-1 summarizes the factors that impacted commercial airline traffic after 9/11. It can be observed from the table that the factors like 'fear of flying' and 'fare discounting' have short term affects on the air passenger traffic. But factors like 'Increased security' and 'Airline financial condition' have mid to long term, negative impacts on the commercial air passenger growth (short term: < 5 years; mid term: 10 years and long term: 15 years). Hence study of these impacts becomes important.

Table 2-1: Factors Impacting Commercial Air Passenger Traffic Growth (Source [21])

Factor	Impact	Duration
Fear of Flying (After 9/11)	Negative	Short-term
Increased Security:		
Added Trip Time	Negative	Short to Mid-term
Added Trip Cost	Negative	Long-Term
Airline Schedule Reductions	Negative	Mid –Term
Fare Discounting	Positive	Short-Term
Airline Financial condition	Negative	Mid-Term
US Economy	Negative	Short to Mid-Term

2.4 PURPOSE OF THE RESEARCH

Air transportation plays a significant role in affecting the economic development of a region. Hence, the state and regional governments consider air transportation system performance as an important factor in their regional planning decisions. Transportation system performance studies have been extensively used in the past to assist regional and state governments in funding decisions for various modes. Funding for various air transportation programs depends on many factors, one of which is the long-term aviation plans.

In the recent past there have been many changes in the aviation system, which can potentially affect the performance of the air transportation system in the mid to long term period (10-15 years). Therefore, it is important for the regional and state governing agencies to study the impacts of these changes on the air transportation system. Mobility which is defined as, ‘The ease, with which one can reach their desired destination within reasonable time and with a reasonable cost,’ has been chosen to study the impact of these changes. For the purpose of this research, *Interregional Mobility* of a region is defined as a measure that captures the travel time and travel cost characteristics between the region under consideration and various other regions around this region.

This purpose of this research is to develop a methodology to quantify *Interregional mobility* and to use the methodology to assess the affects of changes in air service on the mobility of Virginian air passengers.

2.5 SCOPE OF THE RESEARCH

The methodology that has been developed will assist regional and state governing bodies in their long term planning processes. The measure of the air passenger mobility is limited to:

Medium- and small-sized airports: It is known that unlike large airports which drive regional economic development, the small- and medium-sized airports facilitate economic development. Hence the applicability of the developed methodology is limited to the regions that are served by these airports. Medium- and small-sized airports carry less than 1% of the total annual air passenger traffic. Elaborate details have been presented in Section 5.2.2 of the report.

Passenger services: Some of the changes in the transportation system that have been discussed above affect cargo services along with passenger services. Cargo aircraft operations are different from passenger operations because of their flexibility in operations and different operational characteristics when compared to passenger services. The scope of this project is limited to operations of passenger services.

Business passengers: Business activities play a significant role in the regional economics, hence business travel has been considered within the scope of this project.

Commercial aviation: Aviation consists of commercial aviation (cargo and passengers) and general aviation (recreational travel and travel by privately owned planes). Since commercial service at various airports directly affects the long term planning process, the scope has been limited to commercial aviation. General aviation which allows users to operate planes without a fixed schedule has not been considered.

The level of performance can possibly be measured by various factors like mobility, reliability, sustainability, etc. This research uses mobility as the performance measure.

In order to provide the users of the methodology with the relative comparison of the modes of automobile and air, the methodology estimates the mobility characteristics of travel by automobile.

2.6 REPORT OVERVIEW

Chapter 2 presents the description of the existing literature for the air transportation performance measures. The different methods and criteria that have been used in the past to measure the air transportation performance are discussed. Chapter 3 describes the performance measures that have been identified for this research. The chapter also includes the methodology that has been developed to address the service performance measure. Chapter 4 demonstrates the application of the developed performance measures for three regions in Virginia. Chapter 5 presents the results from the application of the developed methodology, and Chapter 6 provides conclusions.

CHAPTER 3: LITERATURE REVIEW

3.1 INTRODUCTION

In the past, various state and regional governments have made attempts to measure the performance of the aviation system. The studies proposed various criterions to measure the performance of the aviation system. Mobility has been used as one of the many criteria in some studies. This chapter describes some the existing works, study of which can help us to develop a methodology to measure the interregional mobility of air passenger.

Journey of the air passengers includes flight in a part of the trip. The journey involves ground travel at the trip ends. For travel involving shorter distances, the time spent in the ground access modes is a significant part of the total door to door travel time. Hence, considering the performance of the ground access mode is important.

This chapter describes some of the studies that dealt with measuring the performance of aviation system and ground access. Most of the conducted studies dealt with the performance of the aviation system and the surface transportation separately. The literature has been categorized into the following two classes and presented in this chapter:

- Literature dealing with the performance of the air side.
- Literature dealing with the performance of the land side airport access.

3.2 DESCRIPTION OF STUDIES

Various studies were conducted in the past to evaluate the operational performance of air transportation system. The type of performance measures that were proposed, and the methods that were designed to measure them, were dependent on the user groups that were in need of the performance measure. The list of the user groups, served by the air transportation system are:

- Providers of air transportation services (aircraft operators).
- Air passengers and air cargo shippers.
- Businesses which directly or indirectly depend on air transportation.

The literature that has been reviewed considered one or more of these user groups in their studies. Each of these user groups tends to approach the performance measure of the aviation system from a different perspective. A classic example is flight delays; airlines are concerned about delays because delays make flights stay in the air for longer time than they otherwise would; this implicates higher crew costs, increase in the cost of operations because of an increase in the amount of fuel burnt, and lower aircraft utilization. For passengers, delays would mean missed connections or late arrivals at meetings.

3.2.1 STUDIES PRESENTING MEASURES OF PERFORMANCE ON THE AIR SIDE

The section presents the studies that propose methods to quantify the performance on the air side of a journey. The limitations of the studies are identified and discussed below.

3.2.1.1 California Aviation System Performance Measures

3.2.1.1.1 *Description of Study*

Institute of Transportation Studies at the University of California, Berkeley has undertaken a study to develop Aviation system performance measures in order to assist the California Department of Transportation in allocating funds for various transportation programs [22]. This study is a part of a larger study to measure the performance of the transportation system. It defines performance measures for commercial air service from the air service operator's, and traveler & shipper's perspective.

This study follows the criteria that have been set by the California Transportation Assessment Steering Committee (TASC) for the development of performance measures or indicators [16]. Some of the guidelines that have been proposed by TASC to assist in the development of performance indicators are as follows:

- Whenever possible, use existing data sources and confirm to existing performance activities of regional transportation planning organizations.
- Measures or indicators must be easy to use and simple to understand.
- To the greatest extent possible, indicators should be measurable across all modes.

The steering committee also identified a desired set of outcomes to present the performance of transportation system. The proposed outcomes were divided into two categories: "Responsibility" and "Effectiveness & efficiency". Outcomes under the category “Effectiveness & Efficiency” are related to our project; details about this set of outcomes are discussed in Table 3-1.

Effectiveness and Efficiency

The following outcomes have been proposed by TASC under this category.

- *Mobility/ Accessibility* – Reaching desired destinations with relative ease within a reasonable time at a reasonable cost with reasonable choices.
- *Reliability* – Providing reasonable and dependable levels of service by mode.
- *Cost-effectiveness* – Maximizing the current and future benefits from public and private transportation investments.
- *Customer Satisfaction* – Providing transportation choices that are safe, convenient, affordable, comfortable, and meet customer needs.
- *Economic well-being* – Contributing to California’s economic growth.

The study proposes methods to quantify various performance outcomes (proposed by TASC) for commercial and general aviation. This study developed methods to quantify these outcomes for commercial service and the proposed methods are presented in Table 3-1 (A total of 78 methods of measuring the performance had been suggested by this report; only relevant performance measures have been presented in this table).

Table 3-1: Methods to Quantify Transportation Performance (Source [23])

Outcome	TASC Proposed Measure	Methods to quantify performance measure
Mobility and Accessibility	Travel time	• Percentage of air trips in markets served by nonstop flights. • Percentage of air trips in markets without nonstop service but served by connections through an airline hub or one-stop service. • Percentage of air trips in markets with at least six nonstop, one-stop or connecting flights per day • Number of international destinations served with nonstop flights with daily departures • Number of international destinations served with nonstop flights with at least three weekly departures.
	Delay	• Average delay experienced in traveling to and from the airport, measured as the average difference between actual highway travel times and free flow times, weighted by the distribution of trip ends. • Average delay experienced during the flight, expressed as the difference between actual flight times and scheduled flight times during periods of light traffic.
	Access to Desired Destinations.	• Percentage of air trips in markets served by three or more carriers with nonstop, one-stop or connecting service • Percentage of international departures in markets with at least two carriers. • Percentage of air trips for which the nearest commercial airport provides direct of connecting air service through one intermediate hub. • Percentage of air trips for which the nearest commercial airport provides direct jet service to the destination or to an intermediate hub with direct service to the destination. • Average additional distance to access the nearest airport with direct air service to the destination, or connecting air service through an intermediate hub when the destination is not served directly, compared to the distance to the nearest commercial airport.

Outcome	TASC Proposed Measure	Methods to quantify performance measure
	Access to the Airport System	• Percentage of air trip ends within 45 minutes highway travel time of the nearest commercial service airport. • Percentage of air trip ends within 45 minutes highway travel time of the commercial service airport used. • Average airport access/egress highway travel times under free-flow travel conditions, weighed by the distribution of trip ends. • Percentage of air trip ends within 5 miles of stops served by scheduled airport ground transportation services, including rail transit and express airport bus services. • Percentage of air trip ends in communities served by airport shared ride van services. • Percentage of air passenger airport access/egress trips using shared ride public transportation.
Reliability	Standard Deviation of Average Trip Time	• Percentage of flights arriving more than 15 minutes late. • Percentage of flights arriving more than 30 minutes late. • Average departure delay per flight. • Standard deviation of highway airport access/egress travel times, weighed by the distribution of trip ends.
Cost Effectiveness	Customer satisfaction index	• Average fare paid per mile for intrastate air trips. • Average fare paid per mile for air trips from California to domestic destinations outside the state. • Average fare paid per mile for air trips to California from domestic origins outside the state.
Customer Satisfaction	User opinion survey	• Air passenger satisfaction index. • Air cargo shipper satisfaction index.
Economic well being	Share of transportation final demand in the gross regional or state product	• Commercial airport productivity in terms of equivalent passengers per dollar of annual operating cost, including airline station costs and annualized cost of capital investments in airport and air traffic control infrastructure.

3.2.1.1.2 *Limitations*

This study gives an idea about the various components of the travel that can be quantified and also proposes some of the methods to quantify them. The main limitation of using these measures directly for this study is that most of these measures are based on the aviation system's perspective, whereas this research is interested in measuring the performance from the user's perspective.

Travel time has been chosen as one of the measures to quantify mobility. But the methods that have been suggested to present travel time include measures like, percentage of air trips in markets served by non-stop flights, number of international destinations served, etc. These measures hardly convey information about the travel time characteristics from a particular airport system.

3.2.1.2 Bureau of Transportation Statistics – Transportation Indicators

3.2.1.2.1 *Description of study*

'Transportation Indicators Report', is a monthly report produced by the Bureau of Transportation Statistics (BTS) of the US Department of Transportation (DOT); it is intended to provide timely and easily accessible information to the transportation community about the performance of the national transportation system [24].

Each indicator is placed under a category corresponding to one of the five strategic goals of the DOT, namely: safety, mobility, economic growth, environment, and national security. Some indicators are related to more than one strategic goal. Aviation mobility is being presented using the following measures:

- Availability and use of domestic flights for air passengers.
- Availability and use of domestic flights for airfreight.
- Airfares and passenger volume for the top five major short routes.
- Airfares and passenger volumes for the top five major long routes.
- US Carriers aircraft capacity utilization for passengers and freight.
- Domestic flight availability and distance.
- US Air carrier on-time performance.

3.2.1.2.2 *Limitations*

The performance indicators developed by BTS provide a qualitative measure of the performance of the aviation system. Mobility is measured by measuring the volume of passengers and availability of flights. These measures fail to give us information about the mobility from the air passenger's perspective.

3.2.2 Studies Presenting Measures of Performance on the Land Side

The section presents the studies that propose methods to quantify the performance on the land side of air travel. The limitations of the studies have been identified and discussed below.

3.2.2.1 National Plan of Integrated Airport Systems

3.2.2.1.1 *Description of study*

The National Plan of Integrated Airport Systems (NPIAS) is prepared by the Federal Aviation Administration to identify airports that are eligible to receive grants under the Airport Improvement Program (AIP), and also to estimate the future airport development costs that are eligible for federal funding under the AIP over the subsequent five year period. The most recent update of the plan was released in September 2004 [25]. This plan describes six performance measures of the aviation system: capacity, safety, noise, surface accessibility, pavement condition and financial performance.

The measures of surface accessibility have been described in this section. Surface accessibility has been presented in terms of the percentage of population residing within a distance of 20 miles from an NPIAS airport. The accessibility measure according to the 2000 census is being described in Table 3-2.

Table 3-2: Population within 20 Miles of an NPIAS Airport (source [25])

Airport Categories	Percentage of US Population
Commercial service airports	66%
Commercial service and relievers	77%
All NPIAS airports	98%

3.2.2.1.2 *Limitations*

NPIAS suggested measures for airport accessibility in the form of distance of the airport from community. But geographic proximity alone does not ensure that airports are easily accessible. Highway congestion in metropolitan areas can seriously impede ground access. This performance measure fails to capture the aspect of highway congestion.

3.2.2.2 Arizona Aviation System Performance Measures

3.2.2.2.1 *Description of study*

The Arizona Department of Transportation is required by the state law A.R.S 28-598, Section I, to reassess the needs of the state's aviation system every five years. Rapid changes in Arizona's aviation system in the early 1990s demanded a continuous evaluation of the aviation system. The State Aviation Needs Study (SANS) is intended to assist the management to effectively and efficiently manage the aviation system. This assessment serves three purposes:

- Assist in determining the relative strengths and weaknesses of the existing system within the context of generally accepted state and federal standards and guidelines.
- Provide guidance in determining future system wide aviation facility needs, and
- Establish a baseline from which trade-offs among different investment strategies can be quantified over time.

Though SANS has been performed every five years starting 1985, aviation performance measures have been incorporated into the study only from 1995. The latest study, SANS 2000, was released in December 2000. Sixteen performance measures have been presented in SANS 2000 [26]. They have been divided into three categories for better understanding: Facility performance measures, Service level performance measures, and Economic measures. The performance measures are mentioned in Table 3-3.

Table 3-3: Arizona State Aviation Performance Measures (Source [26]).

Category	Performance measure
Facility performance measures	The number of airports experiencing delay of aircraft operations; the maximum and average delay in minutes an aircraft experiences due to airside congestion.*
	The extent to which system airports meet FAA and ADOT Transportation Board's minimum aviation development and planning standards.
	The number of airports with an annual demand less than 60 percent of runway annual service volume.
	The number of airports that generate INM noise contours greater than 65 DNL that extend off airport property.
	The number of system airports without adequate utilities (electricity, telephone, water, sewer, and gas).
	The number of airports with no close-in obstructions and where all FAR Part 77 approach obstructions are marked.
	The number of total airports in the state with no or minimal shared airspace and/or restrictions under visual/instrument flight rules.
Service-level performance measures	Percentage of communities in the state with a population greater than 5,000 within 60 minutes driving time of a commercial service airport.*
	Percentage of communities in the state with a population greater than 1,000 within 30 minutes driving time of a general aviation airport.*
	Percentage of communities in the state with a population greater than 15,000 within 30 minutes driving time of a general aviation airport that can accommodate large general aviation aircraft and has instrument meteorological conditions capability.*
	The number of major recreational areas in the state within 30 minutes of a general aviation airport.
	Percent of hospitals in the State within 30 minutes of a general aviation airport with Instrument Meteorological Conditions (IMC) capability, with on-site weather reporting, and jet fuel availability.
Economic performance measures	The dollar cost of aircraft delay to Arizona airport system users.
	Dollars of direct and indirect economic impact on the state from aviation.
	The cost ratio of annual aviation infrastructure to total number of statewide annual enplaned passengers and annual aircraft operations.
	The total dollar cost from aircraft delays associated with airspace congestion.

