RUNWAY INCURSION MITIGATION, CAPACITY ENHANCEMENT, AND SAFETY IMPROVEMENTS WITH PERIMETER TAXIWAY OPERATIONS AT DALLAS FORT WORTH INTERNATIONAL AIRPORT

By

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ABSTRACT

RUNWAY INCURSION MITIGATION, CAPACITY ENHANCEMENT,

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OPERATIONS AT DALLAS FORT WORTH

INTERNATIONAL AIRPORT

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A perimeter taxiway (PT) or end-around taxiway (EAT) operation is a new concept being developed at several airports around the country to eliminate active departure runway incursions during peak periods. PTs will enhance capacity by permitting uninterrupted, safe, continuous takeoffs and landings within the operations framework and guidelines established by the Federal Aviation Administration (FAA). For this research, the Dallas/Fort Worth International Airport's (DFW) proposed PT operations are considered for analysis and evaluation. This concept is tested using actual historical flight data at DFW for simulation and analytical modeling based on the FAA safety factors available in the Visual SIMMOD simulation modeling software. The physical and operational constraints for PT operations pertaining to safety and hazards to other aircraft over-flying the PT, while aircraft on the ground are traveling on

the PT is evaluated using flight track data. The operations analysis, and the standard taxiway procedures and guidelines developed based on the simulation yields a perspective of the PT operations at DFW. The DFW expansion plans and development drawings for PT operations are customized for use in the Visual SIMMOD. The results of the simulation and statistical analysis of the flight track data aid in the development of standards and guidelines for design and construction of PTs at DFW and other airports. The simulation is performed using actual flight data at DFW for 2004 and forecast air traffic data for 2010. The air traffic data is analyzed *with* and *without* PT at the airfield to establish the derived benefits of incorporating a PT system at DFW. The derived benefits are elimination of runway incursion, improvements in departure rate in dedicated departure runways, and overall improvement in safety of operations.

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CHAPTER 1

INTRODUCTION

1.1 Problem characterization

The air traffic at towered airports throughout the United Sates (US) is growing at a steady rate in line with the growth in economy and population [30]. The global market demand for commodities and services has added a new dimension to the concept of travel. Far East and Asian countries have become leaders in manufacturing, which has resulted in the movement of people, raw materials, and finished goods to destinations around the world [30]. The US as a nation is the leading consumer of products and services from around the world, which increases the demand for people flying to and from the US due to the need to visit the US for business. The increase in traffic occurs simultaneously with the introduction of new long-range and short-range aircraft to carry passengers on international and domestic routes [9]. There are no longer peak traffic periods at major airports like Dallas Fort Worth International Airport (DFW), O'Hare International Airport (ORD), Los Angeles International Airport (LAX), Atlanta Hartsfield International Airport (ATL) and San Francisco International Airport (SFO) [30]. At these airports, airlines have rescheduled their flights over the entire day instead of clustering arrival and departure slots together in the morning or afternoon. This has helped to decrease severe delays and has greatly reduced the communication requirements and workload for air traffic controllers. The net effect is better use of gates and baggage handling facilities at these airports [27]. The parallel runway operations at towered airports cause aircraft to wait before they cross the departure runway to reach the terminal gates. The waiting time is increasing and a solution to eliminate this wait time, which will simultaneously make operations safer, save fuel and improve overall gate usage and increase facility utilization while maintaining on time arrivals and departures is a high priority for the Federal Aviation Administration (FAA) [16].

1.2 Runway incursions

The exponential increase in air traffic in the US raises the possibility of a catastrophic incursion by an aircraft onto an active departure runway in parallel runway operations [24]. Landings and takeoffs are taking place at a faster pace considering only the separation between aircraft and their ability to clear an active runway by taking refuge in a taxiway exit before crossing the other active, departure runway to get to a terminal gate. This type of crossing occurs many times a day when parallel runway operations for simultaneous takeoffs and landings are permitted [24, 29]. Concern has been voiced by many in the FAA and Congress over the frequent interruptions of takeoffs and landings to permit the crossing of an active runway by all types of aircrafts to access the terminal area [18, 35].

The FAA defines a "runway incursion as any occurrence in the airport runway environment involving an aircraft, vehicle, or object on the ground that creates a collision hazard or results in a loss of required separation with an aircraft taking off, intending to take off, landing or intending to land"[29]. Between 1999 and 2002 there were 1,480 runway incursions for the 268 million operations at towered airports in the US [15]. Detailed information on DFW runway incursion high alert intersections, their locations and the cause of the incidents are posted in Appendix F and the severity of runway incursion categories as defined by the FAA. The severity ranges from a low of category D to a high of category A depending on the nature of the incident at the airport.

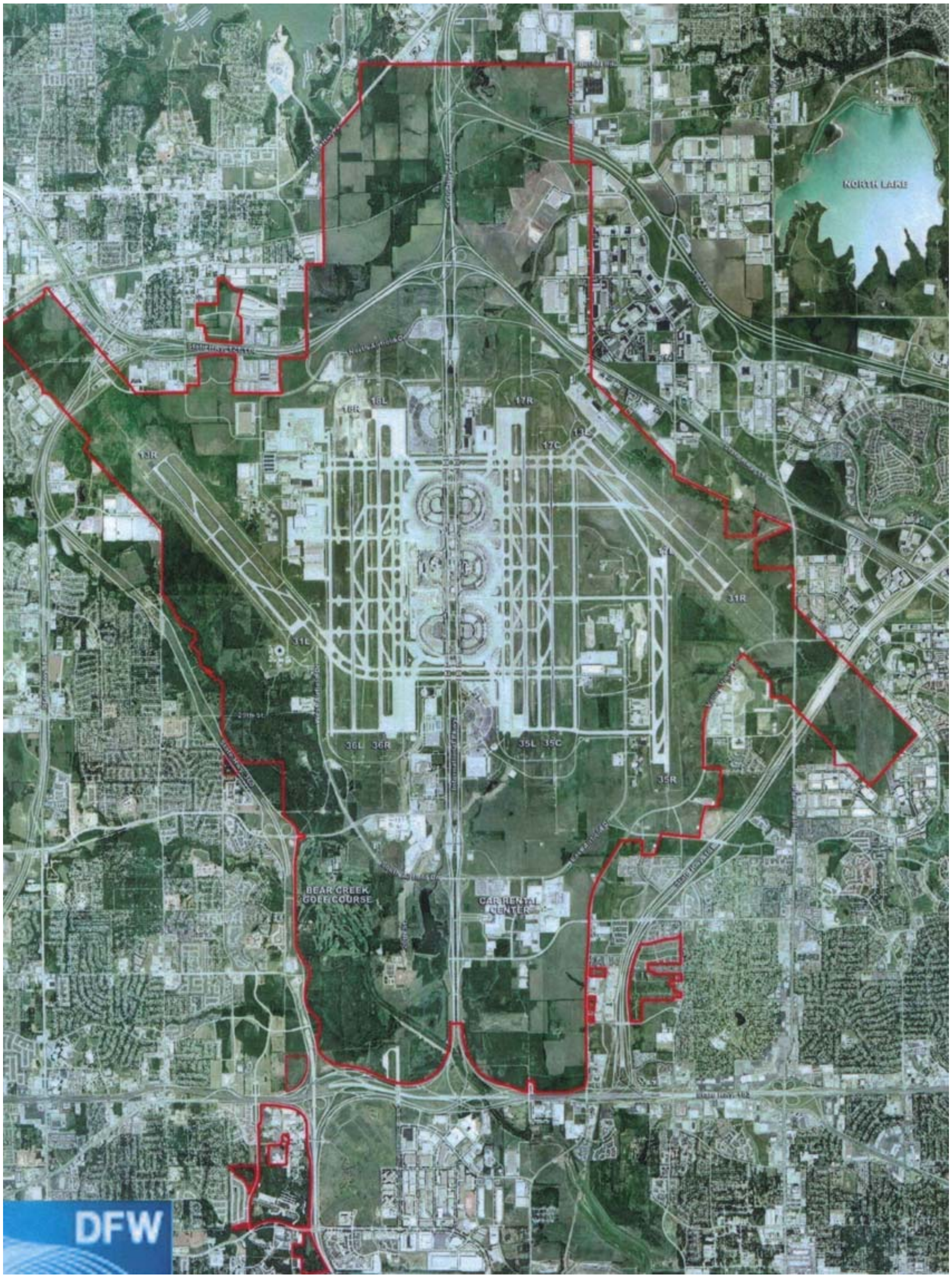


Figure 1 Aerial view of DFW airport [Source DFW Airport]

DFW (aerial view in Figure 1), has experienced several runway incursions over the years. A new Runway Status Light (RWSL) system similar to a traffic signal has been introduced at Runway 18L/35R to avoid collisions between aircraft on the departure runway and an aircraft crossing in front of it [8, 12, 13] MIT is studying and evaluating this concept at DFW and recommends this strategy as an interim solution to prevent runway incursions. But, pilots in the cockpit who are busy with the controls and communicating with the tower may be unable to see the lights turning red

Figure 2 RWSL at DFW view from the West Control Tower [8]

This is an example of human error affecting operations which should be fully avoided. An introduction of a PT may resolve this problem [25]. In Figure 2, an aircraft on its way to terminal is waiting to cross the active departure runway 18L/36R after landing on 18R/36L. The RWSL can be seen on the ground in front of the airplane. Figure 3 shows the runway entrance lights strategically placed at the airfield

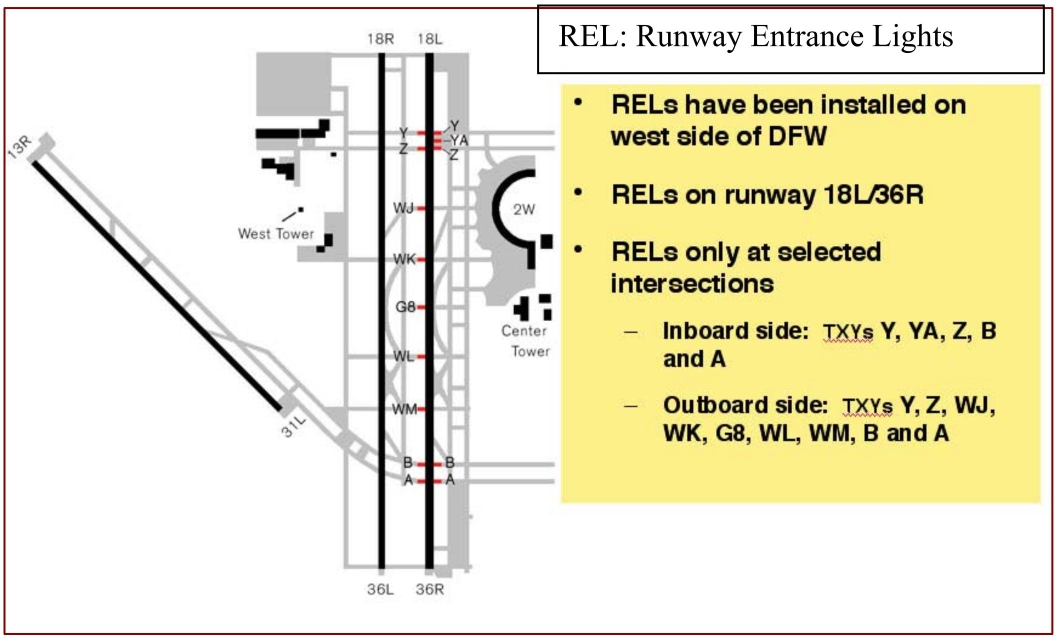


Figure 3 DFW RWSL locations at runway 18L/36R
Source: http://www.faa.gov/and/and500/private/rwsl/
Web site accessed on 11-16-06

on runway 18L/36R where it intersects taxiways on both the inboard and outboard side.

The RWSL and REL will become obsolete once the PT is built which can be seen in the PT operations analysis in Chapter 9. The reason for the RWSL is to prevent an accidental runway incursion of the departure runway by arrival aircraft, but the PT will totally eliminate runway crossings by arrival aircraft in the future.

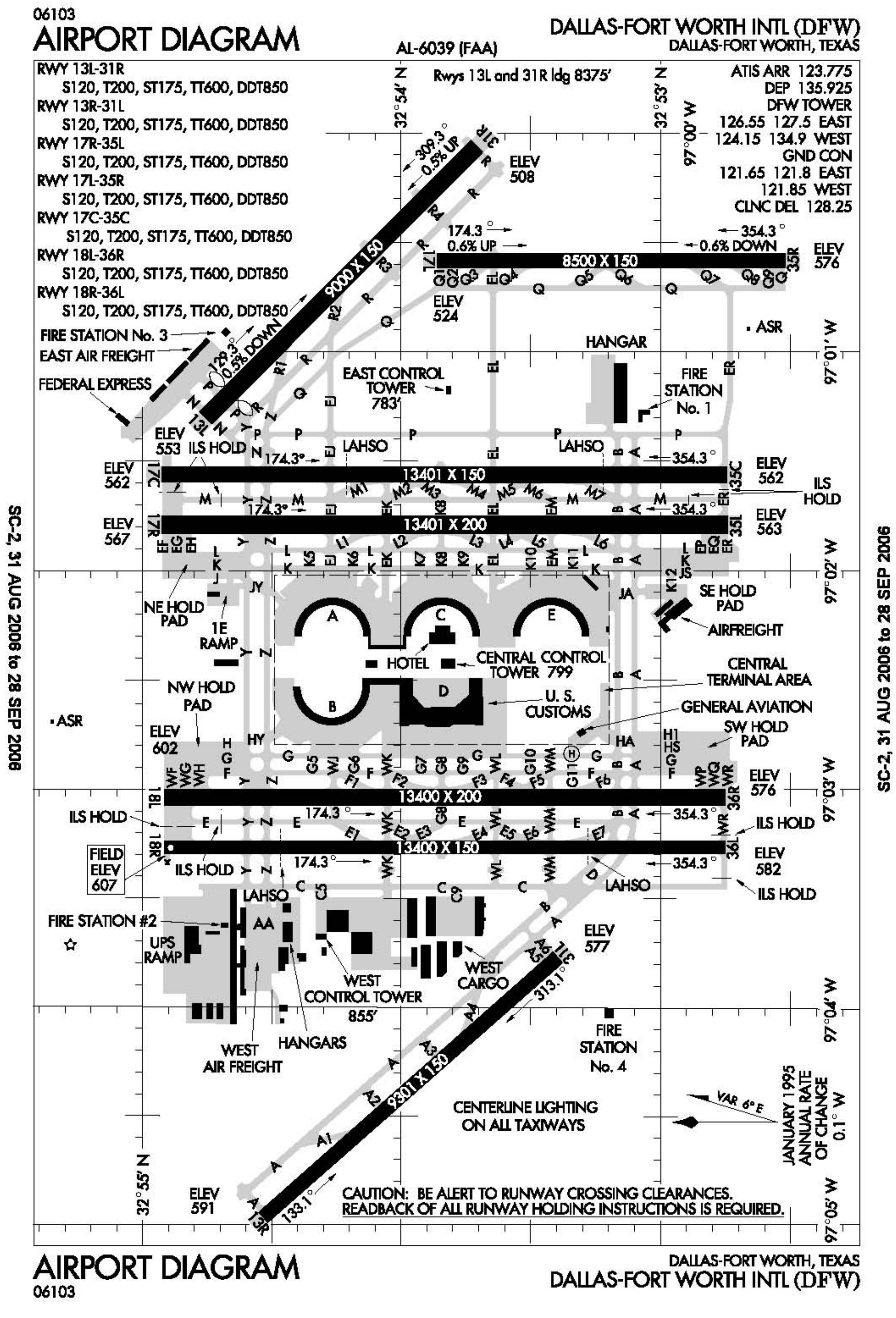


Figure 4 Airport Diagram [Source: FAA]

1.2.1 Types of runway Incursions [12, 13, 26, 52]

The FAA defines runway incursions under three categories. They are:

1. Operational error (OE): An OE is the action of an Air Traffic controller that results in, less than minimum separation between two or more aircraft or between an aircraft and obstacles (vehicles, equipment, personnel on runways) or clearing an aircraft to take off or land on a closed runway. (FAA Order 7110.65)

Example: A pilot is asked to cross the departure (active) runway while another aircraft has since been cleared to takeoff on the departure runway.

2. Pilot deviations (PD): A PD is the action of a pilot that violates any Federal Aviation Regulation.

Example: A pilot crosses a runway without a clearance while enroute to an airport gate.

3. Vehicle/pedestrian deviation (V/PD): A V/PD is a vehicle or pedestrian entering the airport movement area.

Example: Pedestrians or vehicles entering any portion of the airport movement areas (runways/taxiways) without authorization from air traffic control [35]

There have been several serious life threatening runway incursions at quite a few airports and they continue to increase as air traffic increases.

1.3 Runway safety

Runway safety is a major issue that affects airport operations. It is of paramount importance that everyone is made aware of the need to follow operational rules and guidelines so that a high degree of safety can be maintained at all times. Aircraft operators must have situational awareness at an airport to safely operate their aircraft and to permit incident free movement on the runway and taxiway [23]. There are operational constraints at major airports and pilots are made aware of these well in advance of encountering them [35, 43, 52]. For example, there are limitations on the movement of aircraft exceeding a certain wing span from traversing a specific section of the taxiway, because of safety and wingtip clearance [54].

All operations at an airport involve significant human interface at all levels; these interfaces include communication between aircraft, between controllers and between aircraft and controllers while keeping a constant lookout for other vehicle movements on the apron or gates. The pilots and controllers are highly stressed on the job and tend to develop fatigue [26, 46]. Distraction and loss of attention may occur because communication gets interrupted frequently, data and commands are repeated and clutter and noise occurs in the cockpit and control towers. There are cultural issues, language barriers, and professional pride that hinders in the smooth operation of flights in an airport [26, 46]. Runway safety mainly hinges on the success of the pilots to operate safely and the clear understanding of instructions and guidance from personnel in the control towers. Although the amount of information handled in the cockpit has been reduced by the introduction of computers and radar warning systems, still much data has to be *verbally* communicated [56]. The rules of operations remain pretty much standard in all parts of the world in the aviation industry due to the coordination of the FAA and International Civil Aviation Organization (ICAO) in rule making and application of standards. Accident avoidance and safe operation of aircrafts, vehicles, and humans are very important parts of runway safety. Simultaneous operations in multiple parallel runways have caused pilots to confuse the controller's instructions and in several instances they have landed on the wrong runway or taxiway [35, 51].

Figure 5 shows two aircraft at DFW on August 16, 2001, a Continental Airlines B737 aircraft with 55 passengers crossing the departure runway while a Delta Airlines B737-300 aircraft with 125 passengers on board was on a takeoff roll and climbing. Prompt evasive action by the Delta Airlines pilot who executed a steep climb saved both aircraft from a serious collision on the runway. The FAA stated that the Delta Airlines plane came within 500 feet of the Continental jet vertically over the runway. The magnitude of the risk associated with this event makes it a runway incursion. [17, 51].

Identical incidents have happened at ORD, LAX and DTW; efforts are underway at all of these airports to avoid such runway incursions in the future, by developing proper guidelines and improving navigational charts [25, 46].