* - These measures have been discussed in the limitations section because of their relevance.

3.2.2.2.2 <u>*Limitations*</u>

3.2.2.2.2.1 Land side measures

The "Service level performance measures" mentioned in Table 3-3 attempt to reflect the accessibility of commercial and general aviation airports to communities of varying size. The significant problems with these measures are discussed below.

- Measuring the percentage of communities with more than 5,000 people that are within sixty minutes of a commercial service airport means that 10 communities of 6,000 people that are 45 minutes from the nearest commercial airport will have much greater effect on the measure than a city of half a million people that has two commercial service airports within 45 minutes. This measure will be useful when examining the performance of the aviation from the system's perspective but it would not be suitable for this work.
- There exist concerns about how one measures travel time from a community in large metropolitan areas to a commercial airport because within communities travel times vary significantly depending on the time of the day and also the reference point in the community that has been chosen for measuring travel time.

3.2.2.2.2.2 Air side measure

One of the performance measure of the 'Facility Performance Measures' counts the number of aircrafts experiencing delays; this measure does not take into consideration the size (or capacity) of the airport. Measure of the number of flights experiencing delay gives limited information about the performance at the airport. A measure like the percentage of delayed flights would provide better information. Information about the average and maximum delays should also be provided to give complete information.

3.2.2.3 PAG Regional Aviation System Study

3.2.2.3.1 *Description of study*

Pima Association of Governments (PAG) is a coalition of local, state, and tribal governments in Pima County, Arizona; its mission is to build consensus with its members and the public on regional planning issues such as transportation, air quality and water quality. PAG adopted a regional airport system plan in 1985. The plan was updated in June 2001 in order to identify, quantify, and prioritized aviation-related development needs through the year 2030 [27].

A performance-based approach, which contributes to the future sustainability of the planning process, was developed in the update. Six system performance measures were developed and benchmarks identified for each measure. These performance measures are capacity, standards, economic support, compatibility, financial responsibility and accessibility. Details about the accessibility measure have been presented below:

- Percentage of the region’s population and major business centers that are within a 30-minute drive time of a system airport that is capable of accommodating business jets.

- Percentage of the region's population that is within a 30 minute drive time of any system airport.
- Percentage of the region's population that is within a 30 minute drive time of any system airport with a precision approach.
- Percentage of the region's population that is within a 30 minute drive time of any system airport with a non-precision approach.
- Percentage of the region's population that is within a 30 minute drive time of any system airport accommodating 'special use' aviation.
- Percentage of system airports served by public transportation and
- Percentage of system airports that have intermodal transfer capabilities.

3.2.2.3.2 *Limitations*

The measures proposed by the Pima Association of Governments suffer from the following deficiencies:

- Ground accessibility is measured in the form of percentage of airports served by public transportation. The characteristics of the quality and effectiveness of ground transportation which is an important factor in performance is not considered.
- Another measure of accessibility is the percentage of region's population that is within a 30 minute driving distance from the airport. Because of factors like surface congestion, traffic incidents, etc., travel time measures tend vary a lot throughout the day. If travel time is used as a measure, it is important to

specify the network characteristics so that the effect of travel time variability is reduced.

3.2.2.4 TTI Urban Mobility Study

3.2.2.4.1 *Description of study*

Unlike other studies discussed in the previous sections, which focused on the mobility/accessibility between airport and communities, the Urban Mobility study focuses on the study of surface transportation mobility in urban areas. Texas Transportation Institute's (TTI's) Urban Mobility reports are the results of the study that is being conducted every year by TTI since 1982 [28].

The Urban Mobility Study report's procedures provide estimates of mobility at an area wide level. The approach describes congestion in consistent ways using readily available data thus allowing for comparisons across urban areas or groups of urban areas. The study designed eight measures that help measure the performance of surface transportation in urban areas [29]. They are:

- *Travel Delay* – The amount of extra time spent traveling because of congestion.
- *Travel Rate Index* – Represents the amount of additional time that is required to make a trip because of congested conditions on the roadways.
- *Travel Time Index* – Represents the ratio of the travel time during peak periods to that of the travel times during free flow conditions.

- *Fuel Economy* – The average fuel economy calculation is used to estimate the fuel consumption of the vehicles operating in congested and un-congested conditions.
- *Wasted Fuel* – This measure quantifies the amount of fuel that is wasted because of vehicles moving at speeds less than free flow speed during the peak period.
- *Congestion Cost* – This measure presents the total cost of congestion to the road user. This cost consists of two components: Delay cost and Fuel cost.
- *Percentage of Congested Travel* – This measure presents the percentage of travel in every urban area that is congested for peak travel.
- *Roadway Congestion Index* – This is a measure that is estimated using the density of traffic.

TTI's measures are very simple to use and hence they have been widely used to quantify the performance of the surface transportation systems. The projected effects of various congestion reduction strategies have also been presented in these reports.

3.2.2.4.2 *Limitations*

The Indices developed by Texas Transportation Institute do not consider the air travel component of interregional aviation mobility. Besides this limitation, which directly affects the direct applicability of these measures for our work, the study suffers from other limitations discussed below:

- The measures fail to capture the effects of congestion mitigating strategies that the cities are currently using to mitigate congestion. The main reason for this limitation is that TTI's indices use the data from the Federal Highway Administration which contains relatively limited information (Data includes: miles and lanes of freeway and arterial in each city and the average daily traffic volumes for each segment). Furthermore, TTI's equations translate increase in volume of traffic to increased delays; but in reality increase in volume can be attributed to increased capacity due to congestion mitigation measures.
- Another limitation is in the estimation of delay. Change in volume leads to a reduction in speeds; TTI assumes that the reduction in speeds is the same in all the cities across the US. This is not a reasonable estimate.

3.3 SUMMARY OF LIMITATIONS

The description and the limitations of various studies have been discussed in Section 3.2. The main reasons that prevent us from directly using the measures proposed in the previous studies are summarized:

- The studies deal with measuring performance of the air transportation system from the aviation system's perspective or the aircraft operator's perspective and not the user's perspective.

- The land side performance measures and the air side performance measures have been dealt with separately, thus preventing us from directly using these measures to quantify interregional mobility.

3.4 MOBILITY MEASURE AS PERFORMANCE INDICATOR

Rodrigue [30] in his book discussed that mobility is one of the most fundamental and important characteristics of economic activity because it satisfies the basic need of going from one location to another. Texas Transportation Institute's urban mobility study and US DOT's Transportation Indicators report have successfully used mobility measurements to measure and present the performance of transportation system.

3.4.1 MEASURING MOBILITY

Section 3.2 presented the details of various studies that measured the performance of the transportation system. Mobility for interregional travel can be measured using various measures a few of which are as follows:

- Travel time
- Travel cost
- Reliability
- Delay (or) On-time performance

3.4.2 MEASURES CHOSEN TO QUANTIFY MOBILITY

As mentioned in the previous subsection, mobility can be quantified by measuring various aspects of the transportation system. Intercity travel demand modeling and mode choice modeling; have received a lot of attention in the past. While mode choice (and demand for travel) does not measure interregional mobility, lessons learned in mode choice modeling can be used to establish a framework for assessing interregional mobility. Research conducted by Bhat, Yao and Koppelman concluded that the cost and travel time variables have a very high significance (greater than 99%) in determining mode choice [31, 32, 33]. Thus, it is clear that these variables are of primary importance to travelers in selecting how to travel (i.e. what mode to use). It would then follow that an individual's ability to travel (or their mobility) will be increased as cost of travel and time to travel decrease. Hence, this research focuses on measuring interregional travel mobility by estimating the costs and travel times.

3.5 CONCLUSIONS

This chapter provided a comprehensive literature review of the studies that dealt with measuring the performance of the aviation system. Various measures that can be potentially used to quantify mobility have been discussed. The limitations of various studies and the lessons learned from the studies have also been discussed. Travel time and travel cost have been chosen to quantify *Interregional mobility*.

CHAPTER 4: METHODOLOGY DEVELOPED TO QUANTIFY MOBILITY

4.1 INTRODUCTION

The methodology that is developed quantifies mobility by estimating the door to door travel cost and travel time incurred to accomplish a trip. A three step framework is developed to measure *Interregional mobility*; the framework is presented in this chapter.

Interregional Mobility of a region is quantified by measuring the travel time and travel cost between this region and various other regions separated by medium distances (around 400-600 miles). For sake of understanding the region whose '*Interregional mobility*' is being measured is defined as *home region.* The urban area around the *home region* that is separated by medium distance is called *outside region* (travel characteristics are measured between home and outside region). The methodology also captures the changes in these characteristics of travel because of changes in air service. For ease of understanding, the travel characteristics are consolidated into a single measure. The framework that is described in the following sections presents the methodology that has been developed to quantify *Interregional Mobility* of regions.

4.1.1 THE THREE STEP FRAMEWORK

The three steps of the methodology that is developed to assess the *Interregional Mobility* of business passengers are described below:

- Step 1 – Selection of *outside regions*: The travel characteristics between the *home region* and *outside regions* are considered in the analysis. This step identifies the regions around the *home region* that should be considered in the analysis. Guidelines are developed for identifying *outside regions* and they are presented in Section 4.2.
- Step 2 – Estimation of Travel times and costs by Automobile and Air: This step estimates the travel times and travel costs between the *home region* and *outside regions* by air and automobile. The method that is developed to accomplish the same is described in detail in Section 4.3.
- Step 3 – Consolidation: This step estimates the mobility measures (travel time and travel cost) in case of change in air service. The affects of changes in air service are consolidated into a simple and comprehensible measure. The method developed to consolidate the estimates is presented in Section 4.4.

The foundation of the methodology lies in using accepted data and measures that are readily available. Information about the data sources and the proposed use is presented along with the description of the three steps in the following sections.

4.2 SELECTION OF REGIONS FOR ANALYSIS (STEP 1)

Long distance travel by business passengers is largely dominated by air and short distance travel by automobile. But, for travel between regions separated by medium distances, the choice of travel depends on the service levels of various available modes.

Articles in the newspapers in the recent past amplify the significance of service levels for medium distance travel [34, 35].

In order to quantify the distances associated with travel between regions separated by medium distances, it is required to collect the mode choice characteristics of the business and non-business passengers for travel between regions separated with different distances.

4.2.1 DATA SOURCE – AMERICAN TRAVEL SURVEY

4.2.1.1 Background

The American Travel Survey (ATS), which was developed and conducted by the Bureau of Transportation Statistics, obtained information about long distance travel characteristics of persons living in the United States (‘Long distance’ in this context refers to trips between cities spaced by a distance greater than 100 miles). The survey data was intended to help identify the characteristics of current use of the nation's transportation system, forecast future demand, analyze alternatives for investment in & development of the system, and assess the effects of Federal legislation and Federal & state regulations on the transportation system and its use. The most recent American Travel Survey was conducted in 1995 (Previous ATS was conducted in 1977). This survey has been discontinued (in 2000), to be replaced by a comprehensive survey National Household Travel Survey (NHTS). ATS 1995 has been accessed via the web [36].

4.2.1.2 Survey Methodology

Basic demographic characteristics and other classification variables associated with the household and its members were recorded in ATS 1995. Social and economic characteristics included age, sex, marital status, race, household type, Hispanic origin, education, labor force status, and income. Detailed information about each trip taken by each member of the household was collected every three months between April 1995 and March 1996. The trip characteristics included the purpose of trip, means of transportation, origin, destination, intermediate stops, travel dates, trip duration, number of nights away, and types of lodging used.

Approximately 80,000 households nationwide were randomly selected to participate in ATS. In most cases, one adult household member had provided information for all household members. The survey interviews were conducted primarily by telephone and with in-person interviews, for respondents who could not be reached by telephone. This survey achieved an 85 percent response rate from those households that were eligible for interview.

4.2.1.3 Justification for Use

NHTS 2001 is a more recent survey and it would be ideal to use the data from this survey for understanding the mode choice behavior of passengers. But it has been observed that the NHTS data is limited in terms of the amount of data. For e.g., NHTS captured 501 long distance trips in Virginia whereas ATS 1995 captured 18,726 long distance trips in Virginia. Having discussed the fitness for use of the ATS 1995 data with the officials from DOT, it has been decided to use this data for the analysis.

4.2.2 Analysis of the Data

The long distance trip characteristics of the Virginian public as obtained from the ATS 1995 are analyzed. The modal choice characteristics of Virginian business and non-business passengers are presented in Table 4-1.

Table 4-1: Modal Choice Characteristics of Business and Non-business Passengers in Virginia.

Origin	Destination	Distance (miles)	% Air ridership (Business travelers)	% Air ridership (Non-Business travelers)
Richmond, VA	Washington DC	106	3.52	0
Washington, DC	Philadelphia, PA	137	0	0
Richmond, VA	Baltimore, MD	153	37.5	0
Richmond, VA	Raleigh, NC	169	0	1.42
Norfolk, VA	Raleigh, NC	182	0	2.55
Norfolk, VA	Washington DC	194	20.84	2.43
Richmond, VA	Fayetteville, NC	211	0	0
Norfolk, VA	Fayetteville, NC	223	0	0
Rochester, NY	Albany, NY	225	3.57	0
Norfolk, VA	Greensboro, NC	236	0	40
Norfolk, VA	Baltimore, MD	241	17.5	0
Norfolk, VA	Philadelphia, PA	271	52.63	0
Richmond, VA	Charlotte, NC	295	38.09	0
Norfolk, VA	Charlotte, NC	327	100	0
Rochester, NY	Philadelphia, PA	341	66.03	0
Norfolk, VA	New York, NY	360	33.33	44.23
Rochester, NY	Baltimore, MD	361	0	0
Richmond, VA	Charleston, SC	427	0	0
Norfolk, VA	Albany, NY	508	100	0
Richmond, VA	Atlanta, GA	535	100	71.76
Richmond, VA	Boston, MA	555	100	85.71
Norfolk, VA	Columbus, OH	569	100	0
Norfolk, VA	Boston, MA	573	96.55	6.66
Norfolk, VA	Atlanta, GA	596	100	40
Richmond, VA	Jacksonville, FL	601	100	0
Richmond, VA	Nashville, TN	613	100	100
Richmond, VA	Orlando, FL	743	100	41.09
Norfolk, VA	Orlando, FL	755	100	60.52
Richmond, VA	Tampa, FL	801	100	50
Norfolk, VA	Tampa, FL	814	34	0
Norfolk, VA	Sarasota, FL	865	100	0
Norfolk, VA	Miami, FL	965	100	100

Origin	Destination	Distance (miles)	% Air ridership (Business travelers)	% Air ridership (Non-Business travelers)
Richmond, VA	Kansas City, KS	1073	100	100

It can be observed from Table 4-1 that, for distances less than 250 miles, limited number of business and non-business passengers use air as their main mode of transportation. For travel distances greater than 600 miles the business and non-business passengers prefer to use air as the main means of transportation. But for travel distances between 250 and 600 miles the modal choice between air travel and other modes is indeterminate. For travel between cities separated by these distances, the mode choice is affected by various factors like levels of service, convenience, comfort, etc. Hence the regions separated by a distance of 250-600 miles have been given importance in the analysis.

4.2.3 Guidelines for Selection of Regions

Based on the analysis that has been suggested above, the following guidelines are developed to choose the regions around the *home region* for the analysis.

- The region pair should be separated by a distance between 250 and 600 miles.
- The regions should be connected by regular commercial air service.
- These should be a presence of business passengers between these regions.

4.3 ESTIMATION OF TRAVEL TIME AND TRAVEL COST (STEP 2)

This section discusses the travel time and travel cost estimation techniques developed as a part of the methodology. Business passengers use direct flights for most of their trips and hence only direct flights are used in the analysis.

4.3.1 ASSUMPTIONS

In order to simplify the estimation of travel times and costs, assumptions are made concerning the trip characteristics of business passengers. They are discussed below.

4.3.1.1 Surface Transportation Access

Some of the urban regions have public transportation facilities like rail and bus, which connect the airports to city centers. Figure 4-1 presents the details about the share of public transportation at select US Airports. It can be observed that public transportation usually does not attract more than 25% of ground access trips to major airports. Small and medium sized airports lack the connecting public transportation facilities and hence it is assumed that business passengers use private automobile for access from/to airports.

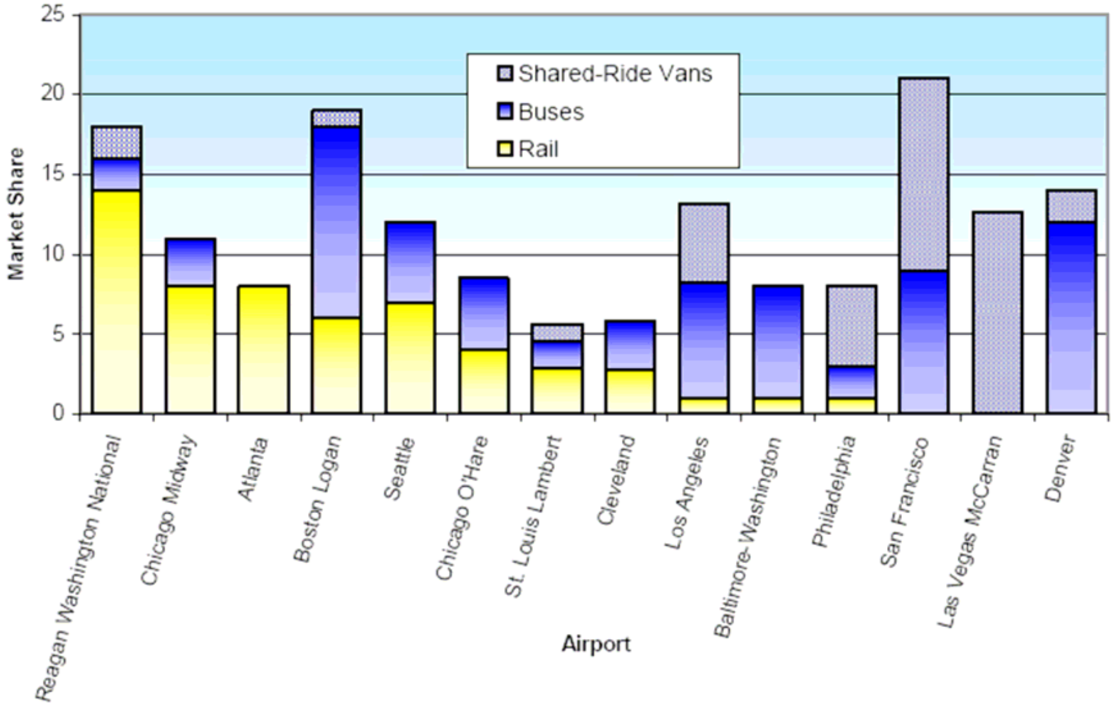

Figure 4-1: Public Transportation Market Share at Select US Airports (source [37])

It is assumed that the business passenger uses his/her personal vehicle for surface transportation access on one end of the trip. At the other end of the trip the business passenger hires a taxi from the airport to reach his/her final destination.

4.3.1.2 Trip Length

It is assumed that the business passenger's trip lasts for a week and he/she parks his/her personal car at the weekly parking lot at the origin airport during the entire week.

4.3.2 Door to door Travel Time Estimation by Air

4.3.2.1 Components of Door to Door Travel by Air

Estimation of the door to door travel times can be accomplished by estimating the various components that make up the travel time. The following components which constitute the door to door travel are identified. The travel time components are classified as 'air side component' (ASC) and 'land side component' (LSC) for ease of understanding.

- Travel from home/work to airport (LSC).
- Parking at airport and travel to terminal (LSC).
- Check in, security screening, airport wait time (ASC).
- Taxi out of aircraft at origin airport (ASC).
- Aircraft en-route (ASC).
- Taxi in of aircraft at destination airport (ASC).
- De-planing and Baggage collection (ASC).
- Transfer to surface mode (LSC), and
- Travel from airport to destination (LSC).

4.3.2.2 Data and Information Sources

The following data sources are identified to obtain the information pertaining to the various components of travel mentioned above. The data for the year of 2002 is collected and used during the course of this project because of its completeness.

4.3.2.2.1 *<u>Airline on-time performance database</u>*

4.3.2.2.1.1 Database overview

This database contains scheduled and actual departure and arrival times reported by certified U.S. air carriers. The data is collected by the Office of Airline Information, Bureau of Transportation Statistics (BTS). The information reported by the commercial air service carriers is added every month to the database. Data from 1987 to present is available in the database.

4.3.2.2.1.2 Purpose and access

These Database tables contains departure delays and arrival delays for non-stop domestic flights by major air carriers, and additional data like origin and destination airports, flight numbers, scheduled and actual departure and arrival times, cancellations and diversions of flights, taxi-out and taxi-in times, air en-route time, and non-stop distance are also provided in the database. Four airline specific variables that help us identify the airline service are also provided.

The data from this database can be freely downloaded via the web [38]. Selective download of variables of interest for different geographic locations (based on state) and time periods (monthly records) is made possible through this web based portal. The downloaded data can be analyzed using any database, spreadsheet or statistical package. Microsoft Excel 2003 has been used for data analysis in this project. Computerized systems are used to record the data in the data set and hence it is reasonable to assume that the data is very accurate.

4.3.2.2.2 *Airline origin and destination survey*

4.3.2.2.2.1 Database overview

This database contains origin data, destination data, reporting carrier data, routing data (for flights going through intermediate airports), itinerary fare and other itinerary related data for domestic flights.

The data is collected by the Office of Airline Information, Bureau of Transportation Statistics (BTS). Origin and Destination Survey is a 10% sample of airline tickets from reporting carriers. The carriers report the data to the DOT once in every three months.

4.3.2.2.2.2 Purpose and access

This database provides information about the travel routing of various trips that were made during a particular time period. Information about travel cost can also be accessed from the database. Ridership for various possible routes between a given origin-destination pair are obtained from this database.

The data from this database can be freely downloaded via the web [39]. Selective download of variables of interest for different geographic locations (based on state) and time periods (quarterly records) is made possible through this web based portal. The downloaded data can be analyzed using any database access software, spreadsheet or statistical package. Microsoft Excel 2003 has been used for data analysis in this project.

4.3.2.2.3 <u>*Map quest*</u>

4.3.2.2.3.1 Overview

MapQuest is a free web service providing detailed surface transportation directions between addresses [40]. This system estimates drive distance and travel time based on roadway network and speed information stored within its spatial database. Upon consultation with the manufactures of the system it was learnt that, speed limits of road segments were stored in the database they are used to estimate the travel times.

4.3.2.2.3.2 Purpose

This web based service is used to estimate the un-congested airport access times by surface transportation modes.

4.3.2.2.4 <u>*Urban mobility report*</u>

4.3.2.2.4.1 Description

This report is published annually by the Texas Transportation Institute and is widely cited for measures of surface transportation mobility and traffic congestion on freeways and major arterials in 85 US cities [28].

4.3.2.2.4.2 Purpose

Information from this report is used to quantify the impact of congestion on surface transportation travel times.

4.3.2.3 Estimation of Components of Travel

This section presents the estimation technique for various components of travel that are mentioned in section 4.3.2.1 . The travel time can be presented as sum of the landside and the air side components, which can be written as:

$$Travel\_Time = Surface\_Transp\_Comp + Air\_Transp\_Comp$$

(Equation 1)

Where:

Travel_Time is the Door to door travel time in minutes between city centers of origin and destination regions.

Surface_Transp_Comp is the time spent (in minutes) on the ground transportation modes

Air_Transp_Comp is the time spent (in minutes) between the origin and destination airports.

The Surface transport component includes the travel time from the city center to the airport at the origin or destination. Speed limits on the roads are used to estimate the un-congested automobile travel times, and modifications are made to these times using the Travel Time Index from the Texas Transportation Institute's *Annual Mobility Report*. Since downtowns of cities are the business hubs for most of urban settlements, they are chosen as the center of regions in the analysis. The travel time between downtowns and airports and the Travel time indices of various urban areas have been presented in Appendix A. The surface transportation component of the travel time is estimated using the following equation.

$$Surface\_Transp\_Comp = Time\_CBD_o\_airport \times TTI_o + ParkingTime_O + Time\_CBD_d\_airport \times TTI_d$$

(Equation 2)

Where:

TTI_o is the Travel Time Index of the origin region.

TTI_d is the Travel Time Index of the destination region.

$Time\_CBD_o\_airport$ is the travel time in minutes (using speed limits) between downtown and airport at origin city.

$Time\_CBD_d\_airport$ is the travel time in minutes (using speed limits) between downtown and airport at destination city.

ParkingTime is the time spent in securing a parking place at the origin airport and traveling from the lot to the terminal. Based on experience of the research team, and consultation with airport personnel, parking is estimated to be 30 minutes.

The Air transportation component includes the time for check-in, security screening, airport "wait", aircraft taxi, air travel, de-planing/baggage claim time, and modal transfer at destination. The methodology also includes an estimation of cancellation penalty and delay penalty in the form of travel time.

$$Air\_Transp\_Comp = CheckIn + Delay + CancPenalty + Taxi\_out$$
$$+ AirTime + Taxi\_in + BaggageClaim + TransferTime$$

(Equation 3)

Where:

CheckIn is the time estimate in minutes for passenger check-in, security screening, and pre-boarding wait time.

Delay is the average delay due to aircraft operations in minutes that is encountered at the airport.

CancPenalty is the average wait time in minutes due to cancellation of flights.

Taxi_out is the aircraft taxi-out time in minutes at the origin airport.

AirTime is the time in minutes the aircraft stays airborne.

Taxi_in is the aircraft taxi-in time in minutes at the destination airport.

BaggageClaim is the estimated time (in minutes) to deplane, locate and collect baggage.

TransferTime is the wait time in minutes to transfer to surface transportation to reach the destination.

Various airline websites were consulted to obtain the data of the minimum check-in time at various airports. It is observed that most of the airports required a 90 minute check in time. The details of the survey are presented in Table 4-2.

Table 4-2: Minimum Check-In Times at Various Airports.

Airport (Airport Code)	Processing time (Minutes)
Baltimore- Washington International Airport (BWI)	90
Charlotte Douglas Airport (CLT)	90
Chicago Midway Airport (MDW)	90
Cincinnati/Northern Kentucky International Airport (CVG)	90
Cleveland Hopkins Airport (CLE)	90
Dallas/Ft Worth International airport (DFW)	90
Detroit Metro Airport (DTW)	90
George Bush Intercontinental Airport(IAH)	60-90
Hartsfield Atlanta International Airport (ATL)	120
Houston William P Hobby Airport (HOU)	60-90
Jacksonville International Airport (JAX)	90
John F Kennedy International Airport (JFK)	90-120
La Guardia Airport (LGA)	120
Lambert-St Louis International Airport (STL)	120
Logan International Airport (BOS)	120
Long Beach/ Daugherty field airport (LGB)	90
Los Angeles International Airport (LAX)	90
Miami International Airport (MIA)	90-120
Nashville International Airport (BNA)	90
Newark International Airport (EWR)	90
Norfolk International Airport (ORF)	120
O’Hare International Airport (ORD)	90
Oakland International Airport (OAK)	90
Ontario International Airport (ONT)	90
Orlando International Airport (MCO)	120
Philadelphia International Airport (PHL)	120
Pittsburgh Airport (PIT)	120
Richmond International Airport (RIC)	90
Ronald Regan Washington National Airport (DCA)	120
San Francisco International Airport (SFO)	90
San Jose International Airport (SJC)	90
Tampa International Airport (TPA)	90
Washington Dulles International Airport (IAD)	120

Delay in aircraft operations has become an important issue of concern in recent past. Most of the airport system measures consider delay as important, because of its direct association with operational costs. Data for the delay, that includes both the arrival and departure delay at the airports are obtained from the On Time Performance Survey and used in the project. Delays at the airports are dependent on the operational characteristics at the airport like air traffic congestion; weather; infrastructure availability, etc., hence the average delays at various airports can be used for the analysis (rather than using average delay on specific routes). The delay characteristics at various airports are presented in Appendix B. The total delay is added into the travel time using the following equation. Since departure delay at origin airport leads for an arrival delay at destination, the affects of both is captured by taking the average of the absolute delay of delayed flights.

$$Delay = \left(\frac{AvgDelay_o \times \%Delay_o + AvgDelay_d \times \%Delay_d}{2} \right)$$

(Equation 4)

Where:

$AvgDelay_o$ is the average delay (in minutes) of the delayed flights at origin airport.

$AvgDelay_d$ is the average delay (in minutes) of the delayed flights at destination airport.

$\%Delay_o$ is the percentage of delayed flights at origin airport.

$\%Delay_d$ is the percentage of delayed flights at destination airport.

Flight cancellations lead to a lot of inconvenience to the air traveler. Flight cancellations can be due to many reasons like weather, excessive delay of arriving flight, mechanical problems, etc. It is assumed that if a flight is cancelled, the air traveler waits for the next flight. The waiting time for that flight varies, depending on the time of the day and the frequency of flights. In order to add a travel time penalty for flight cancellations, it is important to find out if the flights operate all throughout the day. Data of the time between the first and the last flight (say *h*) between 53 pairs of cities had been collected for analysis. It has been observed that in a day, the average time between the first and last flight, say h_{mean}, is equal to 12.198 hours and the variance is equal to 3.965 hours. Statistical test (*t-test)* proved that the mean value of *h* for the population is 12 hours with a 95% confidence.

The average percentage of cancelled flights, which is presented in Appendix C, has been used in the analysis, because travel between city pairs is considered and not one city as origin and the other as destination. A travel time penalty, added in the form of the following equation accounts for flight cancellations.

$$CancPenalty = 12 hours/day \times 60 \min/hr \times \frac{(\%Cancelled_o + \%Cancelled_d)}{(2 \times 100 \times FlightsPerDay)}$$

(Equation 5)

Where:

CancPenalty is the penalty due to cancellation in minutes.

$\%Cancelled_o$ is the percentage of cancelled flights at origin airport.

$\%Cancelled_d$ is the percentage of cancelled flights at destination airport.

FlightsPerDay is the number of flight operations between the origin and destination airport in a day.

The average taxi-in and taxi-out times are calculated using the data from the on time performance survey. These values are used in Equation 3. The average values as calculated from the survey are presented in Appendix D.

Since there is no readily available measure for baggage collection times and the wait time to transfer to another mode, it is assumed that these activities consume 30 minutes.

This methodology estimates the door to door travel times between cities in the presence of direct flights. In cases when direct flights are not available to serve the origin-destination pairs the estimates of the mobility measures should consider the route with one or more stop(s) at intermediate airport(s). Hence the above mentioned methodology is modified to estimate the travel times in the presence of connecting flights, waiting time, cancellations and delays at intermediate airports(s); in addition to those at the origin and destination regions.

Since there are many possible routes between a pair of cities, the routes with a ridership greater than 1% of the total ridership between region pairs have been chosen for analysis. The travel times by direct flights and flights with one or more stops have been consolidated into a single time-measure by weighting them with respect to the frequencies as shown in Equation 6.

$$Travel\_Time\_Measure_{O,D} = \frac{\sum_{\forall c,o,d}\left(T_{Direct,c,o,d} \times f_{direct,c,o,d} + \sum_{\forall i}(T_{i,c,o,d} \times Min(f_{o,i,c}, f_{i,d,c})\right)}{\sum_{\forall c,o,d}\left(f_{Direct,c,o,d} + \sum_{\forall i} Min(f_{o,i,c}, f_{i,d,c}\right)}$$

(Equation 6)

Where:

$T_{Direct,c,o,d}$ is the travel time in minutes by direct flight between the origin airport, *o* and destination airport, *d* using flight carrier, *c*.

$f_{Direct,c,o,d}$ is the frequency of direct flights by carrier *c*, between the origin airport, *o* and destination airport, *d* expressed as flights per day.

$T_{i,c,o,d}$ is the travel time in minutes using a carrier, *c* via an intermediate stop *i*, between the origin destination airport pair *(o-d)*.

$f_{o,i,c}$ is the frequency of flights of carrier, *c*; expressed in flights per day between the origin airport, *o* and intermediate airport ,*i*.

$f_{i,d,c}$ is the frequency of flights of carrier, c; expressed in flights per day between the intermediate airport, *i* and the destination airport, *d*.