Figure 5 Runway incursion at DFW on August 16, 2001 [17]

Source: Movie clip -FAA Runway Safety, Fort Worth office

There have been several near misses at towered airports over the years. The FAA is very concerned about these incursions and is always looking for ways to improve operations that will drastically eliminate or reduce runway incursions. [46]

1.3.1 Land and Hold Short Operations (LAHSO)

LAHSO (FAA Order 7110.118, 7-14-2000) operations include landing and holding short of an intersecting runway, an intersecting taxiway, or some other designated point on a runway other than an intersecting runway or taxiway [8]. The LAHSO is very common on arrival runways in many airports around the US [41]. At DFW the aircraft that land on the arrival runways 17C/35C or 18R/36L are requested to come to a complete stop before the hold point so that a runway crossing by another aircraft that has landed on the parallel runway 17L/35R or crosswind runway 31R is permitted to cross in front of the landed aircraft. This requires a perfect coordination between a pilot and the controllers, and the arriving aircraft pilot's familiarity with the airport [25, 52].

On runway 18R in Figure 6, the distance to the LAHSO is 10,100 ft from the north end of the runway to Taxiway B. On runway 36L it is at 10,650 ft from the south end of the runway to Taxiway Z.

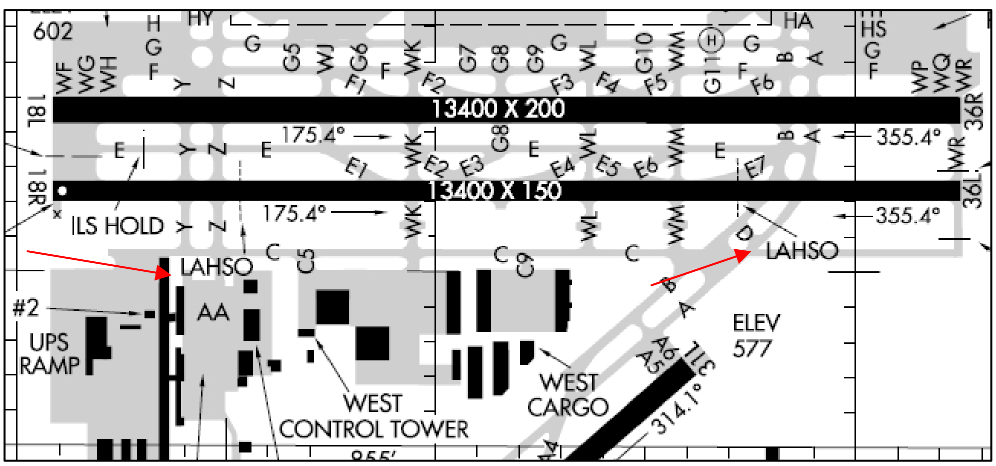


Figure 6 DFW layout shows the location of LAHSO on the West side

On runway 17C in Figure 7, the distance to the LAHSO marker is 10,460 ft from the north end of the runway to taxiway B. On runway 35C the marker is 9,050 ft from south end to Taxiway EJ. Hold positions are clearly marked on the navigation charts, and marked on the runway pavement. Figures 6 and 7 show the location of LAHSO markers at DFW.

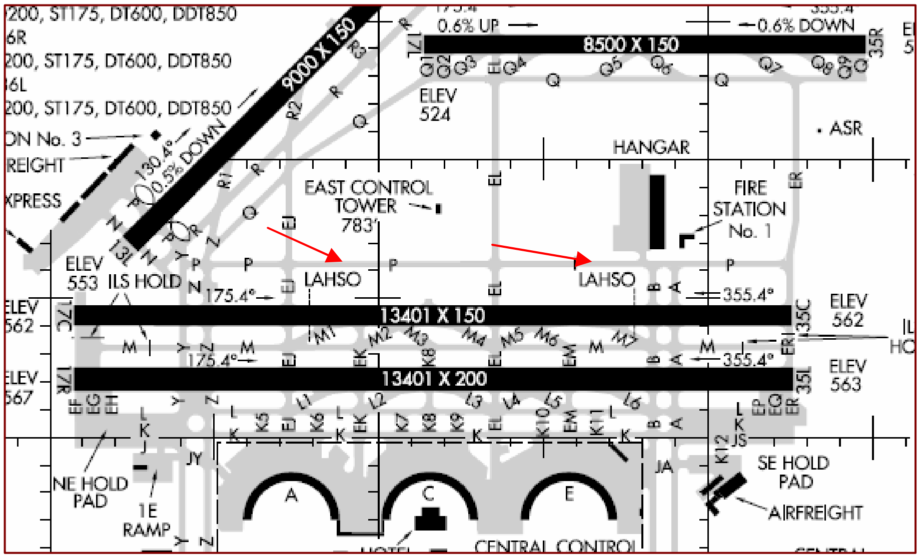


Figure 7 DFW layout shows the location of LAHSO on the East side

The FAA/ATC reported that at least ten percent of arrival aircraft are held short of the runway crossing to permit the aircraft that landed on the outboard runway 17L (east side) and 13R (west side) to reach the terminal by crossing the active arrival and departure runway.

Table 1 LAHSO location and distances at DFW

LAHSO DISTANCE FROM LANDING THRESHOLD		
RWY 17C	**TWY B**	**10,460'**
RWY 18R	**TWY B**	**10,100'**
RWY 35C	**TWY EJ**	**9,050'**
RWY 36L	**TWY Z**	**10,650'**

During the South Flow, an aircraft that lands on runway 17C is given 10,460' to come to a complete stop before Taxiway B, which connects with other taxiways on the west side of 17C to reach the terminals. Taxiway ER is the link for aircraft landing on 17L to reach the terminal buildings. There are no arrivals permitted on runway 13L during the South Flow configuration. In the North Flow operation, an aircraft arriving on runway 35C has to come to a complete stop at a distance of 9,050' before taxiway EJ which is the link to runway 35R and runway 31R. An aircraft that lands on runway 18R during the South Flow, comes to a complete stop before Taxiway B with LAHSO marked at a distance of 10,100' In the North Flow, aircraft landing on 36L has to come to a complete stop before the Taxiway Z hold point marked at distance of 10,650' from the runway threshold. This process increases the waiting time for the arrived aircraft and passengers to reach the gate. In this research, the LAHSO will not be simulated because Visual SIMMOD is not programmed to replicate such airfield operations. This procedure also delays all the aircraft in the arrival stream from landing at DFW. This produces a ripple effect delaying all aircraft in the arrival stream on runway 17C/35C or 18R/36L. Therefore, this procedure is used in moderation by ATC after evaluating all possible alternatives before authorizing the LAHSO at DFW [41].

1.3.2 PT concept at DFW

The planned addition of the PT at DFW will increase the safety and reduce operational constraints during peak period operations [19]. This research focuses on the addition of a PT and its added benefits to an airport in the form of the reduction in waiting time for aircraft to cross the active departure runway after arrival. The objective is the smooth movement of aircraft from the arrival runway to the gate with minimum communication with Ground Controllers. Similarly, the aircraft on the departure runway need not wait for the arrival aircraft to cross, thus allowing continuous departures on the dedicated departure runways 17R and 18L. A detailed risk and operational evaluation of the PT system will be made using Visual SIMMOD (VS) software.

1.4 Demand for air travel

Air traffic at DFW is expected to increase in the coming years, which will certainly increase the runway crossings, and the associated delay to both incoming aircraft waiting to cross and to departing aircraft [25]. Therefore, it is rather essential to identify and define the reasons for an increase in air traffic.

The Dallas Fort Worth Metroplex is experiencing rapid growth in population with the arrival of new industries, support services, and financial institutions. The Dallas Fort Worth area has become a prime location due to the availability of suitable and affordable real estate for both residential and commercial development. This region has access to sufficient power supply and mature highway infrastructure and rail system for movement of people and goods. In the near future, there are plans to connect DFW with both the light and commuter rail systems, which continue to expand throughout the region [23]. The demographics of the Metroplex area population are constantly changing with people of many nationalities settling here [49]. This has resulted in increased traffic at DFW for people coming to visit their friends and family or see one of the many North Texas attractions. This growth is expected to continue through the next several years and tend to proportionately boost traffic at the airport from flights originating in different parts of the world. In 2005, DFW completed a new international terminal, Terminal D, to accommodate flights from international destinations. All international flights arriving and departing are now using terminal D with processing facilities like immigration and customs consolidated in one terminal. The standard of living has also grown steadily around the globe, which allows people to spend a larger portion of their disposable income on air travel to tourist destinations [1]. The air traffic is not expected to stagnate, but expected to increase in proportion to the growth in world population and economy [33, 42]. The forecast is for a steady increase in air traffic around the world with the introduction of large aircraft, like Airbus A380, capable of carrying over 550 passengers in a single flight [1]. The opening of the new international terminal D at DFW is expected to encourage many airlines from Europe, Middle East, Australia and Asian countries to select DFW as their final destination. Moreover, DFW is well positioned as a hub for several destinations in the lower forty-eight states, Central America and South America. Therefore, the demand for air travel is expected to continue to thrive in the near future and forecast to surpass the number of flight operations in 2000, thus requiring additional aircraft to cater to the increased passenger and cargo traffic [9].

1.4.1 Population forecast

Several cities in the DFW Metroplex and neighboring regions are experiencing tremendous population growth. The population of Tarrant, Dallas and other neighboring counties are expected to experience a greater growth in the coming years as shown above in the Table 2

Table 2 Population forecast by NCTCOG for 10 county Urban areas [49]

Ten-County Urban Area	2000	2010	2020	2030
Household Population	5,067,400	6,328,200	7,646,600	9,107,900
Households	1,886,700	2,350,300	2,851,400	3,396,100
Employment	3,158,200	3,897,000	4,658,700	5,416,700

Therefore, the air traffic at DFW will grow in line with the population growth forecast by North Central Texas Council of Governments [49]. The forecast for population growth in Tarrant and Dallas County where DFW is situated is shown in Tables 3 and 4. The households and employment are expected rise in proportion with the population growth in the ten county areas. The forecast expects an 80% increase in population between 2000 and 2030 in the ten county regions shown in the map in Figure 8.

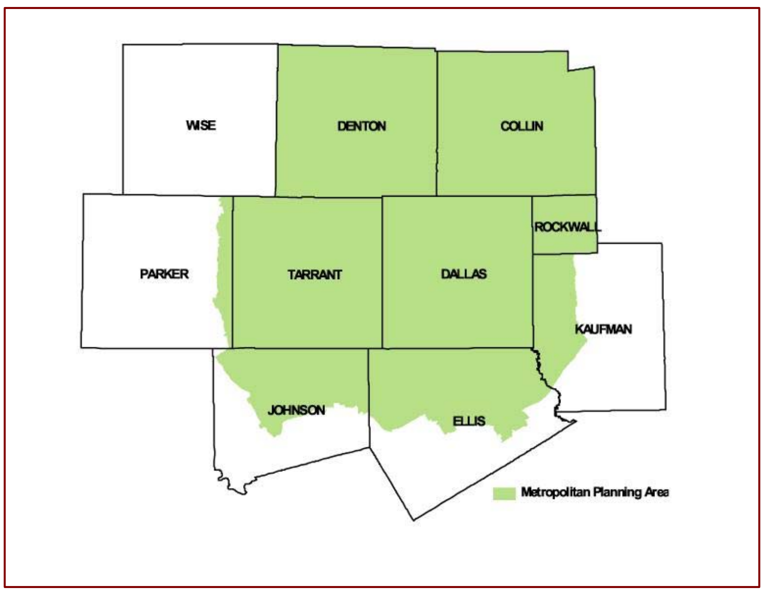


Figure 8 Map of the ten counties considered in the NCTCOG forecast [49]

Similar forecasts have been made for the cities of Dallas, Fort Worth, Denton and several others surrounding DFW where the population is anticipated to grow faster through year 2030 and beyond.

Table 3 Tarrant County population growth projection NCTCOG-2003 [49]

TARRANT COUNTY Population						
2000	2005	2010	2015	2020	2025	2030
1,435,186	1,620,761	1,746,082	1,909,469	2,047,553	2,184,869	2,291,723
Households						
2000	2005	2010	2015	2020	2025	2030
540,420	608,127	653,358	716,420	770,619	821,149	862,121
Employment						
2000	2005	2010	2015	2020	2025	2030
864,360	985,109	1,077,319	1,168,731	1,265,489	1,340,172	1,388,247

The expected increase in population conventionally attracts more industries, housing, schools, retail outlets, service facilities and financial institutions to take advantage of the growth in population. The forecast surmises that the population is expected to grow a whopping 160% above 2000 levels by 2030 in Tarrant County and 126% in the Dallas County [49].

Table 4 Dallas county population growth projection NCTCOG-2003 [49]

DALLAS COUNTY						
Population						
2000	2005	2010	2015	2020	2025	2030
2,232,476*	2,390,491	2,486,989	2,564,350	2,624,989	2,746,427	2,817,191
Households						
2000	2005	2010	2015	2020	2025	2030
832,864*	891,905	929,713	963,107	986,493	1,032,872	1,059,800
Employment						
2000	2005	2010	2015	2020	2025	2030
1,745,109	1,924,193	2,055,686	2,198,367	2,344,392	2,467,769	2,529,371

Therefore, it can be concluded from the above forecasts that the trend in air traffic at DFW is bound to follow the population and employment evolution in the North Texas region thru year 2030 and beyond.

1.5 FAA Aviation Forecasts

The primary focus of this research is to estimate the traffic flow at DFW in year 2010 and determine how the planned introduction of a PT will exalt the operations at DFW. Therefore, a detailed review of the forecasts made by the FAA for DFW is undertaken to study the anticipated increase in traffic by year 2010. The FAA Aerospace Forecasts for fiscal years 2005 to 2016 [27] contains detailed information on the methodology used by the FAA to derive the national forecast for the aviation industry. The document considers the US and world Gross Domestic Product (GDP) growth, economic activity, world travel demand, and domestic travel demand. The FAA forecasts are shown in Appendix C. The forecast passenger markets in the US and the world and the anticipated aircraft supply to meet the expected growth in demand by commercial air carriers. In this document, the FAA has forecast air traffic growth around the country for all thirty-five towered airports. The air traffic is expected to increase at a faster rate thru 2016 [27, 33, 36]. Table 5 contains the forecast growth for US and Foreign flag carriers that are flying into major airports in this country. Passenger traffic to and from the US to other destinations around the world is expected to grow from 134 million to 186.5 million, an increase of 39% in 6 years from 2004 to 2010.

Table 5 U.S. and Foreign Flag carriers forecast [27]

U.S. AND FOREIGN FLAG CARRIERS TOTAL PASSENGER TRAFFIC TO/FROM THE UNITED STATES					
	TOTAL PASSENGERS BY WORLD TRAVEL AREA (Millions)				
CALENDAR YEAR	ATLANTIC	LATIN AMERICA	PACIFIC	U.S. /CANADA TRANSBORDER	TOTAL
Historical*					
1999	48.7	38.8	24.3	19.6	131.4
2000	53.0	40.8	26.0	20.8	140.6
2001	47.5	38.8	23.0	19.5	128.8
2002	43.4	36.9	22.3	18.3	120.8
2003	43.8	38.7	20.0	17.5	120.0
2004E	48.4	42.8	23.5	19.3	134.0
Forecast					
2005	52.0	46.0	26.3	21.1	145.4
2006	55.2	48.8	28.5	22.5	155.0
2007	58.0	51.3	30.4	23.4	163.2
2008	60.7	53.8	32.2	24.1	170.8
2009	63.1	56.4	33.8	24.8	178.2
2010	65.6	59.2	35.4	25.5	185.6
2011	68.0	62.0	36.9	26.2	193.1
2012	70.4	65.0	38.5	26.9	200.7
2013	72.8	68.0	40.0	27.6	208.4
2014	75.3	71.2	41.6	283.0	216.4
2015	77.8	74.5	43.2	29.0	224.5
2016	80.3	77.9	44.8	29.8	232.9

*** Sources: Atlantic, Pacific, and Latin America, INS Form (-92, U.S. Department of Commerce; U.S./ Canada Transborder, Transport Canada.**

Table 6 U S Commercial air carriers-total scheduled U S passenger traffic [27]

U.S. COMMERCIAL AIR CARRIERS 1/ TOTAL SCHEDULED U.S. PASSENGER TRAFFIC						
FISCAL YEAR	REVENUE PASSENGER ENPLANEMENTS (Millions)			REVENUE PASSENGER MILES (Billions)		
	DOMESTIC	INTERNATIONAL	SYSTEM	DOMESTIC	INTERNATIONAL	SYSTEM
Historical*						
1999	610.9	54.9	665.8	482.4	170.1	652.4
2000	641.2	56.4	697.6	512.8	181.8	694.6
2001	626.8	56.7	683.4	508.1	183.3	691.4
2002	574.5	51.2	625.8	473.0	158.2	631.3
2003	587.9	54.1	642.0	492.8	155.9	648.6
2004E	627.2	61.3	688.5	540.0	177.4	717.4
Forecast						
2005	649.6	68.0	717.5	559.7	198.0	757.8
2006	682.7	72.2	754.9	592.0	213.6	805.5
2007	709.6	76.0	785.6	618.2	226.8	845.0
2008	731.3	79.7	811.0	639.6	238.9	878.6
2009	754,0	83.4	837.4	662.8	250.6	913.4
2010	777.8	87.1	864.9	687.9	262.2	950.1
2011	801.8	90.8	892.6	712.6	273.8	986.4
2012	826.3	94.6	921.0	738.2	285.7	1023.9
2013	852.1	98.6	950.7	765.2	297.9	1063.1
2014	879.2	102.7	981.9	794.5	310.4	1104.9
2015	907.8	106.9	1014.7	826.2	323.2	1149.4
2016	937.3	111.2	1048.6	858.5	336.3	1194.8

* Source: Forms 41 and 298-C, U.S. Department of Transportation.
1/ Sum of Mainline Air Carriers and Regionals/Commuters

A review of the total scheduled passenger traffic in Table 6 indicates that the growth rate is about 3.2% from 2004 to 2010. Revenue passenger miles are expected to grow from 717.4 to 950.1 billion miles. Similarly, the emplanements are also expected to grow between 2004 and 2010, at a rate of 11.6% in the domestic sector, 4.2% in the international sector, and 2.6% system wide. The overall trend in the aviation industry is that all sectors are expected to grow, signifying that the facilities at US airports need improvement to handle the forecast increase in passenger traffic. More forecasts from the FAA Terminal area forecasts are posted in Appendix C.

1.6 Global Market Forecast

Figure 9 shows Airbus Industries published forecasts for the top 20 passenger markets in 2023 [1]. In this forecast, they have used a modest 3.2% growth for passengers in the US domestic market for the period between 2004 and 2023.

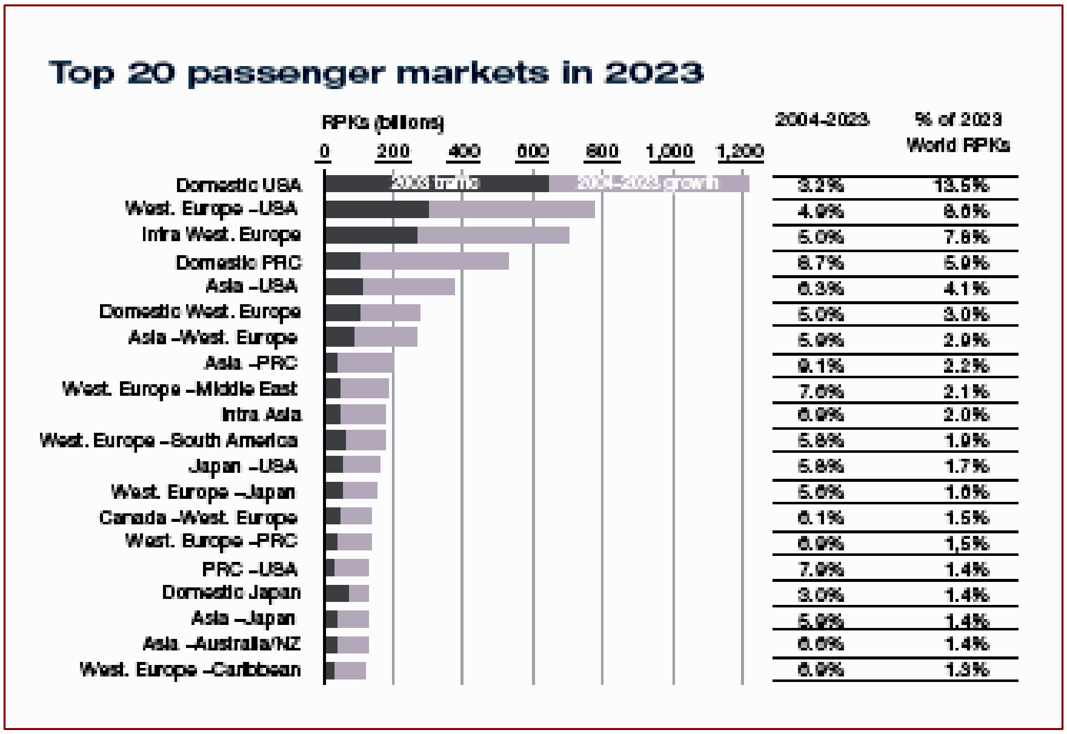


Figure 9 Top 20 passenger markets 2004-2023 [1]

The Revenue Passenger Kilometers (RPK) is forecast to grow at 13.5% per annum from 2004. To quote from this report, “China and India have the potential to reshape the travel industry.” The forecast mentions that the two countries are going through an economic transformation that may turn them into major consumer markets within the next twenty five years. Their combined purchasing power could be five times greater than that of the US today [1].

Similar growth is anticipated in the domiciled airlines in various regions of the world as shown in Figure 10. Projected growth for North America is at 4.9% from 2004 to 2013 and at rate of 3.5% from 2014 to 2023 and an average of 4.2% over the 20 year

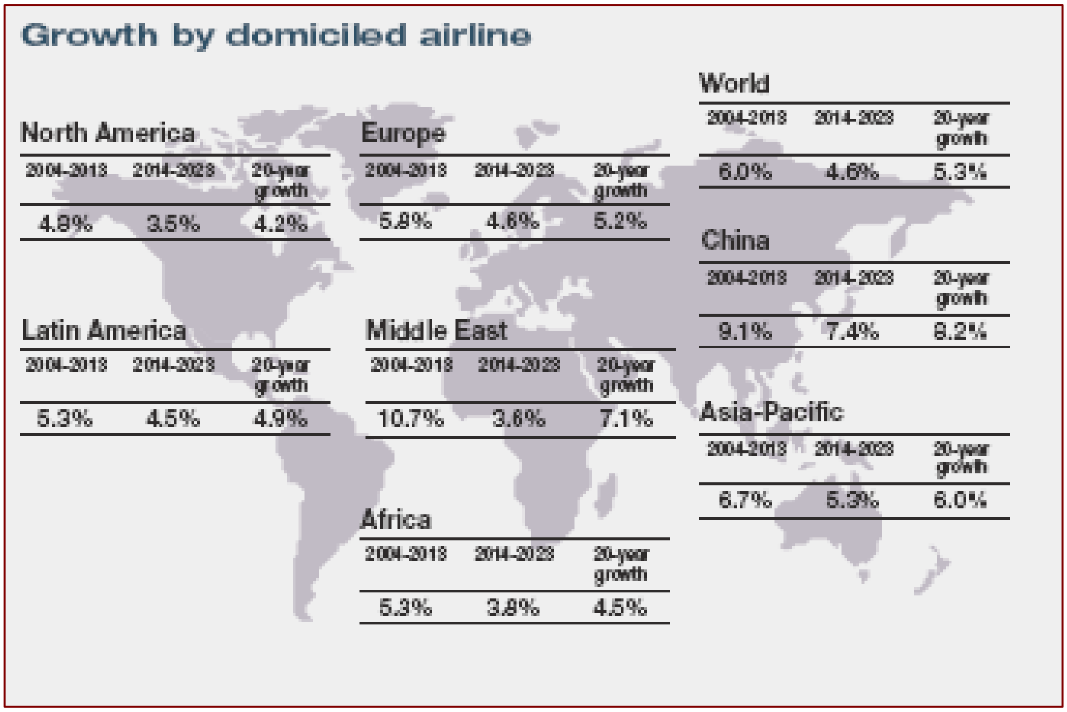


Figure 10 Airline growth forecast by domiciled airline [1]

period. China and African countries are new entries and they are projected to have 9.1% and 5.3% growth over the same forecast period, respectively. Spillover from this growth in air traffic will be felt at DFW in the international passenger and cargo traffic. Since 2004, more new international cargo carriers like Singapore Airlines, Air France, Lufthansa and airlines from Caribbean countries have begun flying into DFW. [Source DFW statistics URL: http://www.dfwairport.com/stats/ web site accessed on 10-15-06]

<u>1.7 Boeing Aircraft Co Forecast</u>

The Boeing Airplane Company has made a similar forecast of 3.5% passenger growth in North America from 2005 to 2024 as shown in Figure 11. Asia-Pacific is expected to achieve a 5.1% growth over the same period. Boeing has appraised the world wide economic activity and its impact on US imports and exports. Boeing has projected a growth rate of 8.8% for China, which is rapidly advancing economically.

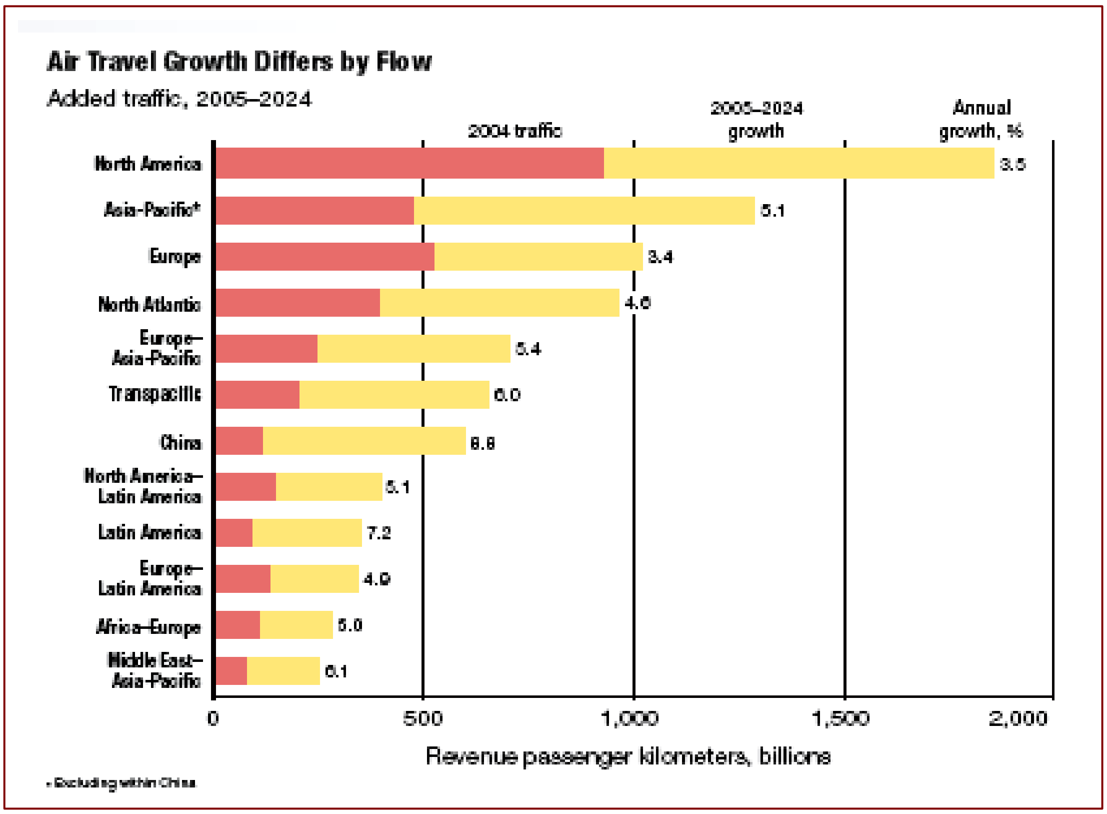


Figure 11 Air travel growth in different regions [9]

Other countries, like Africa, South America are also poised for greater growth, as these countries improve economically and the projected growth in GDP and employment coupled with a propensity for international travel.

As depicted in Figure 11, Boeing Airplane Co forecast for regional flow starts in 1985 and projects the expected growth in Revenue Passenger Kilometers (RPK) to rise from 925.181 in 2004 to 1856.806 by year 2024, an increase of 3.5% over the 20 year period within the North American travel market. China to North America is forecast to grow at 8% per year over the same period. North America to Southeast Asia is projected to grow at 7.3% per annum over the twenty year period. These expected increases in traffic will have a major impact for all airports in the US. DFW, which is expected to attract more international flights in the near future, will have to plan and execute improvements inline with anticipated growth in traffic. The introduction of a PT is an alternative, which is expected to reduce delay to traveling public by eliminating the active runway crossing and continuous departures on the inboard parallel runway 17R and 18L.

Figure 12, shows the anticipated world air traffic by each region. Within North America, the expected growth rate is at 3.6% per year from 2005 to 2024. China to North American destination is forecast to grow at 8.0% per year from 2005 to 2024 and Europe to North America is forecast to grow at 4.6% for the same period. The traffic is expected to have impressive growth over the next twenty years which will put a demand on resources at the airports in US to process flights and reduce delay in the airfield.

World Traffic by Regional Flow

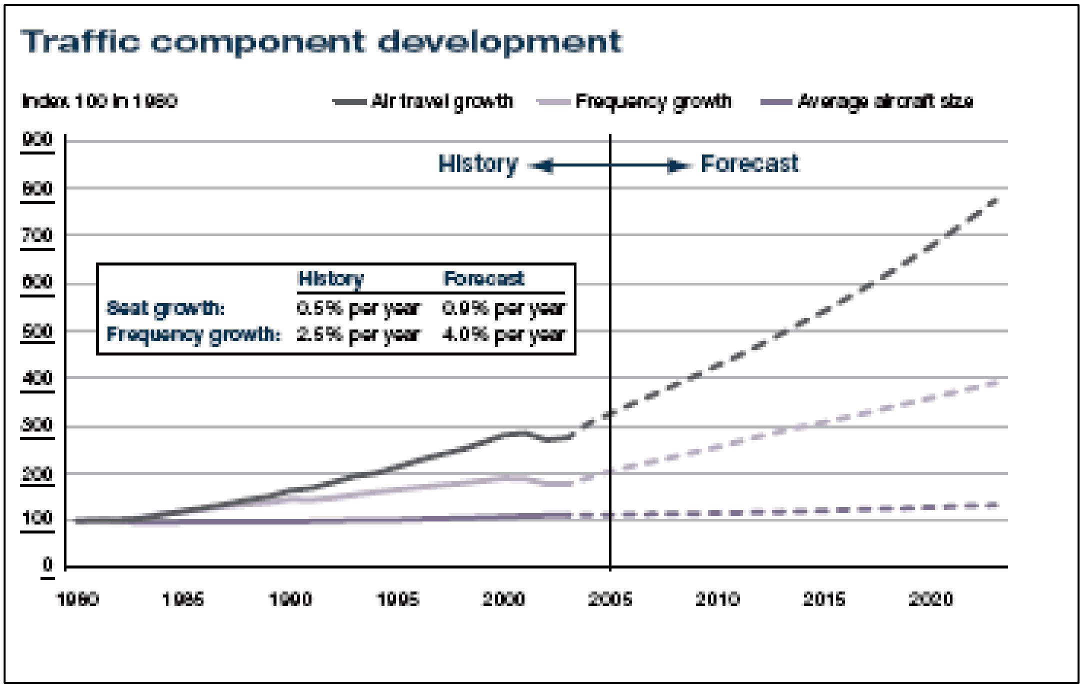
Appendix A

RPKs in billions	1985	1990	1995	2000	2001	2002	2003	2004	2014	2024	2005–24 %/year
Africa–Africa	13.540	14.689	14.775	19.422	19.947	21.203	22.475	23.868	54.278	78.086	6.1
Africa–Europe	43.037	47.732	57.178	99.407	96.226	97.188	99.132	105.179	191.719	278.757	5.0
Africa–Middle East	5.156	7.394	6.479	9.811	10.596	13.192	13.852	13.921	29.939	44.252	6.0
Africa–North America	1.220	1.298	2.640	4.416	4.615	4.292	4.378	3.765	12.093	18.153	8.2
Africa–Southeast Asia	0.280	0.909	3.226	3.244	3.357	3.623	3.650	3.858	9.173	15.799	7.3
Central America–Central America	12.820	14.306	18.267	23.950	23.016	23.382	24.785	25.504	57.648	98.674	7.0
Central America–Europe	17.868	27.647	44.193	66.361	69.750	68.120	69.800	75.733	113.100	167.090	4.0
Central America–North America	43.339	63.714	71.097	90.050	88.609	87.723	92.000	104.880	155.060	234.559	4.1
Central America–South America	3.287	3.499	4.271	7.256	7.169	7.097	7.147	8.219	16.820	28.067	6.3
China–China	8.436	18.254	56.624	73.634	84.630	97.198	96.254	110.209	290.939	596.341	8.8
China–Europe	9.577	16.927	26.611	40.093	40.173	42.583	34.492	45.184	91.351	148.863	6.1
China–North America	7.807	13.434	21.630	33.171	36.179	33.212	24.909	33.222	80.015	154.144	8.0
China–Northeast Asia	6.754	10.916	15.998	19.434	18.423	24.503	20.092	26.321	48.665	81.184	5.8
China–Oceania	3.002	5.810	9.234	12.130	12.434	13.190	10.609	15.011	22.239	32.772	4.0
China–Southeast Asia	8.081	14.489	23.032	29.330	31.677	36.903	27.677	41.150	68.307	109.418	5.0
CIS Region–CIS Region	175.814	224.240	63.395	39.442	43.465	46.942	50.228	54.749	85.208	119.026	4.0
CIS Region–International	15.863	24.098	33.918	42.904	48.052	51.416	56.403	63.002	112.151	169.349	5.1
Europe–Europe	170.049	258.346	306.636	440.104	449.306	453.799	474.700	523.119	729.993	1017.708	3.4
Europe–Middle East	43.436	41.512	44.920	65.011	59.810	58.613	58.906	67.742	126.156	181.997	5.1
Europe–North America	158.599	230.689	278.895	419.961	373.765	345.955	349.471	387.913	660.518	960.947	4.6
Europe–Northeast Asia	17.025	29.347	46.550	63.587	56.829	53.317	48.252	57.833	119.520	180.184	5.8
Europe–South America	12.250	22.309	32.930	53.162	52.098	49.233	49.479	57.890	111.465	178.954	5.8
Europe–Southeast Asia	26.800	46.386	65.684	95.756	95.948	96.428	94.982	104.480	180.767	269.162	4.8
Europe–Southwest Asia	11.859	17.470	20.666	26.227	27.496	27.568	29.498	35.692	64.041	105.532	5.6
Middle East–Middle East	17.685	19.462	20.713	27.834	27.138	27.546	28.096	32.029	55.445	80.659	4.7
Middle East–North America	5.012	6.560	10.309	16.053	12.040	10.354	9.629	12.226	29.612	44.125	6.8
Middle East–Northeast Asia	0.069	0.071	0.328	1.452	1.162	1.220	1.202	2.230	7.724	15.523	10.2
Middle East–Oceania	0.000	0.000	0.000	0.001	0.001	0.432	1.189	4.102	14.953	24.105	9.3
Middle East–Southeast Asia	15.136	10.980	20.584	23.960	22.858	24.001	26.401	29.200	56.681	84.742	5.5
Middle East–Southwest Asia	14.505	16.583	23.194	29.414	29.855	31.050	33.844	35.604	69.681	110.478	5.8
North America–North America	470.633	589.055	670.470	857.471	812.763	783.461	828.273	925.161	1273.262	1856.906	3.5
North America–Northeast Asia	46.880	96.162	121.512	140.150	127.536	121.159	102.985	106.989	224.193	303.398	5.3
North America–Oceania	11.008	16.972	24.135	29.950	27.554	26.452	25.922	30.055	43.131	65.196	3.9
North America–South America	14.460	19.615	35.885	47.248	44.791	42.686	37.564	40.569	98.439	162.511	7.2
North America–Southeast Asia	8.013	15.324	25.896	32.050	29.326	30.499	26.839	32.030	75.315	130.774	7.3
North America - Southwest Asia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.330	1.855	16.402	13.4
Northeast Asia–Northeast Asia	32.273	50.016	67.404	79.032	80.217	85.031	86.136	83.552	155.004	232.803	5.3
Northeast Asia–Oceania	6.055	12.879	31.823	24.066	22.502	24.505	22.789	26.115	48.838	72.326	5.2
Northeast Asia–Southeast Asia	15.998	32.512	44.335	48.515	47.767	54.430	45.721	56.237	103.597	161.338	5.4
Oceania–Oceania	18.614	26.241	42.671	49.244	50.721	50.214	55.486	64.919	76.097	100.208	2.2
Oceania–Southeast Asia	12.233	24.286	33.065	46.190	47.576	46.626	41.962	49.599	78.896	115.263	4.3
South America–South America	29.477	33.841	39.670	53.523	50.793	52.673	47.932	52.556	128.472	220.982	7.4
Southeast Asia–Southeast Asia	17.665	29.891	53.811	53.650	57.030	60.566	59.355	71.920	133.985	213.785	5.6
Southeast Asia–Southwest Asia	5.658	5.604	8.104	10.936	11.591	12.576	12.513	14.890	27.174	45.896	5.8
Southwest Asia–Southwest Asia	10.471	11.602	15.205	16.010	16.818	17.416	17.712	21.254	53.611	99.145	8.0
Rest of the World	5.614	7.242	8.862	13.716	14.880	15.226	15.839	18.784	37.151	72.577	7.0
World Total	**1573.158**	**2181.501**	**2567.213**	**3378.330**	**3287.300**	**3274.810**	**3289.560**	**3699.717**	**6224.160**	**9496.962**	**4.8**

Boeing • Current Market Outlook • 2005 • Appendices 10

Figure 12 World Traffic by Regional Flow [9]

More passengers mean more seats to be filled and more flights to carry them from point to point around the world as shown in Figure 13. Therefore, all forecasts reviewed in the literature [1, 42] have considered this aspect of growth in seats per aircraft and the projected increase in frequency of operations that airlines are



contemplating in

Figure 13 Traffic component developments [1]

the near future. In this connection, it is worth observing that the traffic component forecast by Airbus Industries shown in Figure 13 is based on the expected increase in load factors at 0.9% per year on scheduled airlines and the low cost carriers (LCC). The forecast considers the planned increase in scheduled flight frequencies at 4.0% per year and the addition of new destinations to their growing markets around the world.