$Travel\_Time\_Measure_{O,D}$ is the measure of travel time in minutes between the city pairs *O and D*.

4.3.3 Door to door Travel Cost Estimation by Air

4.3.3.1 Components of the Door to Door Travel Costs by Air

Travel cost is estimated by identifying and estimating the various components that make up the cost. The various components are mentioned below

- Cost of travel from downtown to airport at origin (Land side costs)
- Cost of origin airport parking (Land side costs)
- Airfare (Air side costs)
- Cost of travel from airport to downtown at destination (Land side costs).

4.3.3.2 Data and Information Sources

4.3.3.2.1 *American automobile association*

American Automobile Association (AAA) analyzes automobile driving costs every year. The study includes vehicles equipped with standard and optional accessories including automatic transmission, air conditioning, power steering, power disc brakes, AM/FM stereo, driver and passenger side air bags, anti-lock brakes, cruise control, tilt steering wheel, tinted glass, emission equipment and rear-window defogger.

Information about the driving costs is published annually in AAA’s annual publication ‘Your Driving Costs’ [41]. The details of the costs as presented in the 2002 magazine are presented in Table 4-3. A cost of 50.2¢ per mile is used in this project.

Table 4-3: Ownership and Operating Costs Per Mile (Source[41]).

Miles run per year	Composite national average (cents)
10,000	62.3
15,000	50.2
20,000	45.1

4.3.3.2.2 *Airline origin and destination survey*

Details about this survey have been presented in Section 4.3.2.2.2 . Data about the airfares are obtained from this survey.

4.3.3.2.3 *Websites of various airports*

The websites of most of the airports present information about the airport parking costs and also the cost of hiring a taxi. Since the information about the driving costs is not available for all the airports, a regression equation is developed and used for application at those airports that lack this information. A linear regression model is developed from a set of 16 samples; it has an R^2 value of 0.885.

$$Taxi\_Cost(\$) = 9 + 1.53 \times Dist$$

(Equation 7)

Where:

Taxi_Cost is the cost of travel from downtown to airport in dollars.

Dist is the distance between downtown and airport in miles.

4.3.3.3 Estimation of Travel Cost

The total cost of travel by air is estimated as the sum of the land side and the air side costs. Since the travel cost between the region pairs is important (rather than one region as origin or destination), the average of the both the directional costs is considered.

$$Air\_Cost_{O,D} = \left(\frac{\sum_{i=O,D} (Downtown\_Airport_i + Parking_i + Taxi_i)}{2} \right) + AirFare_{O,D}$$

(Equation 8)

Where

$Air\_Cost_{O,D}$ is the total cost of travel by air between a city pair.

$Downtown\_Airport_i$ is the cost of travel between airport and downtown.

$Parking_i$ is the long term parking cost (for a week).

$Taxi_i$ is the estimated taxi fare between airport and downtown.

$AirFare_{O,D}$ is the average air fare for travel between cities.

If there are more than one airports serving the regions under consideration the costs can be estimated by taking a weighted average of the individual costs with respect to ridership on that route.

4.3.4 DOOR TO DOOR TRAVEL TIME AND COST ESTIMATION BY CAR

4.3.4.1 Travel Time Estimation

Travel time is estimated by using the average speeds and distance of travel between the cities. Delays from the annual mobility report are added to account for congestion that occurs along the trip. The estimate of travel time is calculated using the following equation.

$$Auto\_Travel\_Time_{O,D} = Traveltime_{O,D} + Delay_O + Delay_D$$

(Equation 9)

Where,

$Auto\_Travel\_Time_{O,D}$ is total travel time in minutes between the origin and destination region centers.

$Traveltime_{O,D}$ is the travel time in minutes between downtowns of cities calculated considering the speed limits.

$Delay_O$ is the delay in minutes that is incurred by the traveler at the origin.

$Delay_D$ is the delay in minutes that is incurred by the traveler at destination.

4.3.4.2 Travel Cost Estimation

The cost per mile information given by the American Automobile Association's 'Your Driving Costs' (Section 4.3.3.2.1) is used to estimate the cost of travel by car.

4.4 CONSOLIDATION OF TRAVEL TIMES AND COSTS (STEP 3)

The second step in the methodology estimates the travel times and costs between the *home region* and various *outside regions* selected in the first step. The estimation of the mobility measures when there is a change in service is accomplished in this step. Ease of understanding demands the affects of changes in air service on the travel time and cost estimates to be presented in a very simple way, hence this step also consolidates the output after capturing the affects of changes in air service.

The changes in air service have been captured in the form of increase/decrease in the number of flights connecting the region pairs. The next section provides the modifications applied to the methodology in order to capture these changes.

4.4.1 Travel Time and Travel Cost Estimates After Changes in Air Service

4.4.1.1 Travel Time Estimates

Business passengers tend to use non-stop flights in their business trips. Hence the travel times in the normal situations would be the non-stop air travel time measure. But when an airline moves out from the *home region*, three possible scenarios may occur:

- *No Major Change:* There can possibly exist, more than one non-stop service providers that provide air services between regions under consideration. Loss of a service might not affect the performance in a major way because of existence of other services.
- *Loss of non-stop flights*: Region pairs are connected by some non-stop flights and by some connecting flights. When a non-stop service is lost because of an airline moving out, travel time estimates have to consider the stops at intermediate locations. This travel time can be estimated using (Equation 6.

- *Loss of Connectivity*: It is possible that some city pairs are served only by a single air carrier. Loss of airline can lead to the loss of air connectivity between those cities. In these cases it has been assumed that the business passenger drives to the nearest airport with service to the same destination and use those services.

If *I* represents the region where the business traveler is boarding the aircraft, *O* the origin region and *D*, the destination region; the travel time between *O* and *D* via *I* is estimated using the following equation:

$$TravelTime_{O,D} = \left(AirTravelTime_{I,D} - AirportAccess_{I}\right) + Delay_{O} + DriveTime_{O,I}$$

(Equation 10)

Where,

$TravelTime_{O,D}$ is the door to door air travel time between the origin region (O) and the destination region (D) via intermediate region (I) .

$AirTravelTime_{I,D}$ is the door to door air travel time between regions *I* and *D* calculated using (Equation 1.

$AirportAccess_{I}$ is the Access time from the downtown of region *I* to the airport at *I.* This is equal to the product of un-congested travel time between downtown & airport and the Travel time index of the intermediate region.

$Delay_{O}$ is the delay at the origin city as obtained from the mobility report.

$DriveTime_{O,I}$ is the driving time between the origin region's downtown and the intermediate airport calculated based on the average speeds.

When an airline moves in the estimation of the travel time is accomplished by changing the value of *FlightsPerDay* in (Equation 5.

4.4.1.2 Travel Cost Estimates

Airlines operate under competition and hence it would not be possible to estimate the airfares when there is a loss of air service. But one can estimate the costs of air travel when there is a complete loss of connectivity between region pairs.

If *I* represents the intermediate region where the business traveler is boarding the aircraft, *O* the origin region and *D*, the destination region; the travel cost between *O* and *D* via *I* can be estimated using the following equation.

$$TravelCost_{O,D} = Airfare_{I,D} + \left(\frac{TaxiFare_D + (Parking_D + AirportDowntown_D)}{2} \right) + \left(\frac{Parking_I + TaxiCharge_{I,O} + PrivateTravel_{I,O}}{2} \right)$$

(Equation 11)

Where,

$TravelCost_{O,D}$ is the total cost of travel between region *O* and region *D* via region *I*.

$Airfare_{I,D}$ is the air fare between the airports in regions *I* and *D*.

$TaxiCharge_D$ is the cost of hiring a taxi from the airport to the downtown at region D.

$Parking_D$ is the cost of weekly parking at the airport in region D.

$Parking_I$ is the cost of weekly parking at the airport in region I.

$AirportDowntown_D$ is the cost of travel on personal vehicle between the downtown of region D and the airport in the region.

$TaxiCharge_{I,O}$ is the cost of hiring a taxi from the airport in region I to the final destination in region D. This is estimated using (Equation 7.

$PrivateTravel_{I,D}$ is the cost of traveling on a persona vehicle between the airport of the intermediate region and the destination in the downtown.

4.4.2 CONSOLIDATION INTO A SINGLE MEASURE

4.4.2.1 Travel Time Measure

A single measure that captures the affects of changes in air service is formulated for ease of understanding. This measure which captures the effects of changes in air service is addressed as *Performance Time Index*. *Performance Time Index* is calculated using the following equation.

$$PerformanceTimeIndex = \left[\frac{\sum_i \left(Ridership_i \times \left(\frac{Travel\_time_{NewScenario}}{Travel\_time_{PresentScenario}} \right) \right)}{\sum_i Ridership_i} \right]$$

(Equation 12)

Where,

PerformanceTimeIndex is the index that measures the affects of various externalities on the mobility.

$Ridership_i$ is the air ridership between the home region and region *i*.

$Travel\_time_{NewScenario}$ is the estimate of travel time that incorporates the change in air services.

$Travel\_time_{PresentScenario}$ is the estimate of travel time under the current circumstances.

The *Performance Time Index* is a positive dimensionless number with theoretical value ranging from zero to infinity. But it is observed that in the value of the *Performance Time Index* would not be greater than two, for travel between medium distances. *Performance Time Index* provides a comparison between the aviation travel times during the present circumstances to the travel times in the new circumstances (change in service). *Performance Time Index* of a value less than one implies an increased mobility because of the reduced travel times. *Performance Time Index* of a value greater than one implies reduced mobility because of increased travel times.

4.4.2.2 Travel Cost Measure

Section 4.4.1.2 describes the methodology to estimate the cost of air travel when there is a change in the air service. In order to consolidate cost into a single measure, the ratio of travel costs is weighed with respect to the ridership. This measure is called the *Performance Cost Index* which is calculated using the following equation.

$$PerformanceCostIndex = \left[\frac{\sum_i \left(Ridership_i \times \left(\frac{TraveCost_{i,NewScenario}}{TravelCost_{i,PresentScenario}} \right) \right)}{\sum_i Ridership_i} \right]$$

(Equation 13)

Where,

PerformanceCostIndex is the consolidated measure of the change in air travel costs for travel from the region.

$Riderhship_i$ is the ridership from *home region* to *outside region, i.*

$TravelCost_{i,NewScenario}$ is the travel cost in the new scenario for travel between region pair *i*.

$TravelCost_{i,PresentScenario}$ is the travel cost in the present scenario for travel between region pair *i*.

Similar to the *Performance time index* the *Performance cost index* can theoretically range from zero to infinity. But in reality the *Performance cost index* would not be greater than three. An index greater than one, would imply an increase in the cost of travel from the region which would imply a reduced mobility. Whereas an index less than one would imply reduced costs of travel thereby implying increased mobility.

4.5 CONCLUSION

This chapter presented the three step methodology that has been developed to measure the mobility of a region. Methodology has also been proposed to capture the affects of change in air services.

Simplified measures called the *Performance Time Index* and *Performance Cost Index,* which capture the affects of changes in air service, have been proposed. Synonymous to the modulus of elasticity (in the field of material science), which depends on the properties of a material, these indices reflect the characteristics of the air transportation system serving a region.

CHAPTER 5: CASE STUDIES

5.1 INTRODUCTION

This chapter presents the application of the first step of the methodology. Section 5.2 presents an overview of the Aviation System in Virginia. Section 5.3 presents the logical explanation of how the case studies were selected for demonstrating the applicability of the methodology. The descriptions of various regions and the demonstration of the first step in the application of the proposed methodology is presented in sections 5.4, 5.5 and 4.6.

5.2 AVIATION SYSTEM IN VIRGINIA – AN OVERVIEW

Virginia's air transportation system is one of the most advanced and sophisticated in the country. More than 97 percent of Virginia's population has convenient access to one of Virginia's nine Commercial Service (CS) airports or 59 General Aviation (GA) airports [20].

Virginia Department of Aviation which was established on July 1, 1979 is the state agency responsible for aviation programs in Virginia. Virginia Department of Aviation is a state transportation agency along with the Virginia Department of Transportation, Division of Motor Vehicles, Department of Rail and Public Transportation, Motor Vehicle Dealer Board, and Virginia Port Authority; whose mission is to [42]:

- Cultivate an advanced, market driven aviation system that is safe, secure and provides for economic development;
- Promote aviation awareness and education; and
- Provide executive flight services for the Commonwealth Leadership

Airport Classifications serve as a framework for describing the existing function of each airport in the system and as the reference for evaluating how system airports have changed their functions or are projected to change their functions as a result of accommodating forecast demand. The following subsections give details about how the airports are classified.

5.2.1 Airport Classification – Based on Use

This classification framework is based on the method in which the airports are used. Table 5-1 presents the details of the number of airports by the classification category in the Virginia.

Table 5-1: Number of Airports in Virginia by Category

Classification category	Number of airports
Commercial service	9
Reliever airports	7
General aviation (regional)	17
General aviation (community)	16
Local service	17

Details about the operating characteristics of various categories of airports are given in Table 5-2. The locations of all the airports in the Commonwealth of Virginia and the areas served by them have been presented in Figure 5-1 and Figure 5-2.

Table 5-2: Airport Classification Based on Use (Source [21])

	Commercial Service (CS)	Reliever (RL)	General Aviation – Regional (GR)	General Aviation – Community (GC)	Local Service (LO)
Service Role	Provide scheduled commuter and/or air carrier service to surrounding communities.	Provide alternative GA facilities to reduce congestion at commercial service airports.	Provide a full range of aviation facilities and services to business and recreational users in a broad market area. Service areas are often multi-jurisdictional due to geographic isolation or the relative scarcity of other airport services and facilities.	Provide GA facilities and services to business and recreational users. Community airports typically serve a limited market area.	Provide limited facilities to their respective communities. Substantial expansion is typically precluded by development constraints such as airspace conflicts, environmental concerns, topography, competing services, surrounding land-use patterns and ownership status.
Funding Eligibility	Entitlement as well as air carrier/reliever discretionary funding	Air carrier/reliever discretionary funding	GA discretionary funding	GA discretionary funding	GA discretionary funding - safety and preservation projects only
Market Area	Metropolitan area	Metropolitan area, Relieves CS Airport	Regional market area serving multiple jurisdictions, isolated from other GR airports, convenient access	Community market area, access to a separate GR, RL or CS airport	Local market area
Activity level and mix	Provides scheduled airline service	25,000 annual operations, 50 based A/C with jets, 500 annual jet operations	10,000 annual operations, 25 Based A/C with jets, 100 jet operations	5,000 annual operations, 10 based A/C, 50 jet operations	Low activity levels
Recommended facility attributes	5,500 x 150 runway, parallel taxiway, precision approach	5,500 x 100 runway, parallel taxiway, precision approach	5,500 x 100 runway, non-precision approach	3,100 x 75 runway, non-precision approach	3,000 x 50 runway, visual approach
Available services	Jet fuel and Av.Gas, major maintenance, hangars, passenger terminal, rentals, training, charters	Jet fuel and Av.Gas, major maintenance, hangars and GA terminal, rentals, training, charters	Jet fuel and Av.Gas, minor maintenance, hangars and GA terminal, rentals, training, charters	Av.Gas sales, rentals, training, charters	Limited services
Development/ constraints	No significant constraints	No significant constraints	No significant constraints	No significant constraints	Environmental, airspace, or topographic constraints/ownership status.