1.8 DFW Airport Development Plan Forecast

Hansen et al. [37] conducted an empirical analysis of DFW capacity enhancements and refers to a forecast made by DFW Airport Development Plan (ADP) in June 1991 that the airport expected to handle 1.2 million operations in the year 2010. DFW has been operating as a major hub airport for American Airlines (AA) and Delta Airlines who accounted for more than 80% of its passengers connecting or transferring at DFW. The maximum daily throughput rate was estimated at 119.47 arrivals/hr and in all weather conditions estimated at 115.27 arrivals/hr. Based on these forecasts; several studies have since been completed at the DFW/ADP to improve the operating environment at DFW. One such study performed by Leigh Fisher Associates (LFA) in 1996 led to the conception of introducing the PT system at DFW and to increase the length of runway 17C and 18R to 13,400 ft [45].

1.9 Review of Forecasts

The summary of forecasts made by various agencies is shown in Figure 14. The analysis of forecast growth in passenger traffic from different sources yields an anticipated growth rate of 3.5% to 4% per year through year 2030. The terminal area forecast from FAA predicts an increase of 3.5% per year for air traffic operations at DFW [34]. For this research, it is forecast that the air traffic operations at DFW will increase at the rate of 3.5% per year from 2004 to 2010 inline with the overall growth projected by the FAA for US airline industry. The 2004 actual flight schedule data is obtained from DFW database for every day of the year for all scheduled flights at DFW.

The aircraft type information for each airline and the runway used by each flight at DFW is obtained from the flight tracks/operations database of the DFW Environmental Affairs Department (EAD).

Aviation Forecasts

FAA Aerospace Forecast	2005-2016	4.4% per year
ICAO Outlook for Air Transport	2002-2015	4.4% per year
BOEING Current market outlook	2005-2024	4.8% per year
AIRBUS Global market forecast	2004-2023	5.3% per year
EUROPEAN UNION Flight movements Forecast Vol. 1 & 2	2005-2011	3.7% per year

Figure 14 Summary of forecasts

A detailed analysis of the air traffic data at DFW, which is shown in Table 7, indicates the operations on July 22, 2004 is the highest at 2,477 movements in a day that included scheduled commercial flights, cargo traffic, airtaxi, business jets, military, general aviation, and unscheduled aircraft movement. Touch and go operations and aircraft flight training is strictly prohibited at DFW. The data obtained from the EAD for July 29, 2004 gives the flight number, arrival and departure time and runway assignment by the ATC. The detailed arrival and departure schedule obtained from the DFW scheduling department gives the flight number, arrival and departure time, origin, and destination cities, and the gate assignment for each flight. The flight schedule timetable received from the Official Airline Guide (OAG) for July 22, 2004 give information on flight schedule for all airlines serving DFW with flight number, scheduled arrival and departure time, origin and destination cities and the aircraft type used. The three data files are reviewed, analyzed, and consolidated into one composite file for the Visual Simulation Model (SIMMOD) input data. The procedure used to accomplish this effort is described in Chapter 6.

The FAA operations data for 2004 showed that the operations at DFW were at a maximum of 2,477 movements in July 2004. A detailed review of the data for July 2004, showed that the peak days were on 22 July 2004, when operations at 2,477, and on 29 July 2004 when it was 2454. Both peak operations days were in July 2004. The lowest number of operations was 1,647 on 6 March 2004. The mean of 2,284 operations per day was on 26 June 2004. The traffic operations for 2004 by month, the maximum minimum, mean and range for each month is shown in Table 7.

Table 7 The FAA data for 2004 operations for each month

2004 FAA TOTAL OPERATIONS DATA
PER DAY

Month	Total	Maximum	Minimum	Mean	Range
JAN	68,425	2381	1950	2207	431
FEB	64,039	2358	1653	2208	705
MAR	69,317	2384	1647	2236	737
APR	67,961	2421	1981	2265	440
MAY	69,861	2405	1976	2254	429
JUN	68,511	2434	2038	2284	396
JUL	70,571	2477	1837	2276	640
AUG	70,650	2421	1931	2279	490
SEP	66,113	2408	1737	2203	671
OCT	67,714	2394	2147	2184	1201
NOV	64,930	2361	1665	2164	696
DEC	65,450	2275	1719	2111	556
TOTAL	813,542				

Source: www.apo.data.faa.gov accessed on 8-23-06

The total traffic was at a maximum in August 2004, indicating the summer traffic, and the maximum was 2,477 operations per day in July 2004. The FAA uses the mean traffic volume to forecast the future traffic at each airport.

1.10 Air Cargo Forecasts

DFW is expecting a huge increase in cargo traffic from Europe and the Far East. The statistics from DFW for 2004 showed that UPS and FedEx led the increase in cargo traffic with UPS logging ten flights daily. Other airlines like, Singapore Airlines, Air France, Lufthansa and several small US cargo carriers have joined them over the years [www.dfwairport.com/stats/ accessed on 11-15-06]. DFW is embarking on an ambitious plan to construct new cargo buildings on the east and west side of the airfield with an intention to attract more cargo carriers.

Table 8 Air cargo forecasts [27]

AVIATION DEMAND FORECASTS MAINLINE AIR CARRIERS-AIR CARGO
FISCAL YEARS 2005-2016

AVIATION ACTIVITY	HISTORICAL			FORECAST			PERCENT AVERAGE ANNUAL GROWTH				
	2000	2003	2004	2005	2006	2016	00-04	03-04	04-05	05-06	04-16
Total Cargo RTMs (Millions)											
Domestic	14,699	14,972	15,542	16,143	16,707	22,884	1.4	3.8	3.9	3.5	3.3
International	15,358	18,542	19,567	20,881	22,248	40,940	6.2	5.5	6.7	6.5	6.3
System	30,057	33,514	35,108	37,024	38,954	63,824	4.0	4.8	5.5	5.2	5.1
Total RTMs-Passenaer Airlines											
Domestic	4,415	3,819	3,752	3,842	3,918	4,577	-4.0	-1.8	2.4	2.0	1.7
International	7,790	6,775	7,884	8,346	8,820	14,902	0.3	16.4	5.9	5.7	5.4
System	12,205	10,594	11,636	12,187	12,738	19,479	-1.2	9.8	4.7	4.5	4.4
% RTMs--Passenaer Airlines											
Domestic	30.0	25.5	24.1	23.8	23.5	20.0					
International	50.7	36.5	40.3	40.0	39.6	36.4					
System	40.6	31.6	33.1	32.9	32.7	30.5					
Total RTMs--All-Cargo Airlines											
Domestic	10,284	11,153	11,790	12,302	12,789	18,307	3.5	5.7	4.3	4.0	3.7
International	7,568	11,767	11,883	12,535	13,428	26,038	11.5	-0.7	7.3	7.1	6.9
System	17,852	22,920	23,472	24,837	26,216	44,345	7.1	2.4	5.8	5.6	5.4
% RTMs--All-Cargo Airlines											
Domestic	70.0	74.5	75.9	76.2	76.5	80.0					
International	49.3	63.5	59.7	60.0	60.4	63.6					
System	59.4	68.4	66.9	67.1	67.3	69.5					
Carao Aircraft 1/	1,064	993	974	996	1,011	1,312	-2.2	-1.9	2.3	1.5	2.5

Source:2000-2004; U.S. Air Carriers, Form 41, U. S. Department of Transportation.
2005-2016; FAA Forecasts 1/ Historical and forecast data on a calendar year basis

The FAA air cargo forecast is shown in Table 8 for fiscal year 2005 to 2016. The prediction is that the growth from 2004 to 2016 is expected rise at the rate of 3.3% in the domestic sector and 6.3% in the international market. Systemwide the forecast shows a 5.1% increase for the same period.

1.11 Organization of the Dissertation

This dissertation document is organized as follows: Chapter 1 provided a brief overview on the problem facing the Operational Evolution Airports (OEP) airports operating with parallel runways and the expected growth in traffic due to the increase in population and its impact on air travel demand. Finally, it introduces the concept of a PT at DFW and the research method chosen to analyze the airport operations.

Chapter 2 enumerates the details of the runway incursion problem, runway crossing delay, Taxi In time, Taxi Out time and other delays that are encountered at airports with parallel runway operations.

Chapter 3 focuses on a literature review and recapitulates the various research efforts influencing the decision to introduce the PT system at DFW and its current status.

Chapter 4 describes the problem statement and the methods contemplated to address the PT system at DFW.

Chapter 5 explains the methods used for data collection, compilation, collation, generation, and input to Visual SIMMOD software for simulation, analysis, animation and reporting.

Chapter 6 describes the simulation model VS and the endeavor undertaken to accomplish the goal of this research.

Chapter 7 deals with actual flight track analysis to verify the location of the PT centerline distance criteria and the aircraft height criteria for safe PT operations. A detailed statistical analysis is performed to estimate the probability of an aircraft flying below the threshold height recommended by the FAA/Airport Obstruction Standards Committee (AOSC).

Chapter 8 presents an evaluation of PT operations and reports the research findings. In this chapter, the airport efficiency, the runway capacity and measures of effectiveness (MOE) is discussed while comparing the baseline 2004 operations with the future 2010 operations.

Chapter 9 conducts a critical evaluation of the airfield geometry after the introduction of the PT and outlines development of specific procedures for standard taxiway operations and guidelines for a trouble free PT system implementation at DFW.

Chapter 10 provides a summary of the research findings, conclusions and recommendations for further research needs and opportunities in PT operations in the Operational Evaluation Airports (OEP) in the US.

CHAPTER 2

PROBLEM STATEMENT

2.1 Introduction

DFW is located northwest of the city of Dallas and northeast of the city of Fort Worth. On DFW's south side lies the city of Arlington and Grand Prairie. On DFW's north side is the city of Grapevine. The airport is situated on 18,000 acres of property with sufficient room to accommodate additional runways and taxiways to meet the future growth in air traffic operations. It is the second largest airport in the US and is the busiest airport in Texas and continues to attract more air carriers and air cargo because of its location and its proximity to major freeways like I-35 (north-south) and I-20 (east-west) that connect to major cities on both sides of the state of Texas [23]. Fort Worth, Arlington and Grand Prairie are the home for major defense contractors who deal with domestic and foreign military equipment and supplies. Alliance Airfield in Fort Worth is the primary location for air cargo facilities and aircraft maintenance

2.2 DFW configuration

The current configuration as shown in Figure 4 (Section 1.2) requires that aircraft arriving on the main arrival runways 13R, 18R/36L, 17C/35C, 17L/35R, and 31R cross the main dedicated inboard departure runways 18L/36R and 17R/35L to get to the terminal areas.

In several instances, depending on the direction of air traffic flow and whether or not aircraft are arriving on the three outboard runways, many arriving aircraft have to cross two runways (both arrival and departure) to get to the terminal area. Similarly, the departing aircraft from the terminals or cargo aprons have to cross departure runway or arriving runway depending on the assigned departure runways 13L, 17R/35L, 18L/36R and 31L Runway 18R/36L and 17C/35C are also used for departures depending on the destination of the flight or arrival frequency. It is estimated that on average DFW experiences over 1,700 runway crossings daily [2, 18, 19, 20].

2.3 DFW data

Longitude: W97.0372°. Latitude: N32.8960° Maximum elevation: 607’ at 18R.

Prevailing wind direction: South to North

Table 9 DFW runway data (2005)

Runway ID	Length	Width
13R/31L	**9,301'**	**150'**
18R/36L	**13,400'**	**150'**
18L/36R	**13,400'**	**200'**
17R/35L	**13,401'**	**200'**
17C/35C	**13,401'**	**150'**
13L/31R	**9,000'**	**200**
17L/35R	**8,500'**	**150'**

The runway data is shown in Table 9. There are five terminal buildings in operation at DFW; terminals A, B, C, D E and several cargo facilities on both sides. Appendix I contains the layout of the five terminals and the gates. Under existing operations, the Local Air Traffic Controller conducts all runway crossings before releasing the aircraft to the Ground Controller. This situation increases the Local Controller's workload and creates radio frequency congestion. During major arrival and/or departure periods, trade offs in airfield efficiency have to be made to safely balance all operations [10, 25, 54]. This balancing partially consists of controllers delaying departing aircraft so that arriving aircraft can cross the departure runways to get to the terminal area. Because arrivals stack up at the various runway-crossing points, the Local Controller must "gap" departures to allow these crossings to occur. These situations are most evident during the peak traffic times. In an effort to improve safety and airfield efficiency by reducing the number of active runway crossings (with the added benefit of reducing runway incursion potential and reducing arrival and departure delays), a PT concept is proposed. The concept includes new PTs on the East and West sides of the Airport. DFW airport staff proposed introducing a PT operation in 1996 as part of a capacity enhancement study.

Leigh Fisher Associates [45] studied this concept in detail and developed a working paper for the DFW Airport Board in 1996.

In 2002, Davis [19] conducted a detailed study for implementing a PT system at DFW. In 2003, Davis [20] analyzed the obstruction free zone (OFZ) criteria and proposed that the PT should be centered about 2650 ft from the end of the north-south parallel runways 17R/35L and 18L/36R at DFW. In 2003, a demonstration was conducted in a flight simulator at the NASA's Ames Lab at Moffet field in California [10]. These studies revealed that the PT allowed the aircraft to go around the active departure runway without crossing the runway to reach the terminal buildings, thus increasing safety of operations and departure rate. There was a reduction in communication between the cockpit and the tower during the PT operation. This allowed the flow of arrival aircraft to reach the terminal without having to wait for clearance from the Local Controller or Ground Controller to cross the departure runway. This would greatly increase the efficiency of operations, reduce runway incursions and considerably decrease communications between the Ground Controllers and the cockpit [10]. Figure 15 shows the layout of DFW used in the above studies.

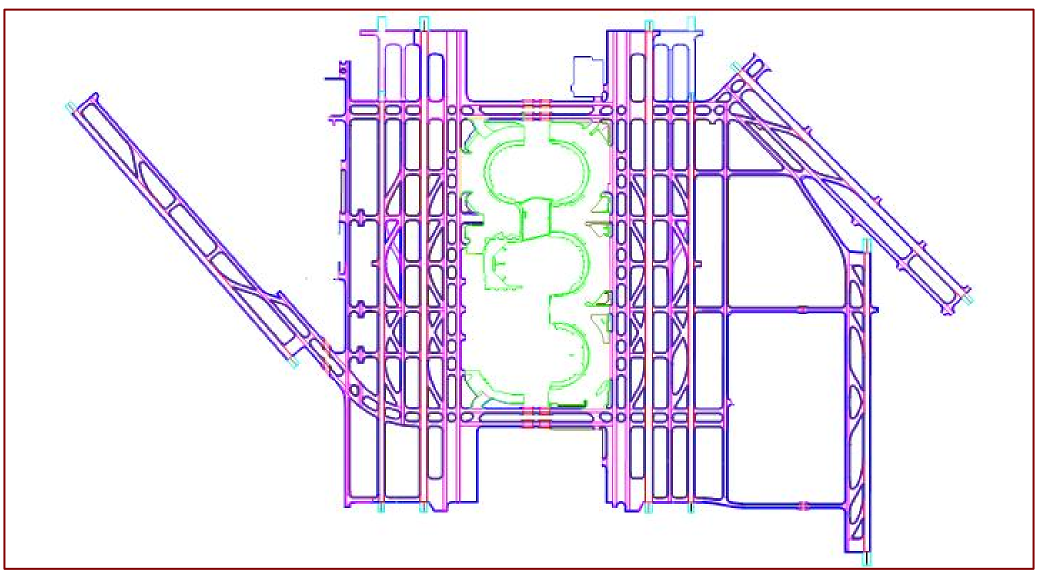


Figure 15 Configuration of runways at DFW [2004]

Daily aircraft operations at DFW include scheduled flights, cargo flights, air taxi, general aviation flights, itinerant military aircraft and helicopters. This PT research forecasts the average operations per day at DFW to increase at a rate of 3.5% per year from 2004 to 2010. In 2010 all five terminals are expected to be in operation and additional cargo facilities have been added on the east and west side of the airfield to accommodate the expected growth in cargo traffic. Figure 16 shows the proposed PT layout and vital dimensions that are used in the design based on various studies. The distance to the centerline of PT is set at 2,650 feet from the end of the north south parallel runway.

The forecast is shown in Table 10, tabulating the actual operations per year from 2000 and the forecast operations from 2004. The actual total for 2004 is 816,910 and the FAA had forecast 816,000 operations in the Terminal Area Forecast Summary [31]. The FAA has revised their forecast in 2006, for year 2010 downward to 827,076 from 1,000,000 operations per year, predicting a growth rate of 2.5% per year or less from 2007.

Table 10 Actual and forecast of operations at DFW

Year	Actual operations per year	Forecast operations per year	Actual average operations per day	Forecast average operations per day	Change	FAA 2006 Forecast [32]	Change
2000	878,461		2,295				
2001	835,727		2,147		-4.9%		
2002	763,211		2,095		-8.7%		
2003	770,706		2,097		1.0%		
2004	816,910		2,284		6.0%		
2005	718,270	845,502	2,276	2,364	3.5%		
2006		875,094		2,447	3.5%	752,036	
2007		905,723		2,532	3.5%	771,094	2.5%
2008		937,423		2,621	3.5%	790,657	2.5%
2009		970,233		2,713	3.5%	810,741	2.5%
2010		1,004,191		2,808	3.5%	827,076	2.0%

[Source: FAA airport actual operations data: ATADS/Towers/the FAA website accessed on 3-25-06]

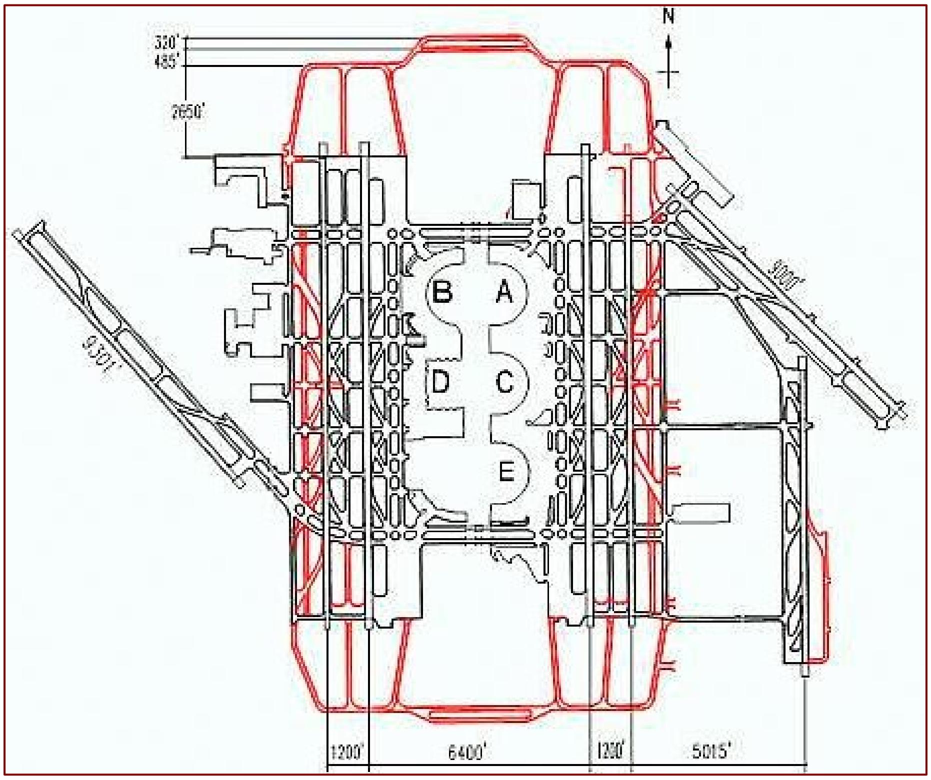


Figure 16 Proposed PTs and taxiways at DFW (2005)

[Source: DFW Capital Development Program office]

In Figure 16, the PT system layout is shown on both ends of the four parallel runways. The PT will enable the arrival aircraft to taxi without waiting for clearance from Ground Controllers. The aircraft may have to taxi a longer distance to reach the gate, but the PT system will induce a significant reduction in communications with controllers in the ground control tower and the elimination of runway crossing delay. The aircraft will be able to move in an orderly queue, thus permitting continuous takeoffs on the departure runway without the risk of runway incursions. The aircraft spacing on the takeoff runway is based on the allowable distance between successive aircraft as specified in FAA standards and guidelines as shown in Figure 17 [19].

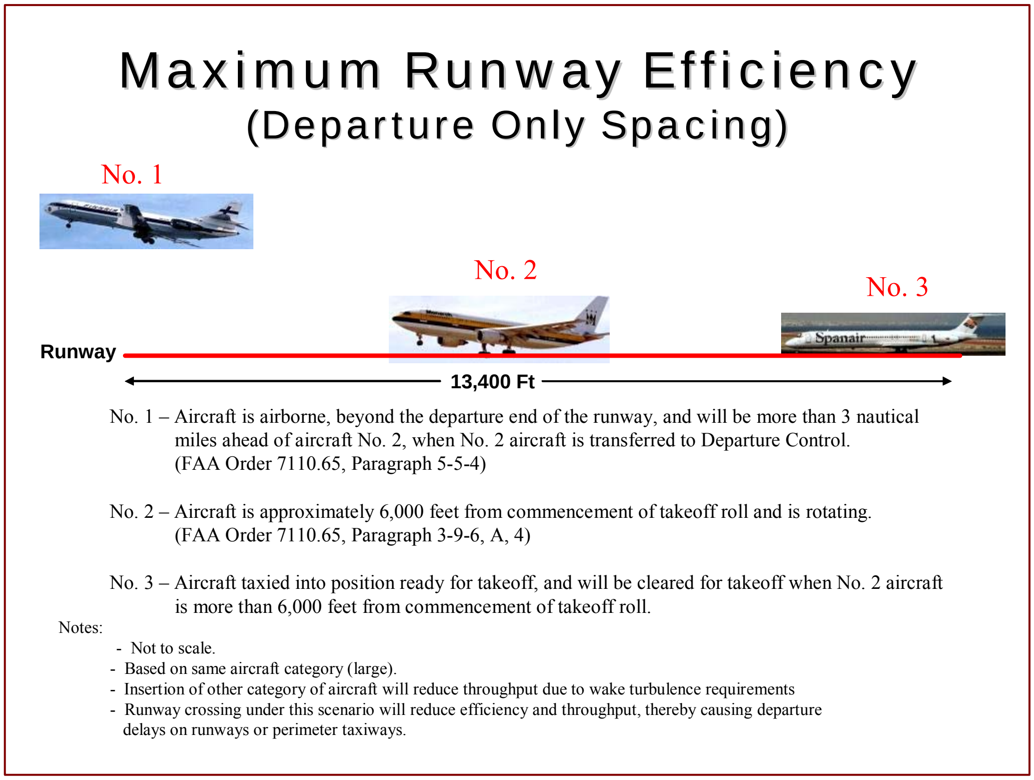


Figure 17 Maximum Runway Efficiency [19]

Based on this Figure 17, the movement of departing aircraft from the primary departure runway 17R/35L and 18L/36R is expected to remain steady during peak hours based on enroute weather, traffic and conditions at the destination airport. It will help the Local Controllers to schedule departures without concern for arriving flights during the PT operations. This departure procedure is replicated in the VS simulation of the proposed PT operations.

2.4 Research project flow chart

The flow chart in Figure 18 shows the order of information development for the research project. Critical aspects to this project include continuing discussions with DFW operations staff and the FAA Runway Safety office staff for input to various guidelines published by the FAA for PT projects over the years.

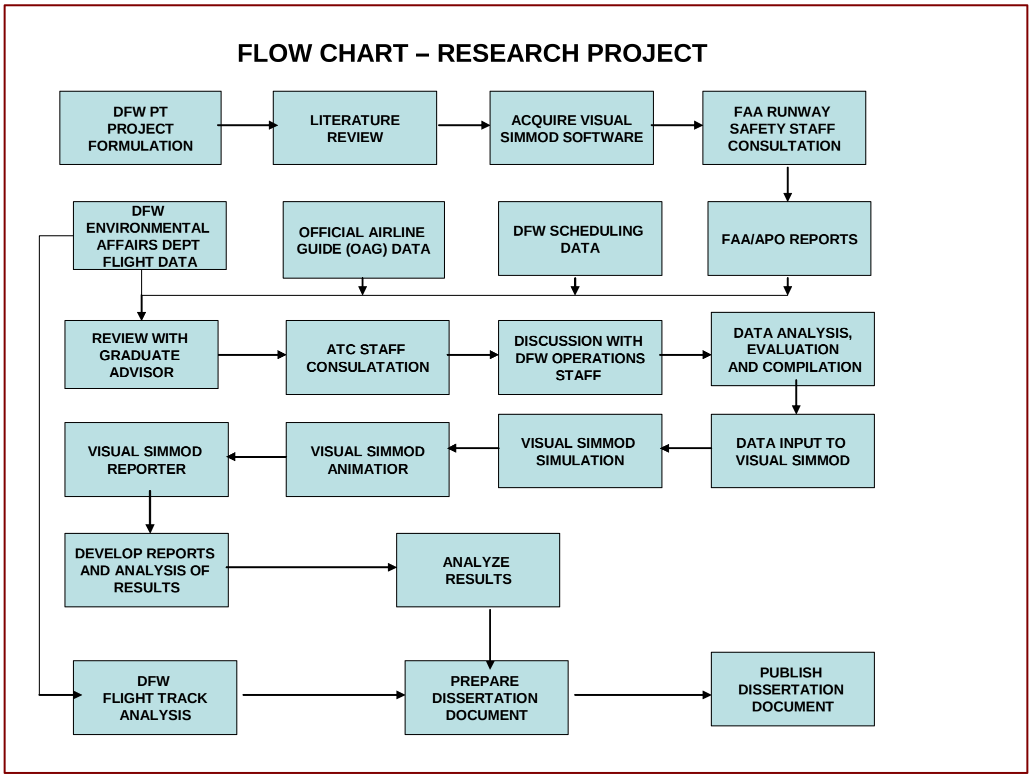


Figure 18 Flow Chart - Research project

The opportunity provided by the FAA/Air Traffic Control (ATC) staff to stay and observe the operations at the west control tower helped the author to better understand the operations at DFW. There are three control towers; they are the East Control Tower, Central Control Tower and West control tower. The location of the control towers is shown in Figure 4 (Section 1.2). East side airfield operations are controlled by East Control Tower and west side airfield operations are controlled from West Control Tower. The Central Control Tower built in 1978 remains open for use in emergency situations and for training of controllers on new equipment and systems.

2.5 Obstacle Free Zone

A detailed evaluation of the obstacle free zone as shown in Figure 19, for PT operations was done by Davis [19]. The results of this analysis was used in developing

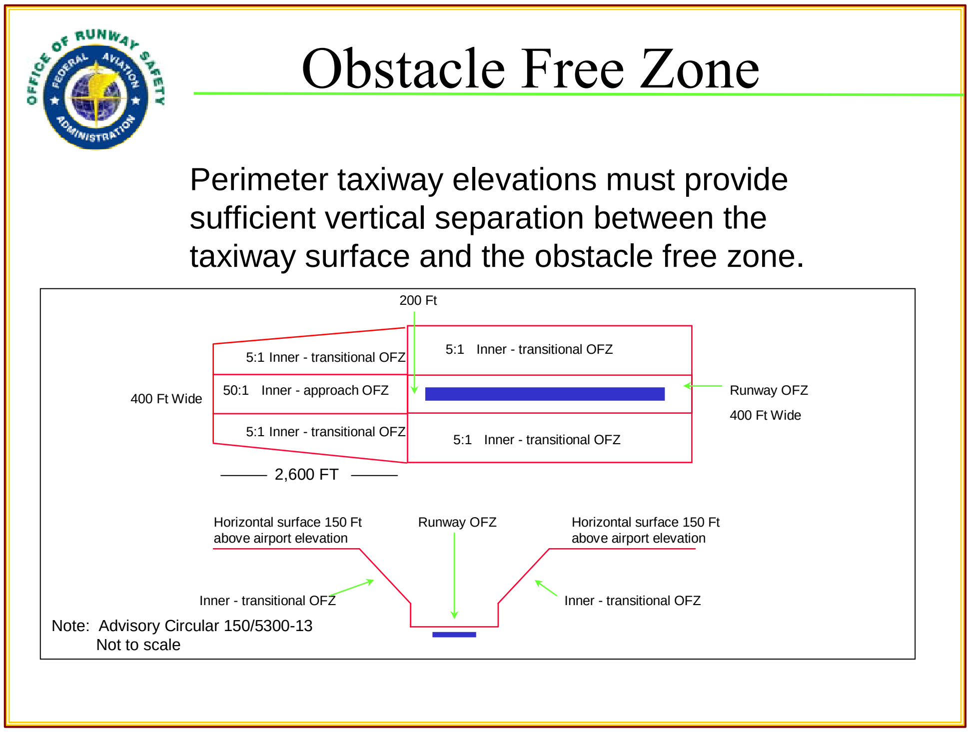


Figure 19 Obstruction free zone Source [19]

the PT alignment on the south and north side. It was found later that the proposed alignment of the PT on the north side was over the existing toll plaza on International

Parkway. Therefore, the north side taxiway bridge centerline had to be moved by 485 ft to the north to clear the toll plaza as shown in Figure 16.

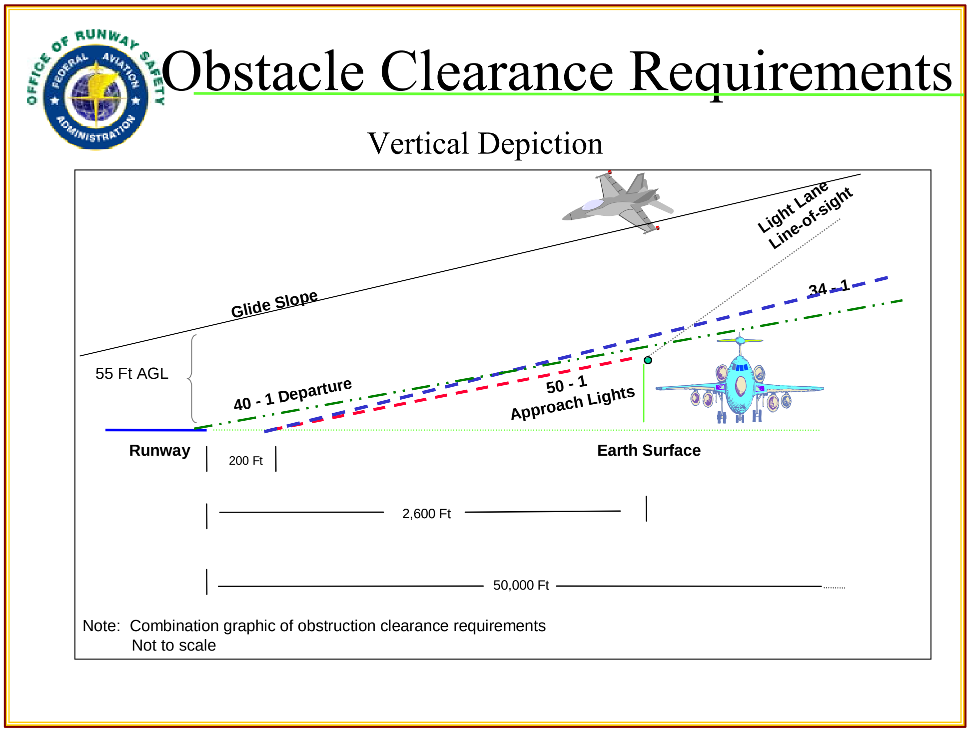


Figure 20 Obstacle clearance requirements Source [19]

Figure 20 shows the approach slope of 34:1 for arrivals and a slope of 40:1 for departure aircraft under expected PT operations. The glide slope at 55 ft above runway end is also shown in Figure 20. As per the FAA Advisory Circular 150/5300-13, the FAA order 8260.3 and the FAA Order 8260.36A, obstacle/object clearance gradient requirements are:

- Approach Lights 50:1 slope
- Runway Object Free Zone 50:1.slope
- Approach Surface Area 34:1 slope

- Departure Surface Area 40:1 slope

These minimum standards were used in the design of the PT at DFW.

2.6 DFW Operations

The "Runway Use Plan" [21] document published by DFW in 1996 is the basic document for assigning arrivals and departures for the 2004 air traffic and the forecast year 2010 airport operations in the VS. The runway use diagram is shown in Figure 21 identifying the South Flow and North Flow operations. The flight operations at DFW include scheduled flights by air carriers, air cargo, air taxi and military. The type of aircraft in use on each flight is obtained from the DFW/EAD database, the FAA/APO/Aviation System Performance Metrics (ASPM) reports, and the Official Airline Guide (OAG)

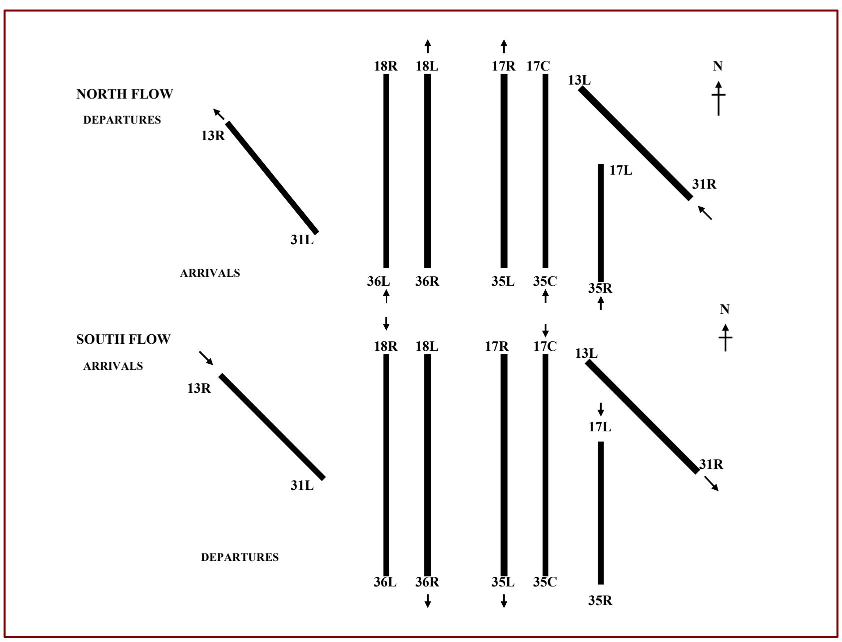


Figure 21 Runway use plan [21]

The pair of taxiways on the new north side bridge over International Parkway connects east and west side of runways thus allowing planes landing on either side to cross over to get to the terminal gates during the North Flow operations. Similarly, the new south side taxiway bridge connects the east and west side runways for easy movement of aircrafts from either side during the South Flow operations.

The scenarios 1 thru 4 use the July 22, 2004, actual flight data obtained from the FAA/APO/ASPM web site, Official Airline Guide (OAG), DFW scheduling, and DFW/ EAD. The flow chart (Figure 18) shows the logic used in collecting information from each source to compile a file consisting a maximum of 2,477 operations for input into VS for 22 July 2004.

In the 2004 scenario, there were four terminals, Terminals A, B, C E, General Aviation apron and cargo aprons on the east and west side. There was a satellite terminal in Terminal A that was used exclusively by American Eagle and a satellite terminal in Terminal E that was used by commuter airlines partnering with Delta Airlines. The two satellite terminals closed after terminal D opened in 2005. American Eagle flights were relocated to Terminal B gates and Delta and its partners reduced their operations in 2005 which reduced the gate requirements.

Scenarios 5 thru 8 use the forecast of 2,808 operations per day in year 2010. The flights are simulated with all five terminals, A, B, C, D, E, General Aviation apron and cargo aprons on the east and west side without PT and all five terminals A, B, C, D, and E with PT. The forecast is based on a 3.5% growth in operations from 2004 to 2010 as shown in Table 14.

Extensive discussion with ATC and DFW operations personnel resulted in an accurate runway assignment for each arriving and departing flight in 2004 and 2010. Appendix G contains the detailed operational flow drawings for taxiway connections for each departure queue and the runway assignment based on the direction of traffic flow.

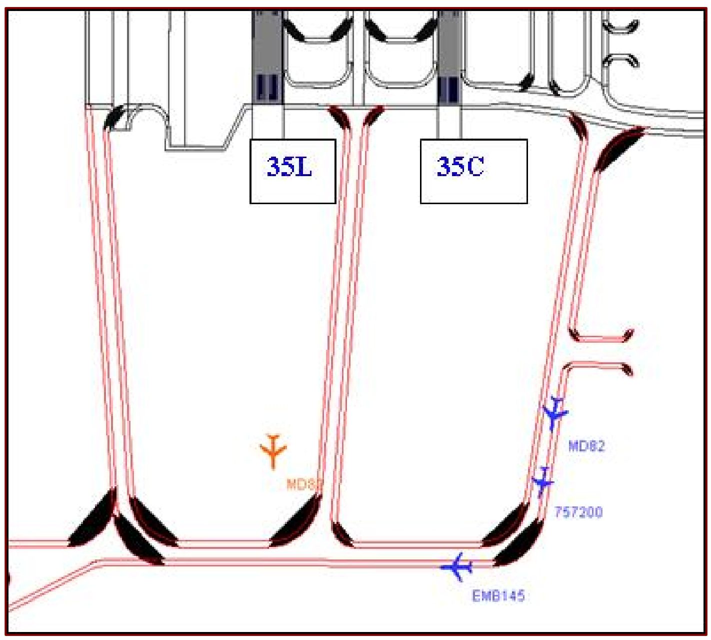


Figure 22 Layout of southeast quadrant PT [Source: DFW]

Figure 22 shows the proposed layout of the southeast quadrant PT or EAT that connects the east and west side runways with a new bridge over International Parkway, allowing aircraft landing on either side to cross over to get to the terminal gates, GA apron and cargo aprons. Figure 22 shows a MD82 (in orange) takingoff from runway 17R to the south, and three aircraft taxiing on the PT to travel to the five terminals, GA apron, and west side cargo aprons. It can be ascertained from Figure 22, why the PT is called EAT because the PT goes around the two parallel runways 35C and 35L leading to the terminal buildings enabling aircraft to travel without having to cross the runways.

CHAPTER 3

LITERATURE REVIEW

3.1 Discussion

The PT is a proposed new concept at DFW to route aircraft around the active departure runway to the gates after they land on the arrival runway. There have been several studies on this subject completed at DFW [10, 18, 19], O'Hare International Airport in Chicago (ORD) [50], and Hartsfield-Jackson International Airport (ATL) in Atlanta [38]. Similar studies are contemplated in the near future to determine the viability of a PT at Los Angeles International Airport (LAX), Detroit Metro International Airport (DTW), Houston Intercontinental Airport (IAH) and St. Louis Lambert International Airport (STL). At DFW and ATL, the concept has moved from the design stage to actual construction at both airports [5, 38].