Figure 5-1: Location of Various Airports in the Commonwealth of Virginia (Year: 2001) (Source [21])

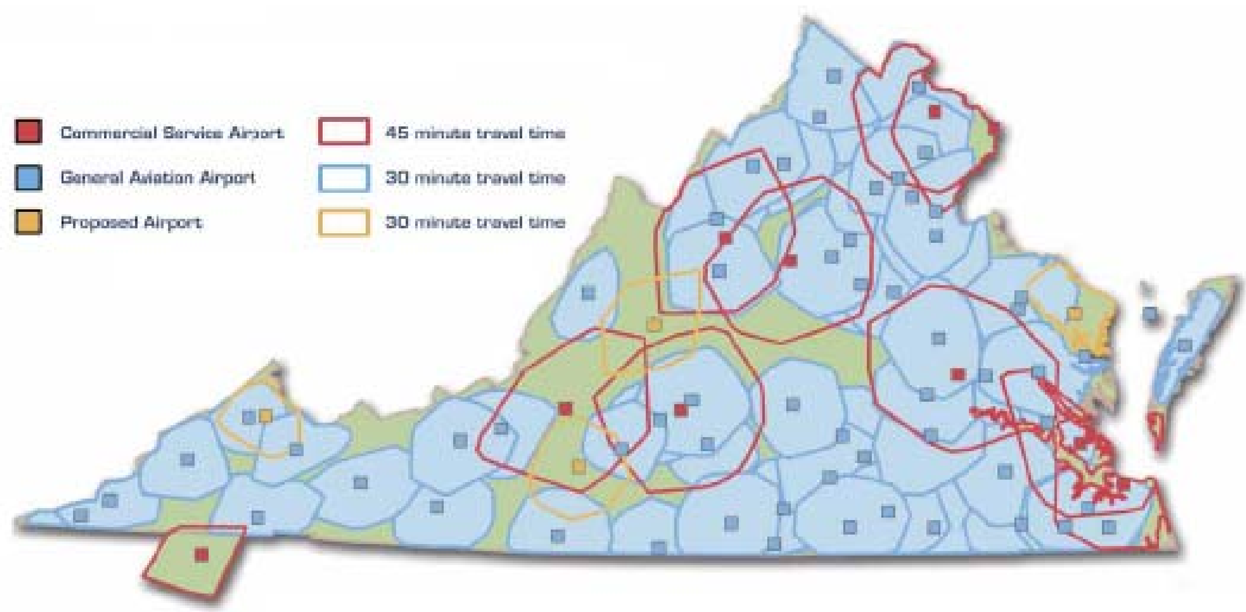

Figure 5-2: Regions Served by Commercial Service and General Aviation Airports (Source [21])

5.2.2 AIRPORT CLASSIFICATION – BASED ON ENPLANED PASSENGERS

This airport classification is based on the number of enplaned passengers. This classification is widely used in all the federal and state aviation agencies. The following table presents the details about the basis for these classifications [43].

Table 5-3: Airport Classification Based on Number of Enplaned Passengers.

Hub category	Percent of total enplaned passengers	Number of enplaned passengers (2000)
Large (L)	1.00 or more	Greater than 6,389,029
Medium (M)	0.25 to 0.99	1,597,257 to 6,389,029
Small (S)	0.05 to 0.249	319,451 to 1,597,257
Non Hub (N)	Less than 0.05	Less than 319,451

Figures for the number of enplaned passengers have been obtained from the year 2000's statistics of the total enplaned revenue passengers. The term 'hub' used in this table is the designated *geographic area* based on the percentage of total passengers enplaned in that area. A hub can have more than one airport in it. This is not the 'hub' referred to in hub-and-spoke model of the airline operations.

5.3 CASE STUDIES – SELECTION OF URBAN REGIONS

5.3.1 AIRPORT CHARACTERISTICS

The scope of this project is limited to the operations of airports served by regular commercial service, hence only the airports under the category of CS (Table 5-2) are considered. Table 5-4 presents details about various commercial service airports present in Virginia. Information about the number of passengers enplaned in the year of 2000 has also been presented in this table.

Table 5-4: Commercial Service Airports in Virginia.

Airport Name (Code)	Geographic Location	Population of region served (Census 2000)	Enplaned passengers in 2000 (Source [44])
Shenandoah Valley Regional (SHD)	Weyers Cave VA	43,004	21,113
Lynchburg Regional Airport (LYH)	Lynchburg VA	65,111	82,459

<table>
<tr><th>Airport Name (Code)</th><th>Geographic Location</th><th>Population of region served (Census 2000)</th><th>Enplaned passengers in 2000 (Source [44])</th></tr>
<tr><td>Charlottesville – Albemarle Airport (CHO)</td><td>Charlottesville VA</td><td>135,152</td><td>165,938</td></tr>
<tr><td>Newport news - Williamsburg international (PHF)</td><td>Williamsburg VA</td><td rowspan="2">1,615,853</td><td>227,635</td></tr>
<tr><td>Norfolk International (ORF)</td><td>Norfolk VA</td><td>1,518,552</td></tr>
<tr><td>Roanoke Regional (ROA)</td><td>Roanoke VA</td><td>180,689</td><td>364,202</td></tr>
<tr><td>Richmond International (RIC)</td><td>Richmond VA</td><td>914,600</td><td>1,330,487</td></tr>
<tr><td>Ronald Regan Washington National (DCA)</td><td>Arlington VA</td><td rowspan="2">-na-</td><td>7,517,811</td></tr>
<tr><td>Washington Dulles International (IAD)</td><td>Chantilly VA</td><td>9,643,275</td></tr>
</table>

As it can be observed from Table 5-4, there are limited number of hubs in Virginia. Bureau of Transportation Statistics listed out the following regions (Table 5-5) as the hubs that are served by Virginia's airports.

Table 5-5: Regional Hubs & Commercial Service Airports Serving those Hubs

<table>
<tr><th>Hubs (Regions)</th><th>Hub Category</th><th>Airports Serving the hub (Airport Code)</th></tr>
<tr><td rowspan="2">Washington DC</td><td rowspan="2">Large</td><td>Washington Dulles International (IAD)</td></tr>
<tr><td>Ronald Regan Washington National (DCA)</td></tr>
<tr><td>Richmond VA</td><td>Small</td><td>Richmond International (RIC)</td></tr>
<tr><td>Norfolk/ Virginia Beach/ Portsmouth/ Chesapeake, VA</td><td>Small</td><td>Norfolk International (ORF)</td></tr>
</table>

5.3.2 Selection of Regions

In order to examine the affects of air service changes on regions of different sizes, the methodology has been applied to three regions of different sizes. The application of the methodology is relevant for regions served by medium or small sized airports, because these airports facilitate regional economic development, rather than directly contributing to development. It can be observed from Table 5-5 that the populations of these small sized hubs vary. Hence the working of this methodology is demonstrated by application to the regions served by the two small hubs listed in Table 5-5 (Richmond and Hampton Roads).

When compared to the airports serving hub regions, the airports serving the non-hub regions have limited air services because of the low passenger volumes. Hence changes in air services might have greater impact on the *Interregional mobility* of non-hub regions. The list of airports serving non-hub regions, and the data availability characteristics of those airports have been presented in Table 5-6.

Table 5-6: Virginian Non-Hub Region Characteristics.

Airport(s) serving the region	Passengers Enplaned (2000)	Data Availability	
		2002	2005
Shenandoah Valley Regional	21,113	X	X
Lynchburg Regional Airport	82,459	X	✓
Charlottesville – Albemarle Airport	165,938	X	✓
Newport news – Williamsburg Intl.	227,635	X	✓
Roanoke Regional	364,202	X	✓

Proximity of the Charlottesville Albemarle Airport to the University of Virginia, (where this research is conducted) promoted interaction with the airport officials to obtain information about the airport operational characteristics. It can also be observed from Table 5-5 that the population of the Charlottesville Albemarle region is many times less when compared to Richmond or Hampton roads region. Hence the Charlottesville – Albemarle region which is served by Charlottesville Albemarle airport is chosen as the third case study.

5.4 CASE STUDY 1 – RICHMOND

5.4.1 BACKGROUND

The City of Richmond is the capital of the commonwealth of Virginia. It is also an independent city in Virginia. As the capital of Virginia, Richmond is home to the state legislature and a growing number of Fortune 500 companies and industries ranging from finance to agriculture. Forbes magazine ranked Richmond, as the 14th best place for business and careers because of its highly educated labor force and low business costs [46].

Greater Richmond region includes the City of Richmond and Chesterfield and the counties of Hanover and Henrico counties. The population of these regions according to the 2000 census is presented in Table 5-7. It can be observed from the table that there is an expected growth of population in the Richmond region and hence loss of air service will have an adverse affect on the business preferences in the long term. This region has been considered as a 'Small sized hub' according to the BTS classification. The downtown of the city of Richmond is considered as the origin or destination point for the trips associated with the region.

Table 5-7: Demographic Characteristics of Richmond

Geographic Area	Population (2000)	Population (2010)
City of Richmond	197,790	191,600
City of Chesterfield	259,903	316,000
Hanover	86,320	106,000
Henrico	262,300	301,000
Total	806,313	914,600

Lying at the junction of east-west Interstate-64 and north-south Interstate 95, two of the most heavily traveled highways in the state, and along several major rail lines, Richmond benefits from an excellent position in reference to the state's transportation network.

The Richmond International airport (RIC) which provides air connectivity to the region is located seven miles from the downtown of Richmond. The airport is served by seven airlines with non-stop flights to 21 destinations and connecting flights to destinations worldwide. In 2004, the airport served approximately 2.5 million passengers. Ground transportation services at the airport include rental car services, taxi services, courtesy shuttles and buses.

5.4.2 Selection of Regions for Analysis

In order to select the *outside regions* (Defined in Section 4.1.1) for analysis, the characteristics of various regions around Richmond are collected and listed out in Table 5-8. According to the guidelines set in the first step of the methodology (Section 4.2.3), the travel pairs have been selected for analysis. The selections have been mentioned in the last column of the table.

Table 5-8: Characteristics of Regions around Richmond.

Region	Distance from Richmond (miles)	Commercial air service data availability	Presence of Business Passengers (Air) [From ATS 1995]	Selection for Analysis
Washington DC	106	X	✓	X
Baltimore, MD	153	X	✓	X
Raleigh, NC	169	X	X	X

Region	Distance from Richmond (miles)	Commercial air service data availability	Presence of Business Passengers (Air) [From ATS 1995]	Selection for Analysis
Philadelphia, PA	252	✓	✓	✓
Charlotte, NC	295	✓	✓	✓
New York, NY	341	✓	✓	✓
Pittsburgh, PA	343	✓	✓	✓
Charleston, SC	427	X	X	X
Atlanta, GA	535	✓	✓	✓
Boston, MA	555	✓	✓	✓
Cincinnati, OH	571	X	X	X
Jacksonville, FL	599	✓	✓	✓

5.5 CASE STUDY 2 – HAMPTON ROADS

5.5.1 BACKGROUND

Hampton Roads is the region in the south east of Virginia that stretches from the banks of the Atlantic Ocean, northwestward across the Chesapeake Bay to Williamsburg. The region is filled with a labyrinth of waterways with the Chesapeake Bay and James River dividing the area into two distinct landmasses – referred to as south side and peninsula. One bridge and two bridge-tunnels link the Southside to the peninsula. The region hosts a strong military, shipbuilding and seaport and is a major east coast tourist destination. The region also houses 133 different companies representing 21 nations.

The land area includes most of the counties, cities and towns in the southeastern corner of Virginia. For statistical purposes the region is officially known as the Virginia Beach – Norfolk - Newport News, VA-NC Metropolitan Statistical Area. The details of various cities and counties, included in this region are presented in Table 5-9. The table also presents details about the population of various regions in Hampton roads as recorded in the census 2000. Projections of the population for the year of 2004 are also presented.

Table 5-9: Characteristics of Various Cities and Counties Constituting Hampton Roads Region.

	Geographic Area	Population (Census 2000)	Population (2004 Projected)
Counties	Gloucester	34,780	37,262
	Isle of Wight	29,728	32,744
	James city	48,102	55,502
	Mathews	9,207	9,226
	York	56,297	60,885
Cities	Chesapeake	199,184	214,725
	Hampton	146,437	145,951
	Newport News	180,150	181,913
	Norfolk	234,403	237,835
	Poquoson	11,566	11,700
	Portsmouth	100,565	99,291
	Suffolk	63,677	76,586
	Virginia Beach	425,257	440,098
	Williamsburg	11,998	11,465
Total		1,551,351	1,615,183

Though the Hampton Roads region is served by 2 major commercial airports Norfolk International Airport and Newport News/ Williamsburg International Airport, most of the air passenger and cargo transport use Norfolk International Airport. The downtown of the City of Norfolk has been used as the origin/ destination of travel associated with this region.

5.5.2 Selection of Regions for Analysis

In order to select the *outside regions* for analysis, the characteristics of various regions around Hampton Roads region are collected and listed out in Table 5-10.

According to the guidelines set in the first step of the methodology (Section 4.2.3), the travel pairs are selected for analysis. The selections are mentioned in the last column of the table.

Table 5-10: Characteristics of Regions around Hampton Roads.

Regions	Distance from Hampton Roads (miles)	Commercial air service data availability	Presence of Business Passengers (Air) [From BTS 1995]	Selection for Analysis
Raleigh, NC	182	X	X	X
Washington DC	194	✓	✓	X
Fayetteville, NC	223	X	X	X
Greensboro, NC	236	X	X	X
Baltimore, MD	241	✓	✓	X
Philadelphia, PA	271	✓	✓	✓
Charlotte, NC	327	✓	✓	✓
New York, NY	360	✓	✓	✓
Pittsburgh PA	431	✓	✓	✓
Albany, NY	508	X	✓	X
Columbus, OH	569	X	✓	X
Boston, MA	573	✓	✓	✓
Atlanta, GA	596	✓	✓	✓

5.6 CASE STUDY 3 – CHARLOTTESVILLE – ALBEMARLE REGION

5.6.1 BACKGROUND

The City of Charlottesville is located within the confines of Albemarle County in Central Virginia. The city is the county seat of the Albemarle County. The City of Charlottesville also houses the University of Virginia which is one of the biggest Universities in Virginia. The city of Charlottesville was ranked the best place to live in the United States in 2004 [47]. The city and county also accommodate various businesses and industries.

For statistical purposes the region of Albemarle County including the city of Charlottesville is officially known as the Charlottesville, VA Metropolitan Statistical Area (MSA). Details about the population in the region have been presented in Table 5-11. The population of this region is expected to increase in the next few years. Externalities like airlines moving out will impact the businesses and industries in the region and hamper the economic development.

Table 5-11: Population of Charlottesville MSA.

Geographic Area	Population (2000)	Projected Population (2010) (Source [45])
City of Charlottesville	39,162	39,650
Albemarle county	79,236	96,502
Total	118,398	135,152

Three major highways, US-29, US-250 and I-64 provide highway access to this region. The region is also connected by rail services provided by Amtrak. Charlottesville-Albemarle airport provides commercial and general aviation services to this region. The downtown of the City of Charlottesville is chosen as the origin/destination of the travelers originating in this region.

5.6.2 SELECTION OF REGIONS FOR ANALYSIS

In order to select the *outside regions* for analysis, the characteristics of various regions around Charlottesville region are collected and listed in Table 5-12. According to the guidelines set in the methodology (Section 4.2.3), the travel pairs have been selected for analysis. The selections have been mentioned in the last column of the table.

Table 5-12: Characteristics of Regions around Charlottesville.

Regions	Distance from Hampton Roads (miles)	Commercial air service data availability	Selection for Analysis
Philadelphia, PA	253	✓	✓
Charlotte, NC	304	✓	✓
Pittsburgh PA	317	✓	✓
New York, NY	342	✓	✓
Atlanta, GA	544	✓	✓
Boston, MA	557	✓	✓

5.7 CONCLUSIONS

The chapter presented the description of various case studies that have been used to demonstrate the applicability of the proposed methodology. Two small sized hub-regions (Richmond and Hampton Roads) and a non-hub region (Charlottesville-Albemarle region) are selected to demonstrate the working of the methodology. The working of the first step of the developed methodology is also presented in this chapter

CHAPTER 6: RESULTS

6.1 INTRODUCTION

This Chapter presents the results from the application of the second and third steps in the methodology. Section 6.2 presents the application of the second and third steps of the methodology. Section 6.3 presents the summary of the results and, Section 6.4 presents the discussion of the results and the implications to the state department of aviation.

6.2 ESTIMATION OF TRAVEL TIMES AND TRAVEL COSTS

Estimates of the travel time and travel costs are made according to the methods presented in Chapter 3. The three subsections below present the analysis for the case studies.

6.2.1 CASE STUDY 1: RICHMOND

6.2.1.1 Estimates of Aviation Mobility Measures under Normal Conditions

A list of various flights that provide services between Richmond International airport and *outside regions* considered for analysis is presented in Table 6-1. Flight routes with a ridership greater than 1% of the total ridership between regions are considered in the analysis.