Leigh Fisher Associates (LFA) performed a detailed study of the PT operations and configurations in 1996 as part of an "Assessment of Runway Crossing delays and Runway Reconstruction Alternatives Dallas/Fort Worth International Airport" [45]. In this research study, LFA took actual measurements for runway crossing time by various types of aircraft in June and October 1995. They evaluated five different configurations for the PT and at different taxiway speed (15, 20, and 25 mph) of movement by aircraft over the PT. When they did this study, there were only four terminals A, B, C and E. Therefore, runway crossing delays were computed mainly for the traffic on the east side of the airfield. They had forecast a yearly operation volume of 950,000, 1,200,000 and 1,400,000 for the Capacity Enhancement Study. The PT operations were studied using a future demand level of 950,000 operations per year for South Flow and North Flow. They had developed five PT scenarios for this study. In each scenario, the PT was located at different distances from the end of the runway viz. 600 feet, 1,400 feet, 2,000 feet and 2,600 feet They also assumed that 30% of the arriving aircraft would not use the PT. The 30% aircraft assumed to arrive at off-peak hours on runway 17C/35C or 18R/36L was allowed to cross the departure runway to reach the terminals. The Simulation Model (SIMMOD) program used in the analysis had limited capability. Therefore, LFA decided to take field measurements for runway crossing delay to supplement the simulation results.

In 2002, Davis [19] completed a detailed study of the PT operations at DFW including assessment of the obstruction free zone, and the alignment of the PT from the end of the north-south runways. When both studies were done in 1996 and 2002, runway 17C was 11,388 feet long. At that time, plans were being developed to extend the runway to a full 13,400 feet. In 2003, another study was performed by Davis [20] to establish the flow of aircraft on the PT during the South Flow and North Flow conditions at DFW considering only the four terminals. During that period, American and Delta were flying a full schedule and runways 17C and 18R were in use for arrivals and 18L and 17R were in use for departures. A review of the approach and departure flight path led to the establishment of PT centerline at a distance of 2,650 feet from the end of the runways. The study team allowed a 40:1 Terminal Instrument Approach Procedures (TERPS) slope for the departure aircraft from runway 17R and 18L, with a clearance height of 66.25 ft, which later was reduced to 65 ft when the FAA decided to build the PT at DFW. This study was the basis for several other studies done by the DFW Capital Development Board and NASA. It was also mentioned in this study that DFW experienced nearly 1800 runway crossings for 2400 operations per day [20].

The FAA Flight Standards Service (AFS-420) performed an End-Around Taxiway Analysis in 2003 [6, 39] to determine the safety of flight operations for the departure phase only. Mathematical models and computations were developed mostly to determine the safe height at which a departure aircraft will clear an aircraft taxiing on the DFW SE quadrant PT during the South Flow operations. It was assumed that during the North Flow operations no aircraft will be allowed to traverse the PT under the arriving aircraft on the SE quadrant, because no evaluation has yet been completed for arrival conditions.

Later in 2003, a detailed study of the DFW PT system was simulated at the NASA Ames' FutureFlight Central (FFC) Facility and Crew Vehicle Systems Research Facility (CVSRF) at Moffett Field, California, with personnel working in the 744 (B747-400) Flight Simulator. Engineers from NASA, the FAA, pilots from American Airlines and air traffic controllers from the FAA joined the simulator study. Historical data from DFW operations were used to create the future demand levels and the desired traffic mix. Only East-side, South Flow, day time traffic operations at DFW were simulated during this flight simulator exercise [10, 48]. Five certified Professional Controllers from DFW were in the FFC simulator. Only two taxiway configurations were simulated during the thirteen runs. The baseline configuration represented the 2003 runway configuration of runway 17C and 18R which were 11,388 ft long. For the future PT configuration, the proposed PT alignment on the SE quadrant, extension of runway 17C and 18R to 13,400 ft, and new high speed exit at 17C exiting to taxiway P on the east were included [10]. Aircraft taxi speeds were limited to three speeds as follows: taxi on runway 50 knots, standard taxiing operations 20 knots, and for turning, cornering and congested areas 10 knots. There were essentially four distinct views tested. They were: 1) the controller view 2) the pilot-on-taxi view 3) the pilot-on-arrival-view and 4) the pilot-on-departure view.

In this flight simulator demonstration, DFW [10, 48] had three objectives to accomplish with its proposed PT concept:

- Gain the acceptance of the PT from the user community by providing the opportunity to observe and experience the proposed improvement first-hand
- Collect and analyze the audio and surface data to derive descriptive statistics to understand the impact of perimeter taxiways
- Create an informational video that includes interviews from the air traffic controller and pilot participants

In this research, DFW is simulated operating in both South Flow and North Flow with five terminals, GA facility, and the cargo aprons. Between 2003 and 2004, the cargo flights have increased [DFW cargo statistics] and the impact of this increase is considered in the VS simulation. All four parallel runways are 13,400 feet long and PT is used in all four quadrants to replicate how the airport will be operating in year 2010.

This research follows a different path to compute the forecast traffic at DFW to perform the VS simulation. In this research, the forecast is based on actual mean operations and maximum operations at DFW in 2004, the baseline year. This research includes all five terminals, GA facility, and cargo aprons on the east and west side.

CHAPTER 4

PERIMETER TAXIWAY SIMULATION APPROACH AND METHODOLOGY

This chapter describes the approach considered for VS simulation and the methodology developed to generate data for a total of sixteen applications to test the viability of constructing PT system on all four quadrants of DFW.

4.1 Overview

The flight data is split into arrivals and departures. Actual flight arrival and departure data is obtained from the DFW database for all days in 2004. The flight data is converted to proper format for input into VS database spreadsheet. The flight data consists of information on airline, flight number, and origin/destination airport, assigned gate at DFW and actual time of arrival or departure to/from the designated gate. All other information in VS database is common for the following simulation scenarios.

<u>Scenario 1</u> Existing runway and taxiway configuration with wind set direction from the South, which is typically referred to as South Flow. In this scenario, the prevailing wind is from the South, and all arrivals and departures are towards the South. The runway assignment is based on actual data obtained from the EAD database. The following four runways are used for arrivals: 13R, 18R, 17C and 17L. The following three runways are used for departure: 18L, 17R and 13L. If weather conditions and visibility permit, aircrafts are allowed to depart from runway 18R and 17C between

arrivals. Only four terminals A, B, C and E, east side freight and west side freight aprons are used in this simulation.

Scenario 2 Existing runways and taxiway configuration with wind set direction from the North, which is typically referred to as North Flow. The following four runways are used for arrivals: 36L, 35C, 35R and 31R. The following three runways are used for departure: 31L, 36R, and 35L. If weather permits and visibility is good, then the aircraft is allowed to depart from runway 36L and 35C. Only four terminals A, B, C and E, east side freight and west side freight aprons are used in this simulation

Scenario 3 Future runway and PT configuration with direction of wind from the South. The flight operations, runway assignments and terminals are identical to scenario 1.

Scenario 4 Future runway and PT configuration direction of wind from the North. The flight operations and runway assignments are identical to scenario 2.

The forecast flight operations data for year 2010 is used to simulate the following scenarios.

Scenario 5 Existing runway, taxiway (without PT) and five terminal (A, B, C, D, E) configuration with east side freight and west side freight aprons and the direction of wind from the South. Flight operations are similar to Scenario 1.

Scenario 6 Existing runway, taxiway (without PT) and five terminal (A, B, C, D, E) configuration with east side freight and west side freight aprons with the direction of wind from the North. Flight operations are similar to Scenario 2.

Scenario 7 Future runway and taxiway (with PT) configuration with wind direction from the South. Flight operations are similar to Scenario 5.

Scenario 8 Future runway and taxiway (with PT) configuration with direction of wind from the North. Flight operations are similar to Scenario 6.

The simulation of the airport flight operations will furnish vital information that is required to analyze the introduction of the PT system at DFW. The delay experienced by each aircraft while waiting to cross the active departure runway to get to the terminal gate, GA apron and cargo apron will be computed.

VS a microscopic model that uses the link and node format whereby the arriving/departing aircraft traverses a path along the links to reach the terminal gate or the departure runway, respectively. VS uses Dijkstra's Algorithm to arrive at the shortest path in the system from the arrival runway (touch down point) to the assigned gate. Similarly, for the outbound movement, the shortest distance is computed from the gate to the designated departure runway along the taxi path leading to the departure queue. The links are the path taken by the aircraft and these links contain many specifications, such as, speed of aircraft, direction of travel, restrictions on movement like unidirectional or bidirectional flow, and other pertinent data required for simulation.

4.1.1 Link creation for runways

Links and nodes are created using the network builder tool in VS. When the line is drawn on the screen, it opens the link editor window where the specifications for the links are entered. The node numbers are automatically generated by the program.

The runway links will have to be drawn from north to south, the primary direction, on the screen signifying the South Flow operations. The nodes are positions where the taxiway links connect to the runway to taxiway to gate. It is designated as operation Plan_01 in the simulation. Once the runway links are completed the runway specifications such as runway number designator, width and offset distance from the threshold are entered in the runway specification window.

4.1.2 Link creation for taxiways

Taxiway links are created in the same manner by drawing a link from a node to another node. The link creation window opens where the specifications for the link is specified, like direction of travel, taxiing speed, taxiing direction like no passing or passing permitted, and aircraft type if any, that are prohibited from using the link.

4.1.3 Link creation for Routes

Airspace routes in VS are a sequence of links that connect to and from a path in space. The aircraft fly from node to node via the links along a designated route. On the arrival route, the first node in space is the leading link to the arrival runway, ending on the last node physically located at the start of the runway. For the departure route the first node is physically placed immediately next to the end of the runway that leads to the departure route. Creating routes is similar to the creation of runway nodes and links. The requirement is that the aircraft must fly from the initial to final nodes similar to the runway links. In the VS simulation for this research there are fourteen major routes, seven for arrivals and seven for departures. In addition, there are three additional routes during South Flow operations that permit turboprop aircraft to depart from runway 18R, 18L and 17R with a runway length of approximately 7,000 feet. This is shown in Figure 23. On the North Flow, there are five additional routes; one each from 31L, 36L, 36R, 35L and 35C allowing the turboprop aircraft to takeoff at a runway length of 7,000 feet as shown in Figure 24.

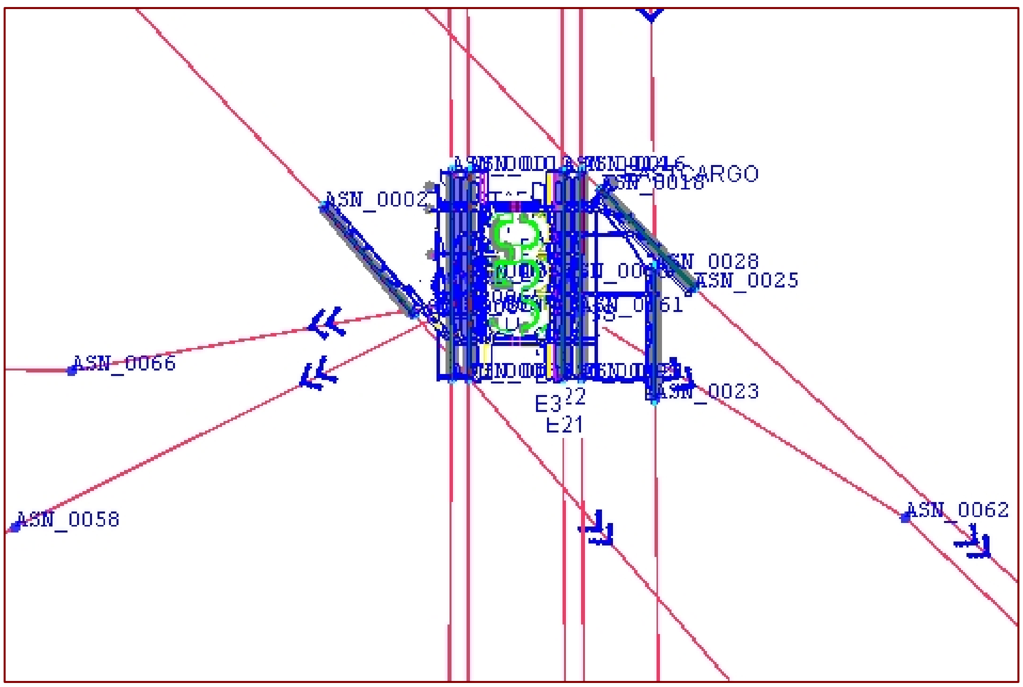


Figure 23 South Flow routes from DFW

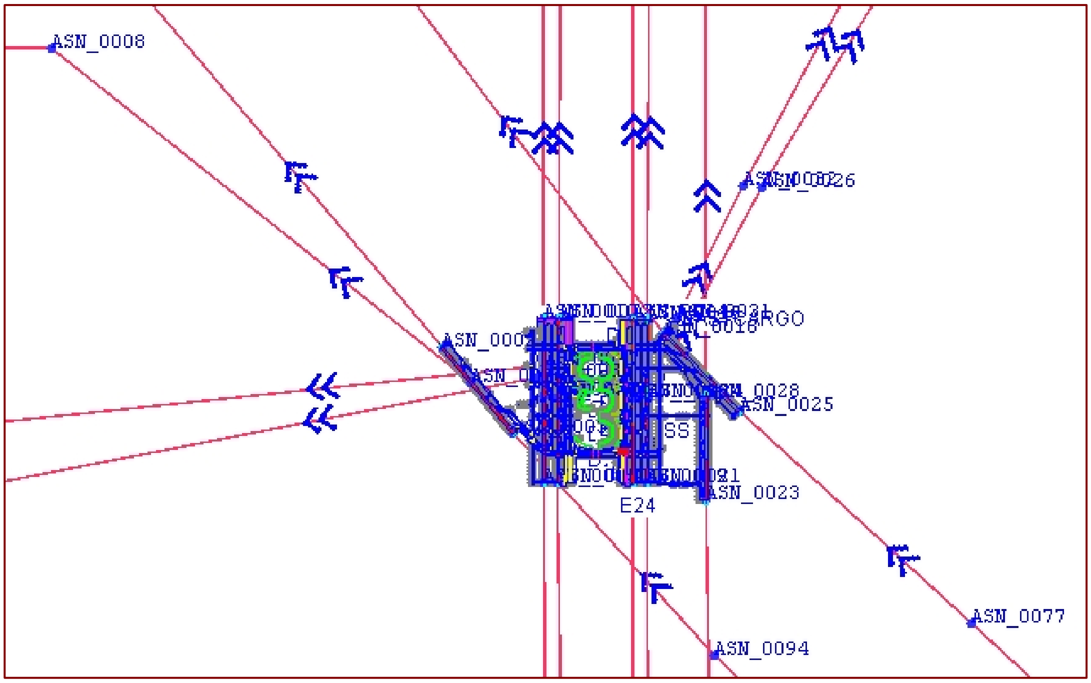


Figure 24 North Flow routes from DFW

4.1.4 Interface node creation

Interface nodes are the airspace nodes that are physically located at or over runway ends. They represent the final node of the arrival routes and the initial route of the departure routes. When this information is combined with VS procedures, the interface nodes tell VS where the airspace network connects with the airfield network. Identification of interface nodes is very important for completion of the procedures information.

4.1.5 Aircraft models used

The Aircraft model number and aircraft specifications are entered in the AC Model spreadsheet. Aircraft types used in the simulation are shown in Appendix J.

Table 11 Aircraft models used in the sixteen applications

AIRBUS	BOEING		OTHERS	
A300-600	B717-200	MD11	ASTR	EMB135
A310	B727-100	MD80	BE40	EMB145
A319	B737-300	MD82	C208	H25B
A320	B737-400	MD83	C500	H25C
A340-300	B737-500	MD87	C550	LJ31
	B737-700	MD88	CRJ1	LJ45
	B737-800	MD90	CRJ2	LJ55
	B747-100	DC8	CRJ7	RJ85
	B747-200	DC9		SF340
	B747-400	DC9-30		
	B757-200	DC9-40		
	B767-200			
	B767-300			
	B777-200			
	B777-300			

Table 11 shows the list of aircraft that were used in the VS simulation for all sixteen simulation applications.

4.1.6 Taxiway speed considered

In this research, the taxiway speed for all aircraft is set at 15 mph for all sixteen simulation applications. No overtaking or no passing is allowed on the taxiway in the simulation.

4.1.7 Hours of operation

The airport is in operation from 0 hrs to 24 hrs in the simulation. In real life DFW partially shuts down operation from 9 p.m. and certain runways are closed because of noise consideration. The data used in the simulation is historical data from year 2004, depicting actual runway use by each flight over the twenty-four hour operation period. The flight track data from EAD gives information for twenty-four hour period for all flights arriving and departing at DFW.

4.1.8 Probability distribution for landing and takeoff

VS has a built in probability distribution approved by the FAA for landing and takeoff on various runways.

4.2 Actual flight data for 2004

There were twelve applications developed for the 2004 flight data. They were: Maximum 2,477 operations, Minimum 1,647 operations and the Mean 2,284 operations as shown in Table 7.

1. Maximum operations were on 22 July 2004 (Thursday), consisting of 1,226 arrivals and 1,251 departures for a total of 2,477 operations for that day. The operations were analyzed using four applications as follows.

Application 1 South Flow *without* PT

- Arrival runway: 13R, 18R, 17C and 17L
- Departure runway: 18L, 17R and 13L (turboprop aircraft only)

Application 2 North Flow *without* PT

- Arrival runway 36L, 35C, 35R and 31R
- Departure runway 31L (turboprop aircraft only), 36R, and 35L

Application 3 South Flow *with* PT

- Arrival runway: 13R, 18R, 17C and 17L
- New high speed exit on 18R to taxiway C and on 17C to taxiway P
- Departure runway: 18L, 17R and 13L (turboprop aircraft only)

<u>Application 4</u> North Flow *with* PT

- Arrival runway 36L, 35C, 35R and 31R
- Departure runway 31L (turboprop aircraft only), 36R, and 35L

2. Minimum operations were on 6 March 2004 (Saturday), consisting of 818 arrivals and 829 departures for a total of 1,647 operations per day. The operations were analyzed using four applications as follows:-

<u>Application 5</u> South Flow *without* PT

- Arrival runway: 13R, 18R, 17C and 17L
- Departure runway: 18L, 17R and 13L (turboprop aircraft only)

<u>Application 6</u> North Flow *without* PT

- Arrival runway 36L, 35C, 35R and 31R
- Departure runway 31L (turboprop aircraft only), 36R, and 35L

<u>Application 7</u> South Flow *with* PT

- Arrival runway: 13R, 18R, 17C and 17L
- New high speed exit on 18R to taxiway C and on 17C to taxiway P
- Departure runway: 18L, 17R and 13L (turboprop aircraft only)

<u>Application 8</u> North Flow *with* PT

- Arrival runway 36L, 35C, 35R and 31R
- Departure runway 31L (turboprop aircraft only) , 36R, and 35L

3. The mean number of operations were on 25 June 2004 (Friday), consisting of 1,122 arrivals and 1,162 departures for a total of 2,284 operations per day. The operations were analyzed using four applications as follows:-

Application 9 South Flow *without* PT

- Arrival runway: 13R, 18R, 17C and 17L
- Departure runway: 18L, 17R and 13L (turboprop aircraft only)

Application 10 North Flow *without* PT

- Arrival runway 36L, 35C, 35R and 31R
- Departure runway 31L (turboprop aircraft only), 36R, and 35L

Application 11 South Flow *with* PT

Arrival runway: 13R, 18R, 17C and 17L

- New high speed exit on 18R to taxiway C and on 17C to taxiway P
- Departure runway: 18L, 17R and 13L (turboprop aircraft only)

Application 12 North Flow *with* PT

- Arrival runway 36L, 35C, 35R and 31R
- Departure runway 31L (turboprop aircraft only), 36R, and 35L

The results of the simulation results are tabulated in Chapter 8.

4.3 Forecast flight data for year 2010

For year 2010, the mean number of operations 2,284 per day in year 2004 is increased at a rate of 3.5% per year giving an average traffic flow of 2,808 operations per day. This data was analyzed by creating four applications as follows:

<u>Application 13</u> South Flow *without* PT

- Arrival runway: 13R, 18R, 17C and 17L
- Departure runway: 18L, 17R and 13L (turboprop aircraft only)

<u>Application 14</u> North Flow *without* PT

- Arrival runway 36L, 35C, 35R and 31R
- Departure runway 31L (turboprop aircraft only), 36R, and 35L

<u>Application 15</u> South Flow *with* PT

- Arrival runway: 13R, 18R, 17C and 17L
- New high speed exit on 18R to taxiway C and on 17C to taxiway P
- Departure runway: 18L, 17R and 13L (turboprop aircraft only)

<u>Application 16</u> North Flow *with* PT

- Arrival runway 36L, 35C, 35R and 31R
- Departure runway 31L (turboprop aircraft only), 36R, and 35L

The output from these analyses is reviewed in detail in Chapter 8.

4.4 Holiday period travel data for 2004

Holiday travel at DFW data obtained from the FAA/ASPM database was reviewed and the information is listed below:

- The Friday before Memorial Day (5-28-04) total operations were 2,389/day.
- The Friday before Labor Day (9-3-04) the operations were 2,290/day.
- The day before Thanksgiving (11-24-04) the operations were 2,325/day.

- The day before Christmas (12-24-04) was 2,013 operations/day.

The three data dates chosen for the research analysis and evaluation of PT operations very closely represent the operations on the four holidays of expected peak travel days at DFW. All the holiday period operations were less than the 2,477 operations chosen for the simulation. During the holidays due to increased volume of traffic at DFW several flights were delayed, rescheduled or cancelled due to unavailability of aircraft or additional flights added to cope up with the increase in demand. Therefore the holiday period data was not analyzed as it was not likely to yield good information for data validation of results from VS simulation.

4.5 Visual SIMMOD data input methodology

The airport operations are modeled and simulated using VS software with information about the airport input into the program. The layout drawing of the airport in AutoCad drawing format is used to overlay the plan on the world map coordinate system. The longitude, latitude, and airport elevation is input to anchor the airport at the correct location on the world map. The DFW layout plan in AutoCad DXF (Drawing Exchange File) format is converted to QGF (Quintessential Graphics File) format for use in VS. The network builder allows creating the runway and taxiway ground links and nodes and the direction of simulated aircraft travel. The arrival and departure flight path, in the airspace is depicted in the airspace links created using the network builder. The simulation is run for two scenarios. The first scenario is run without the PT as shown in the existing configuration of DFW runways and taxiways in

Figure 15 (Section 2.3). This simulates the existing conditions at the airport and is expected to generate the following results:

1. The number of aircrafts arriving and departing at the airport in each hour of simulation.
2. The number of crossings by arrival aircraft of the active departure runways.
3. Delay experienced by each aircraft while waiting on the taxiway to cross the departure runway to reach the terminal gates.
4. The Taxi In time for arriving aircraft and the delay in Taxi In time
5. The Taxi Out time and the delay for the departure aircraft.
6. The number of arrivals and departures in an hour.
7. Number of aircraft waiting in the departure queue at runway 17R/35L and 18L/36R.

The second scenario considers the PT as shown in Figure 16 (Section 2.3), to be constructed on the east and west side of the DFW to facilitate end-around taxiing of arriving aircraft to reach different gates in the terminal, as well as the cargo aprons as shown in the taxiway use plans in Appendix G. Similarly departing aircraft from terminals B and D on the west side to reach assigned runway on the east will have to cross over the new bridge or use the existing bridge Taxiway A or Taxiway Y depending on the traffic flow. The simulation with the PT would estimate the reduction in delay and the increased travel time to reach the gates. The reduction in communication between aircraft cockpit and the Ground Controllers due to the introduction of PT operations will not be evaluated in the VS simulation.

The expected benefits of using a PT are outlined below:

- The arriving aircraft is able to taxi to the gate after exiting from the runway without any delay. It is able to reach the terminal apron traveling on the PT and taxi around the departure runway.
- Planes are able to take off continuously without interruption, with the arrival stream of aircraft adhering to the guidelines established by FAA for aircraft separation on departure runway
- The efficiency of the departure queue is largely dependent on the uninterrupted departure of aircraft based on the allowable in-trail separation and wake vortex avoidance spacing as shown in Figure 17.
- Overall increase in safety of operations at the airport during peak periods.
- The determination of the minimum distance of the center line of the PT from the edge of the runway to permit aircraft taking off or landing to adequately clear the aircraft traveling on the PT safely within the guidelines established by FAA
- Evaluate and report the arrival (landings) and departure (takeoff) improvements due to PT operations.

4.6 Visual SIMMOD drawings

In VS the DFW AutoCad drawing in DXF format is converted to QGF format and placed on the world map using the Latitude (N32.8960°) and Longitude

(W97.0372°) of the DFW airport. The elevation of highest point at the airport (607 feet) is entered in the data field to give the vertical coordinate of the aircraft in space. The time data is entered in full 24 hr format, i.e. 7:00:00 for 7 a.m. in the morning and 19:00:00 for evening 7 p.m. The screen capture of the world map view is shown in Appendix B. The zoom in and zoom out feature assist in selecting various views of the airport during the creation of runway and taxiway node and links.

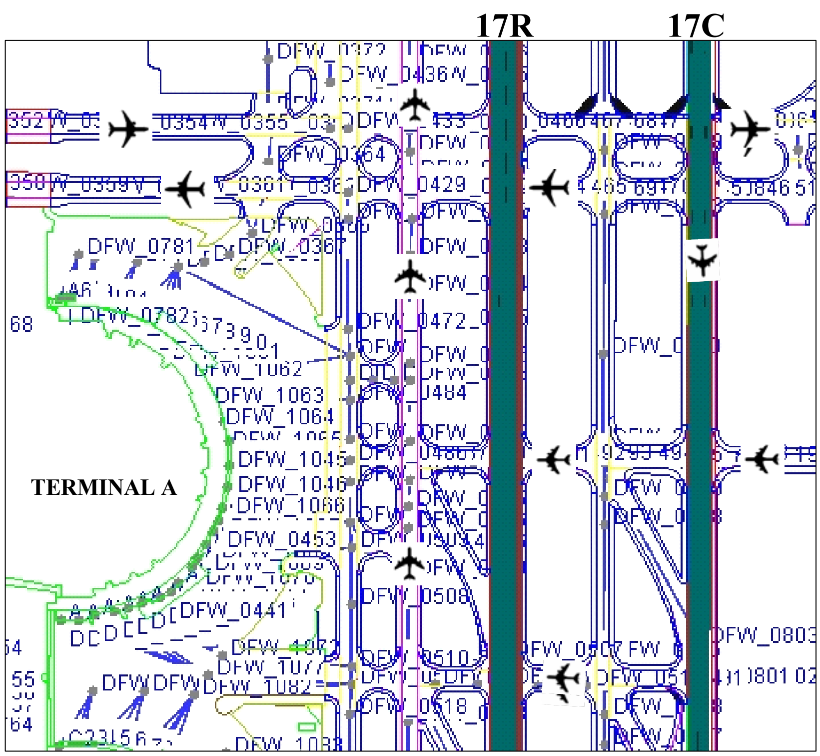


Figure 25 Runway and taxiway links to the Terminal A gates

Figure 25 shows location of Terminal A and the ground links from the taxiway to each gate at the terminal building layout. In Terminal A, all gates are used exclusively by American Airlines.

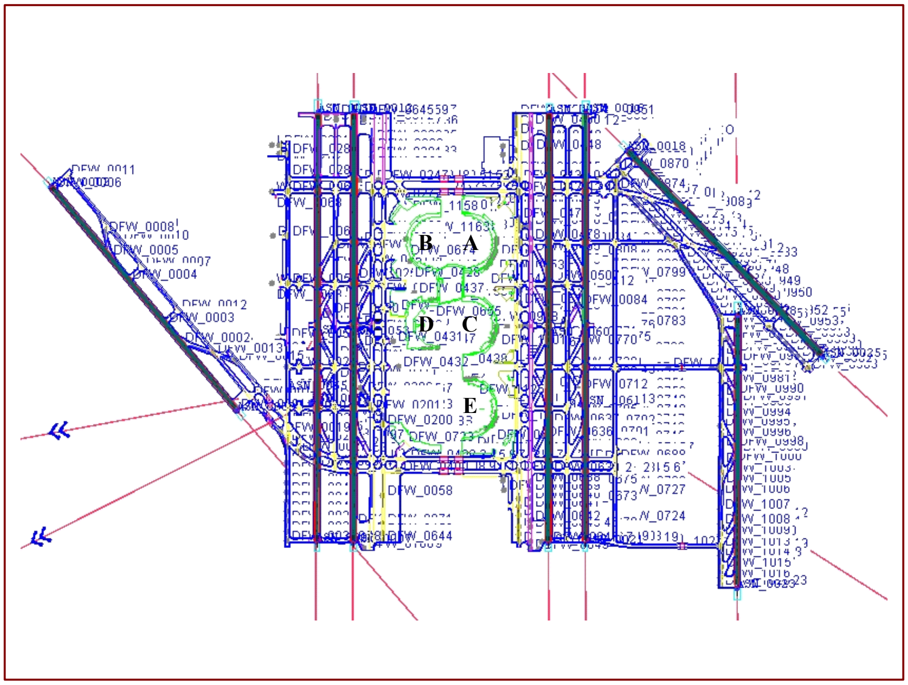


Figure 26 DFW 2004 configurations of runway and taxiway with terminal buildings

Figure 26 shows the ground links for the runway, taxiway and the air space links and the node numbers drawn on the DFW plan Terminals A, B, C, D, and E are also shown in the figure.

4.7 Simulation parameters

The following parameters are used in the simulation of the DFW PT operations. The simulation is run on VFR status for all sixteen applications, to compare data obtained from the FAA for the selected dates in 2004.

- Ceiling: 5,000 ft
- Visibility: 30,000 ft

- Taxiway minimum speed: 15 mph
- Runway minimum speed: 50 mph
- Wind direction: North or South
- All operations: VFR
- No over flights and route metering of arrivals in the simulation.

The following Table 12 shows the FAA data on aircraft classification which is used in VS simulation of all applications.

Table 12 The FAA airport reference codes for design [55]

FAA AIRPORT REFERENCE CODES				
Aircraft Approach Category	**Aircraft Approach Speed (kts)**	**Airplane Design Group**	**Aircraft Wingspan (ft)**	**Tail Height (ft)**
A	**<91**	**I**	**<49**	**<20**
B	**91-121**	**II**	**49-<79**	**20-<30**
C	**121-141**	**III**	**79-<118**	**30-<45**
D	**141-166**	**IV**	**118-<171**	**45-<60**
E	**>166**	**V**	**171-<214**	**57-<66**
F	**-**	**VI**	**214-<262**	**66-<80**

4.8 Simulation procedure

To run the simulation, select the run simulation tool, which will open the run menu window. Multiple iterations could be run from the data provided in the VS. To run multiple iterations, number 1 is entered in the “initial iteration number field and the final number say 5, to indicate five iterations to be run” with the supplied data. The VS program by default creates ten random number streams with each stream having a random number seed which may be affected by input supplied. The program accepts externally entered random number seeds in the cells provided in the run simulation window. The run simulation menu window is shown in Appendix B.

4.9 VS Animator

VS Animator is a 2D model of the airport operations showing the aerial view of the airport. Figure 27 shows the aerial view of airport operations. Aircraft in blue are arrival aircraft and aircraft in orange are departure aircraft.

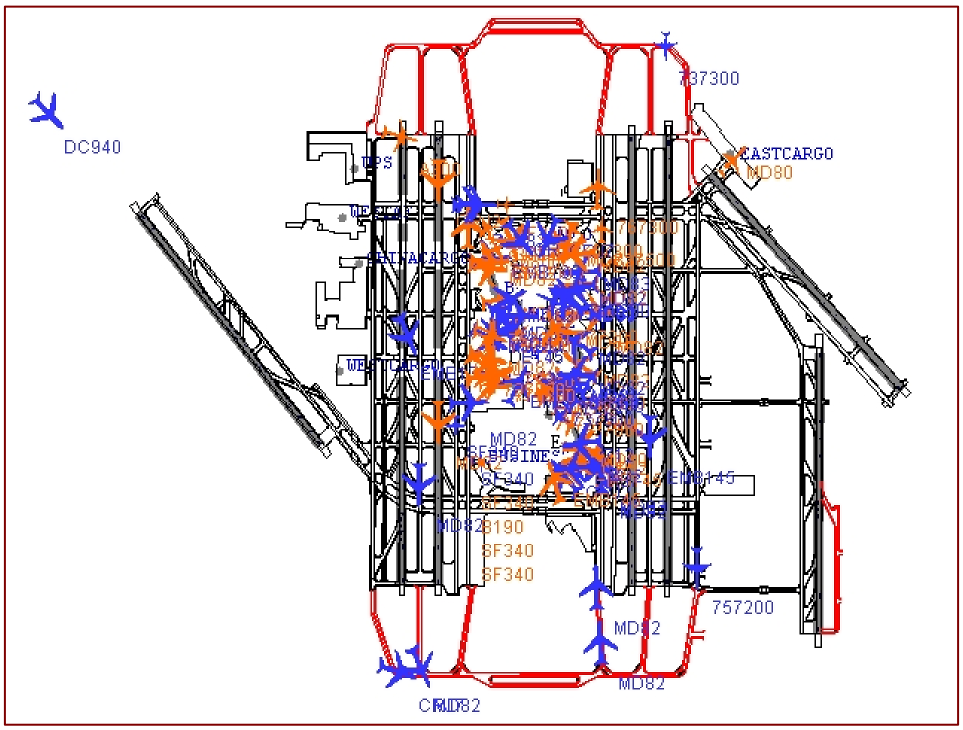


Figure 27 2D model aerial view of future DFW showing terminals and airfield

The animation time can be changed to view the operations at any time of the day. The speed of animation can be changed as the animation is in view. The animator keeps count of the number of aircraft at the airfield every second of the animation. The distance between arriving and departing aircraft can be measured in space between selected nodes in the air space routes. By clicking on any aircraft on the air space route, a drop down table will reveal information about the flight number, airline, aircraft type, co-ordinates, origin and destination cities and the speed of travel in space.

4.10 Visual SIMMOD Reporter

There are several reports produced by VS after the simulation iterations are completed. The VS reporter is a stand alone program module that will produce different reports like, basic metrics, runway usage, taxiway usage, gate usage, departure queue usage, and route usage by using the data from each application. The reports are produced in the OpenOffice.org® program format and supplied free of cost with VS. A complete list of reports available from the VS Reporter module is shown in Appendix B.

The reports generated by VS Reporter can easily be converted to MSExcel or other database programs to produce in any special formats to meet the user's requirements. Many of the reports in this dissertation are from VS Reporter converted to MSExcel format.

The Gate usage report for year 2010 application with and without PT is in Appendix I where the various terminal layouts are included.

CHAPTER 5

DATA GENERATION AND INPUT

5.1 Introduction

The simulation of the air traffic operations at DFW is performed using Visual SIMMOD. The flights and new airlines that are likely to begin service at DFW were developed using the forecast of traffic in 2010. The possible aircraft mix, flight arrival and departure timings and origin/destination airports is also generated from actual fareight data obtained from the DFW database for each day of the month. The maximum use of all gates at the DFW terminals is contemplated in the model. The aircraft types used in the simulation are shown in Table 11 (Section 4.1.5).

The forecast of air traffic operations data was derived from the FAA [29] terminal forecasts developed in 2004. The expected growth rate is set at 3.5% for DFW from year 2004 to 2010.

5.2 Baseline year 2004 airport configuration

In 2004, the following is the data for the runways at DFW as shown in Table 13. Runway 17C was under construction to extend its length from 11,388 ft to 13,401 ft by the end of the year. In 2005, the runway extension was completed. It was decided to use the longer length (13,401') of the runway in this research project for year 2004 and 2010 simulation as this will facilitate comparison of all results without and with PT.

The FAA simulations performed by NASA and Davis (18) had considered the full length for all runways, 17C/35C, 17R/35L, 18R/36L and 18L/36R.

Table 13 Runway data 2004

Runway ID	Length	Width
13R/31L	9,301'	150'
18R/36L	13,400'	150'
18L/36R	13,400'	200'
17R/35L	13,401'	200'
17C/35C	11,388'	150'
13L/31R	9,000'	200
17L/35R	8,500'	150'

The flight track data obtained from the EAD database reflected runway 17C operating at 11,388 ft, but the impact of using the 13,401 ft would not severely skew the final results of runway use and capacity estimate.

In 2004, Terminal A had a satellite terminal from gate A2A to A2N (14 gates) specifically for use by American-Eagle airlines, to facilitate the use of turboprop and small jet aircrafts. Similarly, in terminal E a satellite terminal was available for the exclusive use of Delta airline's partners and regional jets assigned to gates E20 to E30. The satellite terminals were closed in 2005 after the new international terminal D was opened. Security was another reason for closing the satellite terminals. In addition, Delta airlines decided to pull out off terminal E closing major operations at DFW. This resulted in a shuffling of airlines and gates were assigned in terminal D and E for airlines that were using terminal B. The detailed layout of terminal plans for A, B, C, D, and E and the gates are shown in Appendix I

5.3 Visual SIMMOD input

VS data input is normally grouped [47] into the following three categories:

- Airfield-related: includes physical airfield layout of the DFW and the operational parameters such as terminal buildings, gates, taxiway, runway, holding pads, bridge structures, taxiway routings between gates and runways, departure queue locations and aircraft landing and take off characteristics.
- Airspace-related: includes airspace routings, airspace sectors, routes, airspace separation criteria, [44] arrival and departure procedures, flow constraints, and strategies for resolving conflicts.
- Simulation event: allows the user to specify the aircraft departure and arrival (demand) schedules for existing and future conditions and the detail changes in operating conditions, including runway use plans, terminal routing plans and flow. The physical layout is converted from an AutoCad, DXF format drawing into a QGF file for use in VS

5.4 VS database creation

The flight data from EAD, OAG and DFW scheduling database is sorted by arrivals and departures. The arrivals are sorted by flight number and each flight is assigned an arrival runway from EAD data, gate number, origin city, and arrival time from DFW schedule data. The scheduled arrival time, origin city and aircraft type are verified against the OAG data. This data is tallied against the FAA/ASPM report for actual arrival time, actual aircraft used, and the origin city to replicate actual flight information in VS.

The departures are sorted by flight number, and each flight is assigned a departure runway from EAD data and gate from DFW scheduling data. Each departure flight is assigned the respective departure queue for takeoff based on the FAA approved flight procedures and the FAA/ATC assigned taxipath from each terminal. The departure time, destination city, and the aircraft type are verified against OAG data. The FAA/ASPM report is used to tally the actual aircraft used, actual departure time and the destination city to replicate actual flight information in VS.