Table 6-1: Air Services Serving Richmond in 2002.

Region	Routing details (Direct/ Via)	Airline details	Ridership (ATS 1995)	Eligible for analysis
Atlanta	Direct	Delta	2431	✓
	CLT	US Airways	206	✓
	IAD	United airlines	36	✓
	PHL	US Airways	28	✓
	DTW	Northwest	8	X
	CLE	Continental	8	X
	Others*	Various carriers	210	X
	Total		*2891*	
Charlotte	Direct	US Airways	858	✓
	ATL	Delta	12	✓
	Others *	Various carriers	29	X
	Total		899	
New York (LGA)	Direct	US Airways	1497	✓
	Direct	Delta	798	✓
	PHL	US Airways	46	✓
	Others*	Various carriers	66	X
	Total		*2407*	
New York (EWR)	Direct	Continental	931	✓
	Direct	US Airways	213	✓
	PIT	US Airways	17	✓
	Others*	Various carriers	39	X
	Total		*1200*	
Philadelphia	Direct	US Airways	1045	✓
	BWI	US Airways	6	X
	Others*	Various carriers	9	X
	Total		*1069*	
Pittsburgh	Direct	US Airways	692	✓
	BWI	US Airways	5	X
	DTW	Northwest	10	X
	Others*	Various carriers	26	X
	Total		*733*	
Boston	Direct	American airlines	726	✓
	Direct	US Airways	853	✓
	CLT	US Airways	18	X
	IAD	United airlines	81	✓
	LGA	US Airways	74	✓
	PHL	US Airways	109	✓
	PIT	US Airways	18	X
	Others*	Various airlines	132	X
	Total		*2011*	

Region	Routing details (Direct/ Via)	Airline details	Ridership (ATS 1995)	Eligible for analysis
Jacksonville	Direct	US Airways	34	✓
	ATL	Delta	308	✓
	CLT	US Airways	333	✓
	CVG	Delta	33	✓
	PHL	US Airways	22	✓
	Others*	Various airlines	29	X
	Total		*759*	

*Others – Refers to routes that accounted for ridership less than 5 in the survey.

Travel time estimates are made based on the information presented in Table 6-1 (Travel time estimation methodology is described in Section 4.3.2). The estimates for *Interregional Mobility* measures of Richmond by air are presented in Table 6-2.

Table 6-2: Estimates of *Interregional Mobility* by Air (Normal Operations) for Richmond.

Region	Travel Time Estimate (minutes)		Travel Cost Estimate, $ (Ground access cost, %)
	Total time	Ground access time (% of total)	
Atlanta	269	42 (15%)	294 (27%)
Charlotte	230	36 (16%)	415 (14%)
Philadelphia	238	42 (18%)	341 (24%)
Pittsburgh	256	44 (17%)	324 (25%)
Boston	250	30 (12%)	301 (31%)
New York	258	40 (16%)	293 (31%)
Jacksonville	245	44 (18%)	223 (32%)

6.2.1.2 Estimates of Highway Mobility Measures

The estimates of *Interregional Mobility* measures for Richmond by automobile are presented in Table 6-3. The table also presents the ratio of the highway travel time to the aviation travel times under the present circumstances.

Table 6-3: *Interregional Mobility* Estimates of Richmond by Automobile.

Region	Travel Time Estimate (minutes)	Travel Cost Estimate (Dollars)	Highway Travel Time/ Air Travel Time
Atlanta	605	268	2.2490
Charlotte	355	148	1.5435
Philadelphia	310	126	1.3025
Pittsburgh	364	172	1.4218
Boston	612	279	2.448
New York	399	171	1.5465
Jacksonville	637	302	2.6

6.2.1.3 Estimates of Aviation Mobility Measures for Changes in Air Service

The methodology that is proposed in Section 4.4.1 , is used to analyze the affects of changes in air service. The results are presented in this section.

6.2.1.3.1 *Loss of air services.*

This affects of changes in air services because of an airline moving-out of Richmond International airport is presented in this section. The mobility measures are calculated and presented in Table 6-4.

Table 6-4: Estimates of *Interregional Mobility* by Air (Loss of Service) for Richmond.

Region	Travel Time Estimate (minutes)	Travel Cost Estimate (Dollars)
Atlanta	269	Na
Charlotte	427	Na
Philadelphia	333*	386
Pittsburgh	334*	381
Boston	255	Na
New York	259	Na
Jacksonville	450	Na

* There is 'loss of connectivity' in these cases (see Section 4.4.1.1). It has been assumed that the air traveler uses services from Charlottesville-Albemarle airport because of unavailability of alternate air services directly from Richmond.

The *Performance Time Index* and the *Performance Cost Index* as defined in Section 4.4.2 , are calculated using (Equation 12 & (Equation 13 and presented in Table 6-5 and Table 6-6.

Table 6-5: Performance Time Index Calculation for Richmond (Loss of Air Service)

Region	Travel Time Estimate (Normal Operations) [2]	Travel Time Estimate (Airline Moves-Out) [3]	[3]/[2]	Ridership
Atlanta	269	269	1	2891
Charlotte	230	427	1.8565	899
Philadelphia	238	333*	1.3991	1060
Pittsburgh	256	334*	1.3046	733
Boston	251	255	1.0159	2011
Jacksonville	245	450	1.8367	759
New York City	258	259	1.0038	3607
Performance Time Index			**1.1753**	

* - Loss of Connectivity; Alternate origin airport – Charlottesville Albemarle Airport

Table 6-6: Performance Cost Index Calculations (Loss of Air service) for Richmond

City	Costs (Normal Operations) [2]	Costs (Airline Moves Out) [3]	Ratio of costs [3]/[2]
Philadelphia	$341	$386	1.13
Pittsburgh	$324	$381	1.18
Performance Cost Index		**1.0226**	

6.2.1.3.2 <u>*Addition of new service*</u>

This section presents the affects on mobility of business passengers in Richmond because of an introduction of new service at the Richmond International airport. It is assumed that the new air service provider provides three flights per day between all the region pairs considered in the analysis. Calculations of the Performance time index are presented in Table 5-7.

Table 6-7: Performance Time Index Calculation for Richmond (Introduction of New Service)

Region	Travel Time Estimate (Normal Condition) [2]	Travel Time Estimate (New Service) [3]	[3]/[2]	Ridership
Atlanta	269	269	1	2891
Charlotte	230	230	1	899
Philadelphia	238	236	0.9915	1060
Pittsburgh	256	252	0.9843	733
Boston	251	247	0.9840	2011
Jacksonville	245	244	0.9959	759
New York City	258	257	0.9961	3607
Performance Time Index			**0.9941**	

6.2.1.4 Highway vs Aviation Travel Times

A comparison of the automobile travel times and the aviation travel times under different circumstances (Current operations and Loss of airline) are presented in Table 6-8. The second column of the table presents the estimate of aviation travel time under the current operating conditions. The third column of the table presents the travel time estimates when an airline moves out. And the fourth column presents the highway travel time estimate under the present circumstances. In order to understand the affects of the loss of airline, the ratio of highway and aviation travel time estimates under the new circumstances is presented. The results are further discussed in Section 6.4.

Table 6-8: Comparison of Highway and Aviation Travel Times

Region	Air Travel Time Estimate (Present) [2]	Air Travel Time Estimate (Loss of Airline) [3]	Highway Travel Time Estimate [4]	Ratio of Travel times (Loss of service) [4]/[3]
Atlanta	269	269	605	2.2490
Charlotte	230	427	355	0.8313
Philadelphia	238	333	310	0.9309
Pittsburgh	256	334	364	1.0898
Boston	250	255	612	2.4

Region	Air Travel Time Estimate (Present) [2]	Air Travel Time Estimate (Loss of Airline) [3]	Highway Travel Time Estimate [4]	Ratio of Travel times (Loss of service) [4]/[3]
New York	258	259	399	1.5405
Jacksonville	245	450	637	1.4155

6.2.2 Case Study 2: Hampton Roads

6.2.2.1 Estimates of Aviation Mobility Measures under Normal Conditions

A list of various flights that provide services between Hampton Roads region and the *outside regions* considered for analysis is presented in Table 6-9. Flight routes with a ridership greater than 1% of the total ridership between regions are considered in the analysis.

Table 6-9: Air Services Serving Hampton Roads Region in 2002.

Region	Routing details (Direct/ Via)	Airline details	Ridership (ATS 1995)	Eligible for analysis
Atlanta	Direct	Delta	2475	✓
	CLT	US Airways	206	✓
	RIC	Delta	49	✓
	EWR	Continental	11	X
	IAD	United Airlines	12	X
	Others*	Various carriers	190	X
	Total		*2943*	
Charlotte	Direct	US Airways	717	✓
	ATL	Delta	11	✓
	RIC	US Airways	10	✓
	Others *	Various carriers	31	X
	Total		*769*	
New York (LGA)	Direct	American Eagle	2333	✓
	PHL	US Airways	31	✓
	DCA	US Airways	78	✓
	Others *	Various carriers	43	X
	Total		2485	
New York (EWR)	Direct	Continental	1017	✓
	RIC	Continental	11	✓

Region	Routing details (Direct/ Via)	Airline details	Ridership (ATS 1995)	Eligible for analysis
	Others *	Various carriers	38	X
	Total		*1066*	
Philadelphia	Direct	US Airways	1076	✓
	DCA	US Airways	16	✓
	RIC	US Airways	18	✓
	Others *	Various carriers	34	X
	Total		*1144*	
Pittsburgh	Direct	US Airways	783	✓
	DCA	US Airways	16	✓
	DTW	Northwest	17	✓
	PHL	US Airways	22	✓
	Others *	Various carriers	52	X
	Total		*890*	
Boston	Direct	American Eagle	858	✓
	Direct	US Airways	25	✓
	DCA	US Airways	244	✓
	LGA	US Airways	179	✓
	PHL	US Airways	265	✓
	Others *	Various carriers	290	X
	Total		*1861*	

*Others – Refers to routes that accounted for ridership less than 5 in the survey.

Travel time estimates are made based on the information presented in Table 6-9 (Travel time estimation methodology is described in Section 4.3.2). The estimates for *Interregional Mobility* measures of Hampton roads by air are presented in Table 6-10.

Table 6-10: Estimates of *Interregional Mobility* by Air (Normal Operations) for Hampton Roads.

Region	Travel Time Estimate (minutes)		Travel Cost Estimate,$ (Ground access cost, %)
	Total travel time	Ground access time (% of total time)	
Atlanta	276	43 (8%)	215 (39%)
Charlotte	236	38 (16%)	294 (21%)
New York	267	42 (16%)	257 (33%)
Philadelphia	239	44 (18%)	306 (28%)

Region	Travel Time Estimate (minutes)		Travel Cost Estimate,$ (Ground access cost, %)
	Total travel time	Ground access time (% of total time)	
Pittsburgh	253	45 (18%)	269 (32%)
Boston	270	31 (11%)	283 (34%)

6.2.2.2 Estimates of Highway Mobility Measures

The estimates of *Interregional mobility* measures for Hampton roads region by automobile are presented in Table 6-11. The table also presents the ratio of the highway travel time to the aviation travel times under the present circumstances.

Table 6-11: *Interregional Mobility* Estimates of Hampton Roads by Automobile.

Region	Travel Time Estimate (minutes)	Travel Cost Estimate (Dollars)	Highway Travel Time/ Air Travel Time
Atlanta	666	284	2.4130
Charlotte	424	164	1.7966
New York	460	179	1.7288
Philadelphia	403	136	1.6862
Pittsburgh	436	216	1.7233
Boston	704	288	2.6074

6.2.2.3 Estimates of Aviation Mobility Measures for Changes in Air Service

The methodology that has been proposed in Section 4.4.1 has been used to estimate the affects of changes in air service. The results are presented in this section.

6.2.2.3.1 *Loss of air services.*

The affects of change in air services because of an airline moving out of Norfolk international airport is presented in this section. The mobility measures have been calculated and presented in Table 6-12.

Table 6-12: Estimates of *Interregional Mobility* by Air (Loss of Service) for Hampton Roads.

Region	Travel Time Estimate (minutes)	Travel Cost Estimate (Dollars)
Atlanta	276	Na
Charlotte	429	Na
New York	267	Na
Philadelphia	360*	419
Pittsburgh	463	Na
Boston	271	Na

* There is 'loss of connectivity' in this case (see Section 4.4.1.1). It has been assumed that the air traveler uses services from Richmond International airport because of unavailability of alternate air services directly from Hampton Roads.

The *Performance Time Index* and the *Performance Cost Index* as defined in Section 4.4.2 , have been calculated using (Equation 12 & (Equation 13 and presented in Table 6-13 and Table 6-14.

Table 6-13: Performance Time Index Calculation for Hampton Roads (Loss of Air Service)

Region	Travel Time Estimate (Normal Operations) [2]	Travel Time Estimate (Airline Moves-Out) [3]	[3]/[2]	Ridership
Atlanta	276	276	1	2943
Charlotte	236	429	1.8177	769
New York	267	267	1	3551
Philadelphia	239	360*	1.5062	1144
Pittsburgh	253	463	1.8300	890
Boston	270	271	1.0037	1861
Performance Time Index			**1.1751**	

* - Loss of Connectivity; Alternate origin airport – Richmond International Airport

Table 6-14: Performance Cost Index Calculations (Loss of Air service) for Hampton Roads Region

City	Costs (Normal Operations) [2]	Costs (Airline Moves Out) [3]	Ratio of costs [3]/[2]
Philadelphia	$306	$419	1.37
Performance Cost Index		**1.0379**	

6.2.2.3.2 *Addition of new service*

This section presents the affects on mobility of business passengers in Hampton roads region because of the introduction of a new service from Norfolk International airport. It is assumed that the new air service provider provides three flights per day between all the region pairs considered in the analysis. Calculations of the Performance time index are presented in Table 6-15 .

Table 6-15: Performance Time Index Calculation for Hampton Roads (Addition of Service)

Region	Travel Time Estimate (Normal Condition) [2]	Travel Time Estimate (New Service) [3]	[3]/[2]	Ridership
Atlanta	276	275	1	2943
Charlotte	236	236	1	769
New York	267	257	0.9652	3551
Philadelphia	239	238	0.9958	1144
Pittsburgh	253	252	0.9960	890
Boston	270	268	0.9925	1861
Performance Time Index			**0.9861**	

6.2.2.4 Highway vs Aviation Travel Times

A comparison of the automobile travel times and the aviation travel times under different circumstances (current operations and Loss of airline) are presented in Table 6-16. The second column of the table presents the estimate of the aviation travel time under the current operation conditions. The third column of the table presents the estimate of the aviation travel time when an airline moves out of Richmond. The fourth column presents the highway travel time estimates. In order to understand the affects of the loss of airline, the ratio of highway and aviation travel time estimates under the new circumstances is presented. The results are further discussed in Section 6.4.

Table 6-16: Comparison of Highway and Air Travel Times

Region	Air Travel Time Estimate (Normal operations) [2]	Air Travel Time Estimate (Loss of Airline) [3]	Highway Travel Time Estimate [4]	Ratio of Travel times (Loss of Service) [4]/[3]
Atlanta	276	276	666	2.4130
Charlotte	236	429	424	0.9883
New York	267	267	460	1.7228
Philadelphia	239	360	403	1.1194
Pittsburgh	253	463	436	0.9416
Boston	270	271	704	2.5977

6.2.3 CASE STUDY 3: CHARLOTTESVILLE-ALBEMARLE

6.2.3.1 Estimates of Aviation Mobility Measures under Normal Conditions

A list of various flights that provide services between Charlottesville-Albemarle Airport and the *outside regions* considered for the analysis is presented in Table 6-17. Flight routes with a ridership greater than 1% of total ridership between regions are considered in the analysis

Table 6-17: Air Services Serving Charlottesville-Albemarle Region.

Region	Routing details (Direct/ Via)	Airline details	Ridership (ATS 1995)	Eligible for analysis
Boston	CVG	Delta	21	✓
	IAD	United Airlines	101	✓
	LGA	US Airways	30	✓
	PHL	US Airways	93	✓
	PIT	US Airways	117	✓
	Others*	Various carriers	10	X
	Total		*372*	
Atlanta	Direct	Delta	343	✓
	CLT	US Airways	78	✓
	CVG	Delta	12	✓
	IAD	United Airlines	22	✓
	PIT	US Airways	11	✓
	Others*	Various carriers	18	X
	Total		*484*	

Region	Routing details (Direct/ Via)	Airline details	Ridership (ATS 1995)	Eligible for analysis
Charlotte	Direct	US Airways	74	✓
	Others*	Various carriers	2	X
	Total		*76*	
New York (EWR)	PIT	US Airways	63	✓
	Others*	Various carriers	6	X
	Total		*69*	
New York (LGA)	IAD	United Airlines	15	✓
	Direct	US Airways	288	✓
	PHL	US Airways	18	✓
	PIT	US Airways	46	✓
	Others*	Various carriers	17	X
	Total		*384*	
Philadelphia	Direct	US Airways	123	✓
	PIT	US Airways	11	✓
	Others*	Various carriers	6	X
	Total		*140*	
Pittsburgh	Direct	US Airways	86	✓
	Others*	Various carriers	6	X
	Total		*96*	

*Others – Refers to routes that accounted for ridership less than 5 in the survey.

Travel time estimates are made based on the information presented in Table 6-17 (Travel time estimation methodology described in Section 4.3.2). The estimates for *Interregional Mobility* measures of Charlottesville Albemarle by air are presented in Table 6-18.

Table 6-18: Estimates of *Interregional mobility* by Air (Normal Operations) for Charlottesville Albemarle Region.

Region	Travel Time Estimate (minutes)		Travel Cost Estimate, $ (Ground access cost, %)
	Total Travel time	Ground access time (% of total time)	
Atlanta	276	42 (15%)	252 (33%)
Charlotte	245	36 (15%)	285 (21%)
New York	277	40 (14%)	304 (27%)
Philadelphia	254	42 (17%)	315 (27%)
Pittsburgh	255	43 (17%)	310 (27%)

Region	Travel Time Estimate (minutes)		Travel Cost Estimate, $ (Ground access cost, %)
	Total Travel time	Ground access time (% of total time)	
Boston	477	29 (06%)	271 (35%)

6.2.3.2 Estimates of Highway Mobility Measures

The estimates of *interregional mobility* measures for Charlottesville Albemarle region by automobile are presented in Table 6-19. The table also presents the ratio of the highway travel time to the aviation travel times under the present circumstances.

Table 6-19: Estimates of *Interregional Mobility* Measures for Charlottesville Albemarle Region

Region	Travel Time Estimate (minutes)	Travel Cost Estimate (Dollars)	Highway Travel Time/ Air Travel Time
Atlanta	588	273	2.1304
Charlotte	340	153	1.3877
New York	427	172	1.5415
Philadelphia	333	127	1.3110
Pittsburgh	348	159	1.3372
Boston	655	280	1.3732

6.2.3.3 Estimates of Aviation Mobility Measures for Changes in Air Service

The methodology that is proposed in Section 4.4.1 , is used to analyze the affects of changes in air service. The results are presented in this section.

6.2.3.3.1 *Loss of air service.*

The affects of change in air services because of an airline moving-out of Charlottesville-Albemarle airport is presented in this section. The mobility measures have been calculated and presented in Table 6-20.

Table 6-20: Estimates of *Interregional Mobility* Measures by Air (Loss of Service) for Charlottesville-Albemarle Region.

Region	Travel Time Estimate (minutes)	Travel Cost Estimate (Dollars)
Atlanta	276	Na
Charlotte	310*	383
New York	414	Na
Philadelphia	318*	411
Pittsburgh	336*	394
Boston	495	Na

* There is 'loss of connectivity' in this case (see Section 4.4.1.1). It has been assumed that the air traveler uses services from Richmond International airport because of unavailability of alternate air services directly from Charlottesville-Albemarle region.

The *Performance Time Index* and the *Performance Cost Index* as defined in Section 4.4.2 , are calculated using (Equation 12 & (Equation 13 and presented in Table 6-21 & Table 6-22.

Table 6-21: Performance Time Index Calculation for Charlottesville Albemarle region (Loss of Air Service)

Region	Travel Time Estimate (Normal Operations) [2]	Travel Time Estimate (Airline Moves-Out) [3]	[3]/[2]	Ridership
Atlanta	276	276	1	484
Charlotte	245	310*	1.2653	76
New York City	277	414	1.4945	443
Philadelphia	254	318*	1.2519	140
Pittsburgh	255	336*	1.3176	92
Boston	477	495	1.0377	372
Performance Time Index			**1.1977**	

* - Loss of Connectivity; Alternate origin airport – Richmond International Airport

Table 6-22: Performance Cost Index Calculations (Loss of Air service) for Charlottesville Albemarle Region

City	Costs (Normal Operations) [2]	Costs (Airline Moves Out) [3]	Ratio of costs [3]/[2]
Philadelphia	$315	$411	1.30
Pittsburgh	$242	$394	1.62
Charlotte	$285	$383	1.35
Performance Cost Index		**1.0782**	

6.2.3.3.2 Addition of new service

This section presents the affects on mobility of business passengers in Charlottesville-Albemarle region because of an introduction of new service at the Charlottesville-Albemarle airport. It has been assumed that the new air service provider provides three flights per day between the region pairs considered in this analysis. Calculations of the *Performance time index* are presented in Table 6-23.

Table 6-23: Performance Time Index Calculation for Charlottesville-Albemarle (Addition of Service)

Region	Travel Time Estimate (Normal Operations) [2]	Travel Time Estimate (New Service) [3]	[3]/[2]	Ridership
Atlanta	276	272	0.9855	484
Charlotte	245	244	0.9959	76
New York	277	271	0.9783	443
Philadelphia	254	250	0.9842	140
Pittsburgh	255	251	0.9843	92
Boston	477	253	0.5303	372
Performance Time Index			**0.8784**	

6.2.3.4 Highway vs Aviation Travel Times

A comparison of the automobile travel times and the aviation travel times under different circumstances (Current operations and Loss of airline) are presented in Table 6-24. The second column of the table presents the estimate of aviation travel time under the current operation conditions. The third column of the table presents the estimate of the aviation travel time when an airline moves out. The fourth column presents the automobile travel time estimate under the present circumstances. In order to understand the affects of the loss of airline, the ratio of highway and aviation travel time estimates under the new circumstances is presented. The results are further discussed in Section 6.4.

Table 6-24: Comparison of Highway and Air Travel Times

Region	Air Travel Time Estimate (Normal operations) [2]	Air Travel Time Estimate (Loss of Airline) [3]	Highway Travel Time Estimate [4]	Ratio of Travel times (Loss of service) [4]/[3]
Atlanta	276	276	588	2.1304
Charlotte	245	310	340	1.0967
New York	277	414	427	1.0314
Philadelphia	254	318	333	1.0471
Pittsburgh	255	336	348	1.0357
Boston	477	495	655	1.3232

6.3 SUMMARY OF RESULTS

Table 6-25 presents the summary of results from the application of the methodology to capture the affects of changes in air services.

Table 6-25: Summary of Results – Affects of Changes in Air Service

Home Region	Loss of Air Service		Introduction of Air Service
	Performance Time Index	Performance Cost Index	Performance Time Index
Richmond	1.1753	1.0226	0.9941
Hampton Roads	1.1751	1.0379	0.9861
Charlottesville – Albemarle	1.1977	1.0782	0.8784

Table 6-26 summarizes the relative performance of highway and aviation modes by comparison of the highway and air travel times (with loss of air service).

Table 6-26: Summary of Results – Comparison of Travel Times

Home Region	# of Region pairs considered	# of regions for which the travel times become comparable*
Richmond	7	3
Hampton Roads	6	2
Charlottesville – Albemarle	6	4

* - Comparable implies the travel times by air and highway are nearly the same. Highway travel time is less than 1.1 times the air travel time in the new circumstances.

6.4 DISCUSSION OF RESULTS

6.4.1 EFFECTS OF CHANGES IN AIR SERVICE ON THE MOBILITY OF RICHMOND

Travel between seven *outside regions* and Richmond was analyzed. The results illustrate a number of interesting features about the mobility of the business passengers in Richmond.

- Loss of a major air carrier from Richmond international airport increases the aviation travel times between couple of region pairs by 80% and for two other region pairs by 30%;
- In the present operating scenario, travel time by highway is 30-120% more than that by air. But loss of a major carrier from Richmond International airport will result in a higher travel time by air than highway, for two region pairs.
- Loss of air service leads to a 13% and 18% increase in the cost of travel for two region pairs.
- Introduction of new services will reduce the travel times for the region pairs by 1 - 2%.

Summary:

The loss of a major air carrier from Richmond International Airport will have a significant negative impact on the mobility of business passengers in Richmond. The loss of airline will lead to an approximate increase of 17% in air travel times and 3% in air travel costs, for travel between Richmond and various regions separated by medium distances. A couple of regions will lose connectivity by air because of this loss. Travel by air, between three of the seven region pairs, loses dominance to highway travel in terms of travel time.

In the case of introducing a new carrier, the estimated benefit in terms of travel times (only 0.5% reduction) between region pairs is very small.

6.4.2 Effects of Changes in Air Service on the Mobility of Hampton Roads

Travel between six *outside regions* and Hampton Roads was analyzed. The results illustrate a number of interesting features about the mobility of Hampton Roads.

- Loss of a major air carrier from Norfolk international airport increases the aviation travel times between couple of region pairs by 80% and for a region pair by 50%;
- In the present operating scenario, travel time by highway is 70-140% more than that by air. But loss of a major carrier from the Norfolk International Airport will result in a higher travel time by air than highway for two region pairs.
- Loss of air service leads to a 37% increase in the cost of travel to a region.
- Introduction of new service will reduce the travel times for the region pairs by 1 - 4%

Summary:

The loss of a major air carrier from the Norfolk airport will have a significant negative impact on the mobility of business passengers in Hampton Roads region. The loss or airline will lead to a 17% increase in the travel times and 4% increase in travel costs. Connectivity between one of the regions and Hampton roads by air is lost because of the loss of air service. Travel by air, between two of the six region pairs, loses dominance to highway in terms of travel time.

In the case of introducing a new carrier, it is estimated that there will be small reduction (up to 4%) in travel times.

6.4.3 Effects of Changes in Air Service on the Mobility of Charlottesville - Albemarle

Travel between six *outside regions* and Charlottesville-Albemarle was analyzed. The results illustrate a number of interesting features about the mobility of Charlottesville-Albemarle region.

- Loss of a major air carrier from Charlottesville-Albemarle airport increases the aviation travel times to a region by 50% and for three region pairs by 30%;
- Loss of air service will lead to a 30-60% increase in the cost of travel to three regions.

- Introduction of new service will reduce the travel times for the region pairs by 1 – 47%.

Summary:

The loss of a major air carrier from Charlottesville-Albemarle airport will have a significant negative impact on business passengers in Charlottesville Albemarle region. This loss or airline will lead to an approximate increase of 19% in travel times and 8% in travel costs. Three of the regions will lose connectivity by air because of the loss of air service. Travel time by air, between four of the six region pairs, becomes comparable to highway travel times.

In the case of introducing a new carrier, it is estimated that there will be a very large reduction in air travel times to one of the regions; the overall reduction in air travel times would be around 12%.

6.4.4 COMPARISON OF RESULTS ACROSS DIFFERENT REGIONS

The working of the methodology has been demonstrated by application to three urban regions of different sizes in Virginia. The discussion in the above sub-sections is consolidated into the following table to facilitate discussion across regions.

Table 6-27: Results from Analysis

	Richmond	**Hampton Roads**	**Charlottesville - Albemarle**
Airline Moves Out (Travel Time)	80%↑ (2 regions) 30%↑ (2 regions)	80%↑ (2 regions) 50%↑ (1 regions)	50%↑ (1 regions) 30%↑ (3 regions)
Airline Moves Out (Travel Cost)	13-18%↑ (2 regions)	37%↑ (1 region)	30-60%↑ (3 regions)

	Richmond	Hampton Roads	Charlottesville - Albemarle
Present Travel times (Highway vs. Air)	30-160% high (Avg 87%)	70-160% high (Avg 99%)	30-110 % high (Avg 51%)
# of Travel pairs with high travel times by air than highway (airline moves out)	2 region pairs	2 region pairs	-none-
# of region pairs loosing air connectivity (airline moves out)	2 out of seven	2 out of six	3 out of six
Change in Travel time after airline moves in	0.5% ↓	1.5% ↓	12% ↓
Population of region	914,600	1,615,853	135,152
Annual ridership at regional airport	1,330,487	1,518,552	165,938

It can be observed that loss of airline leads to around 80% increase in travel times from Richmond and Hampton roads but only 50% increase from Charlottesville – Albemarle region. One might be tempted to say that the affect on Charlottesville – Albemarle because of an airline moving out is less. But from the comparison of highway and air travel times under the present circumstances we can observe that the highway travel times at Richmond and Hampton Roads regions are nearly 90% higher than the air travel times; for the Charlottesville – Albemarle region the highway travel times are only 51% higher than aviation travel times. From this discussion we can infer that Hampton roads and Richmond regions are relatively well connected by air when compared to Charlottesville – Albemarle region.

The increase in cost (due to loss of air service) is very high at the Charlottesville – Albemarle region when compared to the other regions considered; loss of service also leads to the loss of connectivity between half the region pairs. For Hampton roads and Richmond regions, it is observed that the cost increase is very less (around 2.5%) when compared to Charlottesville – Albemarle region; only thirty percent of the region pairs lose connectivity by air. Introduction of new service would present a significant impact on Charlottesville – Albemarle region when compared to other regions. The main reason for larger impact on Charlottesville Albemarle region when compared to other regions can be attributed to the facts that:

- This region is served by limited air services, non-stop air service to all the major regions around Charlottesville – Albemarle region do not exist.
- The total number of flights serving a given destination is limited.
- There exist very limited services offering flights on a given non-stop route. Limited competition also leads to an increased cost of travel.

Loss of air service might increase the attractiveness of highway to air for travel between two region pairs at Hampton roads and Richmond (because of a high travel time by air than highway). But it is observed that the loss would not have any similar affect on Charlottesville – Albemarle region (Air travel times would be lower than the highway travel times in the new circumstances). This might be due to the fact that passengers at Charlottesville – Albemarle region can use the services from Richmond International Airport which is nearly 60 miles from Charlottesville. It would be advantageous for these passengers to use the services of Richmond international airport than shift to automobile for travel. This observation is specific for Charlottesville because of its location with respect to Richmond. This will not be true for other non-hub regions served by Lynchburg regional airport, Roanoke regional airport, etc.

6.4.5 Implications to State Department of Aviation

The Aviation issues that affect the long term planning process as described in Section 2.3.3.1 , and the affects of those changes (resulting from the methodology application) are summarized below.

Loss of air service because of bad financial performance: Loss of a major air carrier will have a relatively equal adverse affect on the travel time performance of small sized hubs and non-hubs in Virginia. The increase in travel costs due to the loss of service will be very significant for non-hubs regions when compared to small hub regions.

Increasing presence of Regional Jets and low cost services entering Virginian markets: Low cost services will reduce the cost of air travel at small hubs and non-hub regions. But, there would not be any significant travel time reductions at small hubs because of the addition of these new services. There will be significant travel time reductions at the non-hub regions because of these new services.

Hence for the benefit of the overall aviation system of Virginia, it would be advantageous to promote new services at non-hub regions because they tend to increase the mobility of the region. It is also important to preserve the existing services at small and non-hub regions.

6.5 CONCLUSIONS

Mobility has been quantified for the three case studies that have been studied in this project. The results from the analysis of changes in air service and the implications to the state aviation department have been presented.

CHAPTER 7: CONCLUSION

7.1 INTRODUCTION

Accurate assessment of Virginia's long term needs is one of the objectives of the Virginian Airport Capital Improvement Program. The methodology developed in this research captures the affects of changes in air service on interregional mobility, thus assisting in the long term planning process in Virginia. The applicability of the methodology has been successfully demonstrated in the three case studies of the Richmond, Hampton Roads and Charlottesville-Albemarle regions. Section 7.2 presents the conclusions of the work, Section 7.3 presents the contributions of the research, Section 7.4 presents the limitations of the developed methodology, and Section 7.5 presents the recommendations for future research.

7.2 CONCLUSIONS

The working of the developed methodology has been presented by application to three regions of different sizes in Virginia. The following conclusions can be drawn from the application.

- **Ground Access**

  Travel by air is accomplished by ground access modes at both the ends of the trip. Ground access time is a significant component of the door to door travel time for travel between regions separated by intermediate distances. It is observed that, ground access time accounts for nearly 15% of the total travel time.

Ground access cost accounts for nearly 28% of the total cost of travel between regions. From these observations we can conclude that level of service of ground access modes has a lot of significance in affecting the interregional mobility.

- **Affects of Loss of Air service**

Loss in air service will have a very large impact on the mobility at non-hub regions. The impact can be observed in terms of increased travel costs and travel times. In the case study that considered a non-hub region, it was observed that travel times increased by 19% and travel costs increased by 8% because of a major airline discontinuing services at the region's airport.

The loss of air service would affect the mobility of small hub regions only in terms of travel times. The increase in costs would not be significant. Upon applying the methodology to two small hub regions it was found that there was a 17% increase in travel times and no significant change in the travel costs (around 3%).

The loss of air service would also increase the attractiveness of highways to air for travel between 45% of the region pairs (because travel time by highway becomes comparable to that of air).

- **Affects of Introduction of New Air service**

Introduction of a new service will have a very limited impact on the mobility of small hub regions. From the case studies it was found that a new service’s introduction would lead to very small reductions (<1.5%) in travel times from the region. New services would significantly impact the mobility at non-hub regions. A 12% reduction in travel times was obtained.

7.3 CONTRIBUTIONS

Interregional mobility is a complex concept that requires the consideration of numerous factors like travel comfort, travel time, travel cost, etc. The main contributions of the research can be listed as follows:

- **Long-term need assessment**

  The developed methodology projects the affects of changes in air service on interregional mobility. This methodology is useful to the state aviation departments (like Virginia Department of Aviation), which study the long term need assessment as a part of the airport planning process.

- **Easy of Reproducibility**

  The developed methodology quantifies some of the above mentioned factors of interregional mobility using publicly available sources. Since the methodology uses publicly available data, it can be easily reproduced by any governing agency for their use.

- **Comparison between Modes**

  The methodology provides a comparison of the mobility by the modes of highway and air. Hence this methodology can be used by state transportation agencies that allocate funds for modal improvements.

  The indices developed as a part of the methodology are independent of the mode. Hence this methodology can be readily reproduced in regions where modes other than highway or air serve interregional travel. E.g., Rail in the north-east corridor.

- **Consideration of Supplementary Modes**

  Travel by air involves use of different modes to accomplish the trip. Unlike various works that considered characteristics of aviation and ground access separately, this methodology considers the performance of both the modes together. This methodology is very useful to the passenger who considers door to door characteristics of a trip during his modal choice decisions.

7.4 LIMITATIONS

Every methodology that is developed in research has some limitations. The limitations of this methodology are as follows:

- **Origin and Destination Points**

  The methodology assumes that the origin and destination points of the travelers are the downtowns of the cities. But in reality businesses are spread out throughout the city.

- **Distribution of flights throughout the day**

  It has been assumed that the time between flights is equal throughout the day. But in reality, more flight services would operate during particular times of the day. The methodology does not consider this variation.

- **Use of intermediate airports**

The methodology assumes that in case of loss of direct connectivity by air, the air passenger would drive to the nearest airport and fly to his destination. The methodology does not capture the exact choice made by the passenger.

7.5 RECOMMENDATIONS FOR FUTURE RESEARCH

In order to improve the methods to quantify mobility and expand the working of the methodology, the following actions are recommended:

- **Measuring performance with respect to time**

  The indices that have been developed in the methodology calculate the ratio of travel times in the new scenario to the travel times in the current scenario. This can be replaced by the ratio of travel time in current year to the travel time in a base year. The new measure would give us a direct measure of the change in mobility with respect to time.

- **Estimating non-existent measures of Travel cost**

  The true cost of the trip includes the value of time of the traveler and also the opportunity costs because of cancellations and delays of flights. These values are difficult to quantify because they vary a lot among different people and also for the same persons they vary depending on the importance of their lost opportunity. Surrogate measures have to be developed to capture this concept. These measures can be quantified by conducting surveys among business passengers to obtain information about their value of time.

- **Estimating non-existent measures of Travel time**

  Assumptions have been made about some of the access times at airports (security check and baggage collection) in the total air travel time estimation.

Surveys can be conducted to quantify these measures and hence they can make our mobility estimates more reliable.

- **Estimating non quantifiable measures**

  Comfort and convenience of the passengers are factors that affect the mode choice and the mobility by various modes. These factors are difficult to quantify. Inclusion of these factors in the mobility estimate will enhance the usage of the performance measure that has been proposed. These factors could be possibly captured by taking into account the type of aircraft and number of seats available, etc.

- **Passenger's perception Airport level of service**

  The measures that have been developed, includes the service performance of airports to a limited extent. It has been documented that passenger's perception of the level of services at airports varies and hence inclusion of these factors into the travel time and travel cost estimates will make the methodology more reliable.

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APPENDIX A

Appendix Table 1 presents the estimates of the travel time between the downtown of urban area and the airports in the urban areas.

Appendix Table 1: Travel Time Index and Estimated Un-congested travel times.

Urban Area	Airport Name (Code)	Travel Time Index	Estimated Un-congested Travel Time (minutes)
New York – Newark NY-NJ-CT	John F. Kennedy International Airport (JFK)	1.4	28
	LaGuardia Airport (LGA)		15
	Newark Liberty International Airport (EWR)		18
Los Angeles-Long Beach CA	Los Angeles International Airport (LAX)	1.77	22
	Long Beach Airport (LGB)		29
	Ontario International Airport (ONT)		38
Chicago IL-IN	Chicago O'Hare International Airport (ORD)	1.54	17
	Chicago Midway International Airport (MDW)		26
Miami FL	Miami International airport (MIA)	1.4	9
San Francisco-Oakland CA	San Francisco International Airport (SFO)	1.55	19
	Oakland International Airport (OAK)		27
	Norman Y. Mineta San Jose International Airport (SJC)		46
Philadelphia PA-NJ-MD-DE	Philadelphia International Airport (PHL)	1.35	17
Detroit, MI	Detroit Metropolitan Wayne County Airport (DTW)	1.35	25
Dallas, TX	Dallas-Fort Worth International Airport (DFW)	1.34	27
Washington DC-VA-MD	Washington Dulles International Airport (IAD)	1.5	33
	Ronald Reagan Washington National Airport (DCA)		9
	Baltimore-Washington International Thurgood Marshall Airport (BWI)		49
Houston, TX	William P. Hobby Airport (HOU)	1.39	26

Urban Area	Airport Name (Code)	Travel Time Index	Estimated Un-congested Travel Time (minutes)
	George Bush Intercontinental Airport (IAH)		18
Boston MA-NH-RI	Logan International Airport (BOS)	1.45	7
Atlanta GA	Hartsfield-Jackson Atlanta International Airport (ATL)	1.42	16
Phoenix AZ	Phoenix Sky Harbor International Airport (PHX)	1.35	12
Baltimore MD	Baltimore-Washington International Thurgood Marshall Airport (BWI)	1.36	17
Tampa-St. Petersburg FL	Tampa International Airport (TPA)	1.31	7
Richmond VA	Richmond International Airport (RIC)	1.08	18
Virginia Beach VA	Norfolk International Airport (ORF)	1.21	17
Pittsburgh PA	Pittsburgh International Airport (PIT)	1.1	22
Charlotte NC-SC	Charlotte/Douglas International Airport (CLT)	1.31	13
Cincinnati OH-KY-IN	Cincinnati-Northern Kentucky International Airport (CVG)	25	24
Orlando FL	Orlando International Airport (MCO)	1.29	24
Nashville-Davidson TN	Nashville International Airport (BNA)	1.19	11
Cleveland OH	Cleveland-Hopkins International Airport (CLE)	1.1	17
Jacksonville FL	Jacksonville International Airport (JAX)	1.16	21

APPENDIX B

Appendix Table 2 presents the average delay encountered by delayed flights and the percentage of flights that have been delayed during 2002 in various US airports.

Appendix Table 2: Delay Characteristics at various airports in the US.

Airport Name (Code)	Sample Size	Average Delay (minutes)	Percentage of delayed flights
John F. Kennedy International Airport (JFK)	50409	27	39.91
LaGuardia Airport (LGA)	93563	37	31.29
Newark Liberty International Airport (EWR)	102417	28	32.38
Los Angeles International Airport (LAX)	181493	21	33.99
Long Beach Airport (LGB)	3241	23	29.95
Ontario International Airport (ONT)	32376	19	35.24
Chicago O'Hare International Airport (ORD)	327388	28	36.41
Chicago Midway International Airport (MDW)	52445	25	43.21
Miami International airport (MIA)	62835	26	35.00
San Francisco International Airport (SFO)	98838	23	32.59
Oakland International Airport (OAK)	60443	21	43.08
Norman Y. Mineta San Jose International Airport (SJC)	60594	21	32.45
Philadelphia International Airport (PHL)	107756	27	38.82
Detroit Metropolitan Wayne County Airport (DTW)	140681	25	45.64
Dallas-Fort Worth International Airport (DFW)	281084	24	35.42
Washington Dulles International Airport (IAD)	44425	24	33.93
Ronald Reagan Washington National Airport (DCA)	63764	26	29.07
Baltimore-Washington International Thurgood Marshall Airport (BWI)	86856	26	40.69
William P. Hobby Airport (HOU)	55236	32	42.15
George Bush Intercontinental Airport (IAH)	119695	24	36.59
Logan International Airport (BOS)	109820	29	36.32
Hartsfield-Jackson Atlanta International Airport (ATL)	231928	20	51.71

Airport Name (Code)	**Sample Size**	**Average Delay (minutes)**	**Percentage of delayed flights**
Phoenix Sky Harbor International Airport (PHX)	173942	30	40.03
Tampa International Airport (TPA)	62319	25	31.99
Richmond International Airport (RIC)	14121	25	32.11
Norfolk International Airport (ORF)	18604	24	33.24
Pittsburgh International Airport (PIT)	81404	23	33.21
Charlotte/Douglas International Airport (CLT)	4627	17	37.56
Cincinnati-Northern Kentucky International Airport (CVG)	61586	19	46.60
Orlando International Airport (MCO)	81483	24	32.31
Nashville International Airport (BNA)	49884	24	30.79
Cleveland-Hopkins International Airport (CLE)	44584	26	31.24
Jacksonville International Airport (JAX)	23747	22	33.63

APPENDIX C

Appendix Table 3 presents the average percentage of cancelled flights at various US airports in 2002. Data from the On-Time performance database provides the details about the flight cancellations in the form of number of cancelled arrivals and number of cancelled departures. The average of the number of cancelled arrivals and departures has been used to arrive at the percentage of cancelled flights at airport.

Appendix Table 3: Delay Characteristics at various airports in the US.

Airport Name (Code)	Sample Size (1)	Number of cancelled arrivals (2)	Number of cancelled departures (3)	Percentage of cancelled flights [(2)+(3)]X 100/[2*(1)]
John F. Kennedy International Airport (JFK)	50409	833	741	1.561
LaGuardia Airport (LGA)	93563	2318	2113	2.367
Newark Liberty International Airport (EWR)	102417	1516	1373	1.410
Los Angeles International Airport (LAX)	181493	2119	1895	1.105
Long Beach Airport (LGB)	3241	40	39	1.218
Ontario International Airport (ONT)	32376	298	262	0.864
Chicago O'Hare International Airport (ORD)	327388	6979	6499	2.058
Chicago Midway International Airport (MDW)	52445	674	534	1.151
Miami International airport (MIA)	62835	448	310	0.603
San Francisco International Airport (SFO)	98838	960	818	0.899
Oakland International Airport (OAK)	60443	584	512	0.906
Norman Y. Mineta San Jose International Airport (SJC)	60594	707	638	1.109
Philadelphia International Airport (PHL)	107756	2095	1930	1.867
Detroit Metropolitan Wayne County Airport (DTW)	140681	2487	2217	1.671

Airport Name (Code)	**Sample Size (1)**	**Number of cancelled arrivals (2)**	**Number of cancelled departures (3)**	**Percentage of cancelled flights [(2)+(3)]X 100/[2*(1)]**
Dallas-Fort Worth International Airport (DFW)	281084	3852	3449	1.298
Washington Dulles International Airport (IAD)	44425	663	591	1.411
Ronald Reagan Washington National Airport (DCA)	63764	1377	1273	2.077
Baltimore-Washington International Thurgood Marshall Airport (BWI)	86856	885	775	0.955
William P. Hobby Airport (HOU)	55236	1601	1490	2.797
George Bush Intercontinental Airport (IAH)	119695	793	666	0.609
Logan International Airport (BOS)	109820	2285	2127	2.008
Hartsfield-Jackson Atlanta International Airport (ATL)	231928	2855	2541	1.163
Phoenix Sky Harbor International Airport (PHX)	173942	2165	1902	1.169
Tampa International Airport (TPA)	62319	406	298	0.564
Richmond International Airport (RIC)	14121	328	299	2.220
Norfolk International Airport (ORF)	18604	276	246	1.402
Pittsburgh International Airport (PIT)	81404	1022	901	1.181
Charlotte/Douglas International Airport (CLT)	4627	21	20	0.443
Cincinnati-Northern Kentucky International Airport (CVG)	61586	951	853	1.464
Orlando International Airport (MCO)	81483	517	371	0.544
Nashville International Airport (BNA)	49884	414	322	0.737
Cleveland-Hopkins International Airport (CLE)	44584	648	588	1.386
Jacksonville International Airport (JAX)	23747	130	96	0.475

APPENDIX D

Appendix Table 4 presents the average taxi-in and taxi-out times at various airports. Data from the On-Time performance database has been used to obtain these characteristics.

Appendix Table 4: Taxi-in and Taxi-out times at various airports in the US.

Airport Name (Code)	Average Taxi-in times (minutes)	Average Taxi-out times (minutes)
John F. Kennedy International Airport (JFK)	6.91	23.68
LaGuardia Airport (LGA)	7.12	21.53
Newark Liberty International Airport (EWR)	6.72	22.89
Los Angeles International Airport (LAX)	5.98	13.74
Long Beach Airport (LGB)	10.72	13.90
Ontario International Airport (ONT)	5.42	8.82
Chicago O'Hare International Airport (ORD)	5.86	18.81
Chicago Midway International Airport (MDW)	4.80	12.26
Miami International airport (MIA)	7.70	19.19
San Francisco International Airport (SFO)	6.66	16.3
Oakland International Airport (OAK)	5.00	9.87
Norman Y. Mineta San Jose International Airport (SJC)	5.97	12.66
Philadelphia International Airport (PHL)	6.34	21.27
Detroit Metropolitan Wayne County Airport (DTW)	6.19	18.51
Dallas-Fort Worth International Airport (DFW)	6.17	18.39
Washington Dulles International Airport (IAD)	7.18	16.37
Ronald Reagan Washington National Airport (DCA)	7.17	13.62
Baltimore-Washington International Thurgood Marshall Airport (BWI)	5.63	12.12
William P. Hobby Airport (HOU)	3.91	8.32
George Bush Intercontinental Airport (IAH)	6.15	20.74
Logan International Airport (BOS)	6.92	17.03
Hartsfield-Jackson Atlanta International Airport (ATL)	6.57	18.69
Tampa International Airport (TPA)	6.59	11.87
Richmond International Airport (RIC)	7.92	12.59
Norfolk International Airport (ORF)	7.29	11.26
Pittsburgh International Airport (PIT)	6.10	15.74
Charlotte/Douglas International Airport (CLT)	4.77	17.24

Airport Name (Code)	Average Taxi-in times (minutes)	Average Taxi-out times (minutes)
Cincinnati-Northern Kentucky International Airport (CVG)	6.79	17.34
Orlando International Airport (MCO)	6.89	12.85
Nashville International Airport (BNA)	5.93	10.18
Cleveland-Hopkins International Airport (CLE)	6.69	15.74
Jacksonville International Airport (JAX)	6.81	11.34