For the baseline, 2,477 flights were input into VS database spreadsheet for simulation of South and North flow without and with PT. For the future 2010 date, 2,808 flights were input into the VS database spreadsheet for simulation of the South and North Flow without and with PT. Two other database were created, one for the minimum of 1,647 flights on March 6, 2004 and another for the mean 2,284 flights on June 25, 2004, to compute various basic metrics for flight operations at DFW.

CHAPTER 6

VISUAL SIMMOD SIMULATION

This chapter describes the method used to perform the simulation for the sixteen applications developed to determine the viability of constructing PTs on all four quadrants of DFW.

6.1 Simulation procedure

The VS simulation process is indicated below. The data entered in the Run title field will be in the RUNDATA file that is read by VS. All output files will have this information displayed on them for ease of identification.

From a single set of input data, VS can run multiple iterations. The iterations are referred to by numbers, for example, a zero entered in the final iteration field, VS will read all the input data, verify them for correctness and exit without performing a simulation. VS has a built in program to generate its own random number seed used for simulation. Externally, the user can enter specific set of random number seeds in the field identified as seed #1 through #10. These seeds will override the internally generated random number seeds. The simulation parameters can be saved and retrieved by using the save and load buttons. The menu windows in VS are shown in Appendix G. There were sixteen applications developed and each one was run ten iterations. The 2004 baseline data and 2010 future operations are simulated for ten iterations to determine the runway crossing delay for South Flow and North Flow with and without the PT. There is no significant change in the runway crossing delay from five iterations to ten iterations for the conditions stipulated in the applications.

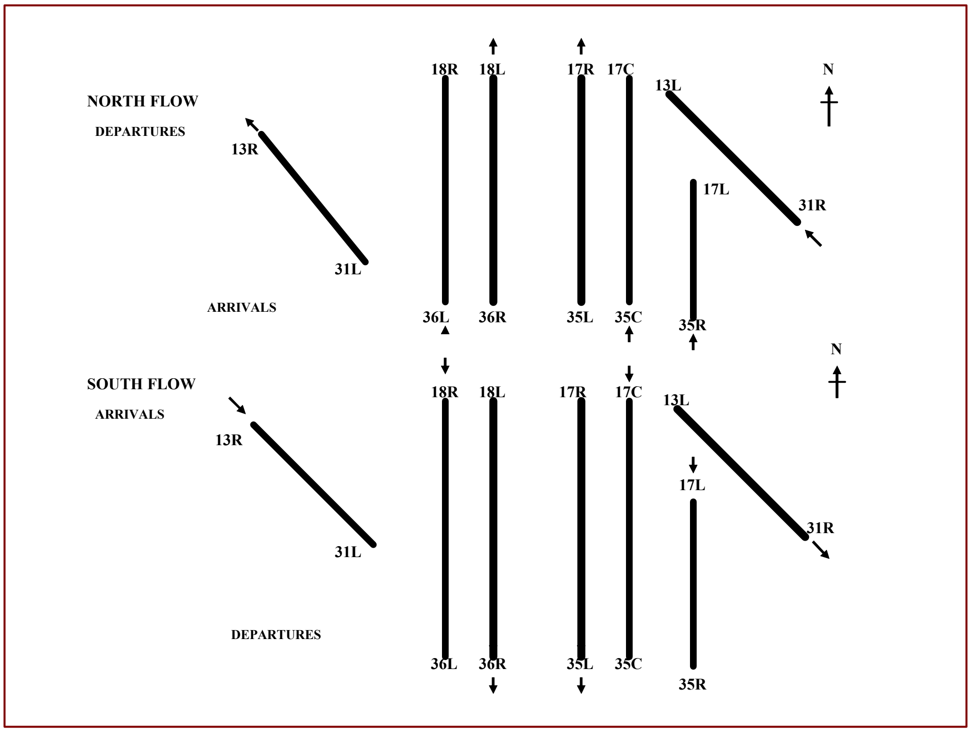


Figure 28 Typical runway use diagram at DFW [21]

Runway assignment for the various simulation runs is based on the runway use plan shown in Figure 28. The flight schedule spreadsheet contains information on arrival and departure runway assignment based on the runway use plan. A sample copy of the flight schedule used in VS can be found in Appendix A. As a general rule, flights arriving from west are assigned runway 18R/36L and flights arriving from east are assigned runway 17C/35C and runway 17L/35R depending on the direction of flow. On July 22 2004, the weather is variable with wind speed ranging from 0 to 13 knots. The temperature ranges from 81° F in the morning to 95° F in the afternoon. The visibility is 7 to 10 statute miles with good ceiling. The following runways are in use for arrivals:

13R, 17C, 17L, and 18R and the following runways are in use for departures: 13L, 17R, 18L and 18R [Source FAA/ASPM weather data report for 22 JUL 04]. The prevailing wind is from the South; therefore, the airport is operating in a South Flow configuration as shown in Figure 28 (Section 4.9). All types of aircraft are allowed to land on runway 13R at DFW and taxi to terminals. The runway 13L is used primarily for departure of turboprop aircraft. No jet departures are allowed from this runway. Runway 17R and 18L can handle departures of all types of aircrafts from DFW. No departures are scheduled from 17L/35R in all simulations so as to reflect the real operations at DFW. These criteria are specified in the input data files for all 16 applications for VS simulation.

6.2 Taxiway use diagrams

The taxiway for arriving flights is dictated by the group size of the aircraft. GA, and small aircraft use the first high-speed exit and travel along the taxi path that is the shortest in length to reach the gates. The large and heavy aircraft use the second high-speed exit and taxi along the shortest taxiway route to the gates. For the departure of aircraft from the terminals, detailed "taxiway path" diagrams used in VS simulation are appended in Appendix G showing designated paths specified by DFW operations and approved by the FAA/ATC.

The VS taxiway link routing diagrams conform to the taxiway routes shown in the taxiway layout diagrams in Appendix G. As it is not practical to replicate the actual DFW operations for departures in VS, simulation, "outer" path is specified for use by Small aircraft and GA. The "inner" path is specified for use by Large aircraft. The “full length” path is specified for use by Heavy aircraft that require the full length of the runway for takeoff. These specifications are applicable to runway 17R, 18L, 35L and 36L for departure taxipath criteria to the departure queue from respective terminals. The VS simulation program has a built in probability distribution for landing and takeoff roll distances on runways. Runway crossing time is a minimum 20 seconds for each aircraft in VS.

6.3 Gate assignment

The gate assignment in each terminal is based on the terminal layouts shown in Appendix I. The terminal A and C are used exclusively by American Airlines. The information from the DFW flight schedule is the basis for assigning gates for each flight’s arrival or departure. The scheduled time of arrival and departure of each flight is based on information from OAG and EAD files. There is a probability assigned for push back time of aircraft from the terminal gates. The maximum time for pushback in the simulation is 100 seconds. There are no turn-around flights in this simulation. No time is assigned for passenger loading or unloading at the gates, because each flight is simulated on its scheduled arrival or departure to/from the gate. No factor is input in the simulation for any delay in the arrival or departure of each flight. The focus of this research is to estimate the runway crossing delay, Taxi In time and Taxi Out time with and without the PT. Therefore, no gate processing time is included in the simulation for each flight.

CHAPTER 7

FLIGHT TRACK DATA ANALYSIS FOR PERIMETER TAXIWAY OPERATIONS

The flight track data analysis is a brand new procedure. This has never been attempted in the industry to establish the height of an aircraft above an airport ground elevation and predict its position in space with respect to the planned PT or EAT.

7.1 Introduction

The proposed PT will be built at a distance of 2,650 feet from the end of the four parallel runways on the North and South side as shown in Figure 28.

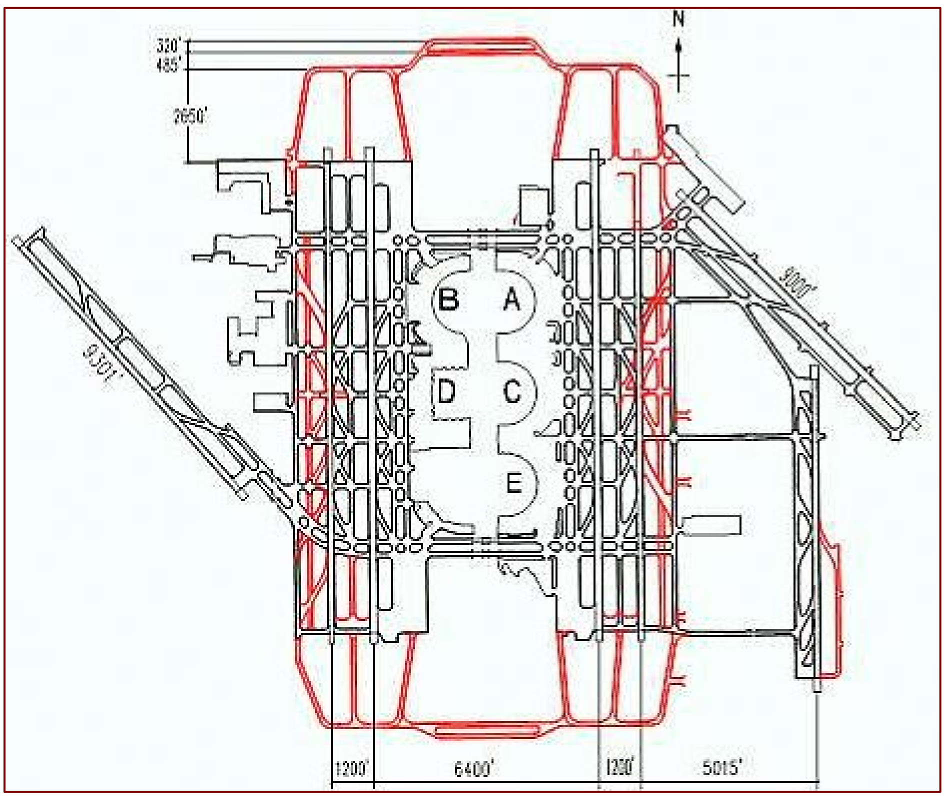


Figure 29 Proposed PT systems and new taxiways at DFW

It is crucial to establish the height at which an aircraft would fly over the PT during the arrival (descent) and the departure (climb) phase for safe operation. To accurately determine the aircraft height over the PT centerline, the author obtained historical, real time flight data at random for one day in each year 2001, 2002, 2003, 2004 and 2005 from the DFW/Environmental Affairs Department (EAD). The flight track data was collected for the following dates: 1-3-2001, 7-17-2002, 8-6-2003, 7-29-2004 and 8-2-2005 from the EAD computer database. The data collected had information on date, time, flight number, aircraft type, runway assignment, type of operation (arrival or departure) and elevation above Mean Sea Level (MSL). Average ground elevation (GL) of the airport was set at 600 feet above MSL by the FliteGraph® database system for aircraft height computation. Table 14 shows the number of arrivals, number of departures, visibility, wind speed and the weather conditions for the selected dates obtained from the FAA/Airport System Performance Metrics (ASPM)/weather database.

Table 14 Flight track weather data for the five days

DATE	VISIBILITY IN STATUTE MILES	TEMP (F)	WIND ANGLE	WIND SPEED (KNOTS)	WEATHER	NUMBER OF ARRIVALS	NUMBER OF DEPARTURES
1/3/2001	8 TO 10	19 TO 50	230 TO 180	3 TO 12	VA	1170	1183
7/17/2002	10	74 TO 84	150 TO 120	6 TO 16	VA	1103	1132
8/6/2003	10	81 TO 108	50 TO 360	4 TO 13	VA	1102	1127
8/6/2003			200 TO 230	4 TO 10	VA		
7/29/2004	1 TO 10	72 TO 84	120 TO 270	5 TO 17	VA	1191	1220
7/29/2004			10 TO 30	4 TO 5	VA		
8/2/2005	7 TO 10	77 TO 100	120 TO 210	0 TO 14	VA	1082	1080

The EAD through an agreement with the FAA acquires the flight track data every day of the year, 24/7. The FAA provides Automated Radar Terminal System (ARTS) data through an interface called the Gateway. The data is gathered and processed by a proprietary program called, Total Airport Management Information System (TAMIS®) supplied by BAE Systems North America of Austin, Texas. Through TAMIS®, the DFW central computer system DFW gathers, stores, and retrieves data in a variety of formats including animated replay of flight activity for a specified time in history, generates formatted reports or produces fields of data to be used in generating new types of reports. All flight data, such as flight number and altitude associated with a specific aircraft's flight track is provided through the FAA's ARTS system. Retrieval of the flight track data for analysis is done using FliteGraph®, an application within the TAMIS® System. FliteGraph® allows DFW to display the actual flight track data over a geographic layer, viz. the DFW Airport Plan. This permits very accurate depiction of the flight's passage over the ground. Each ARTS flight track has embedded identification about the flight. This information is available through the "Flight Headers" tool of the FliteGraph®. The Flight Headers include, date/time of flight, type of operation, flight ID, Equipment, Runway, navigation fix, etc. This data is exportable from FliteGraph® into any database program like, Excel, dBase and OpenOffice. Aircraft models in the arrival and departure flight track data are shown in Table 14.

Another advantage of the FliteGraph® data is that it contains information on the runway used by both the arriving and departing aircraft at DFW. It also provides the wheels off time on the departure runway and time of arrival at the touch down point of runway threshold for each aircraft. Sample flight track data sheets used in the analyses are provided in Appendix L.

Table 15 Aircraft models in the arrival and departure flight track data

AIRBUS	BOEING		OTHERS	
A300-600	B717-200	MD11	ASTR	EMB135
A310	B727-100	MD80	BE40	EMB145
A319	B737-300	MD82	C208	H25B
A320	B737-400	MD83	C500	H25C
A340-300	B737-500	MD87	C550	LJ31
	B737-700	MD88	CRJ1	LJ45
	B737-800	MD90	CRJ2	LJ55
	B747-100	DC8	CRJ7	RJ85
	B747-200	DC9		SF340
	B747-400	DC9-30		
	B757-200	DC9-40		
	B767-200			
	B767-300			
	B777-200			
	B777-300			

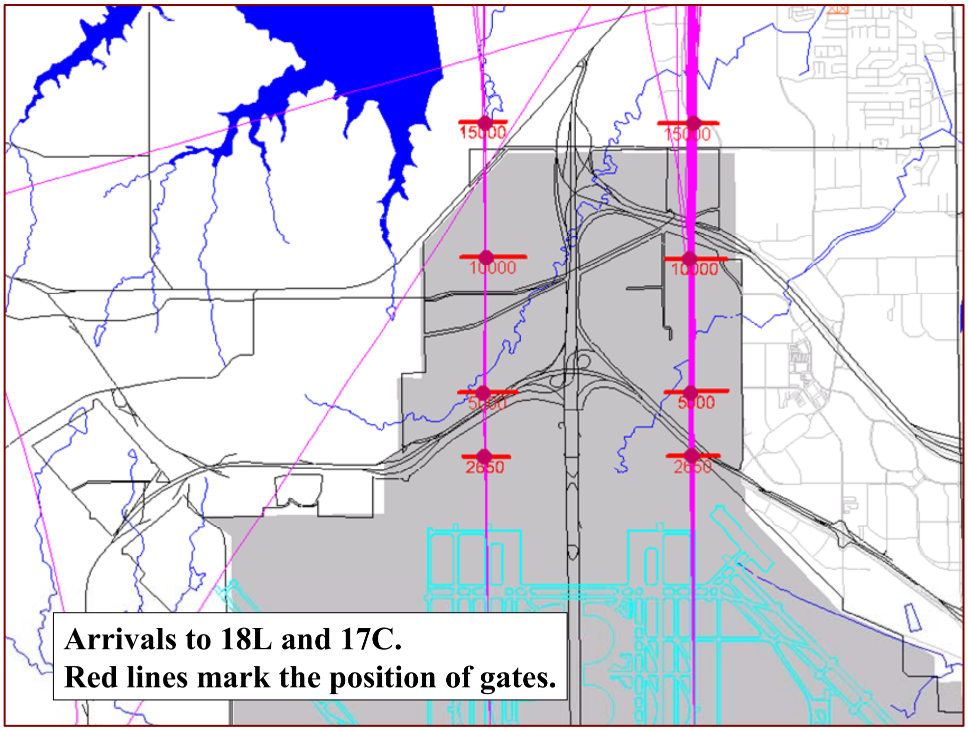


Figure 30 South Flow arrivals on 18L and 17C showing the location of gates

A virtual vertical plane in space is placed like a gate on the (South Flow) arrival path of runway 18L and 17C as shown in Figure 30. There are four gates placed at 2,650, 5,000, 10,000, and 15,000 feet from the end of the runway. The flight data including the date and time of entry into the gate is obtained from the FliteGraph® for the aircraft that crosses the gate.

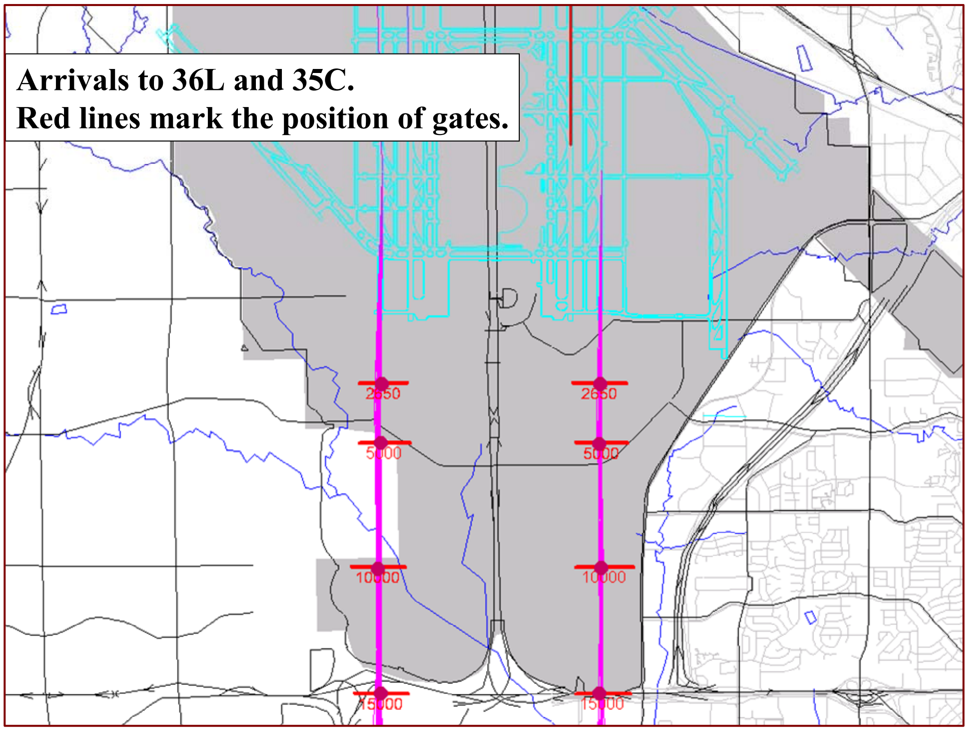


Figure 31 North Flow arrivals on runway 36L and 35C showing the location of gates

During North Flow operations, runway 36L and 35C are the primary runways assigned for arrivals. Figure 31 show the location of gates placed at 2,650, 5,000, 10,000, and 15,000 feet from the end of the runway to record flight data for arriving flights from the FliteGraph®.

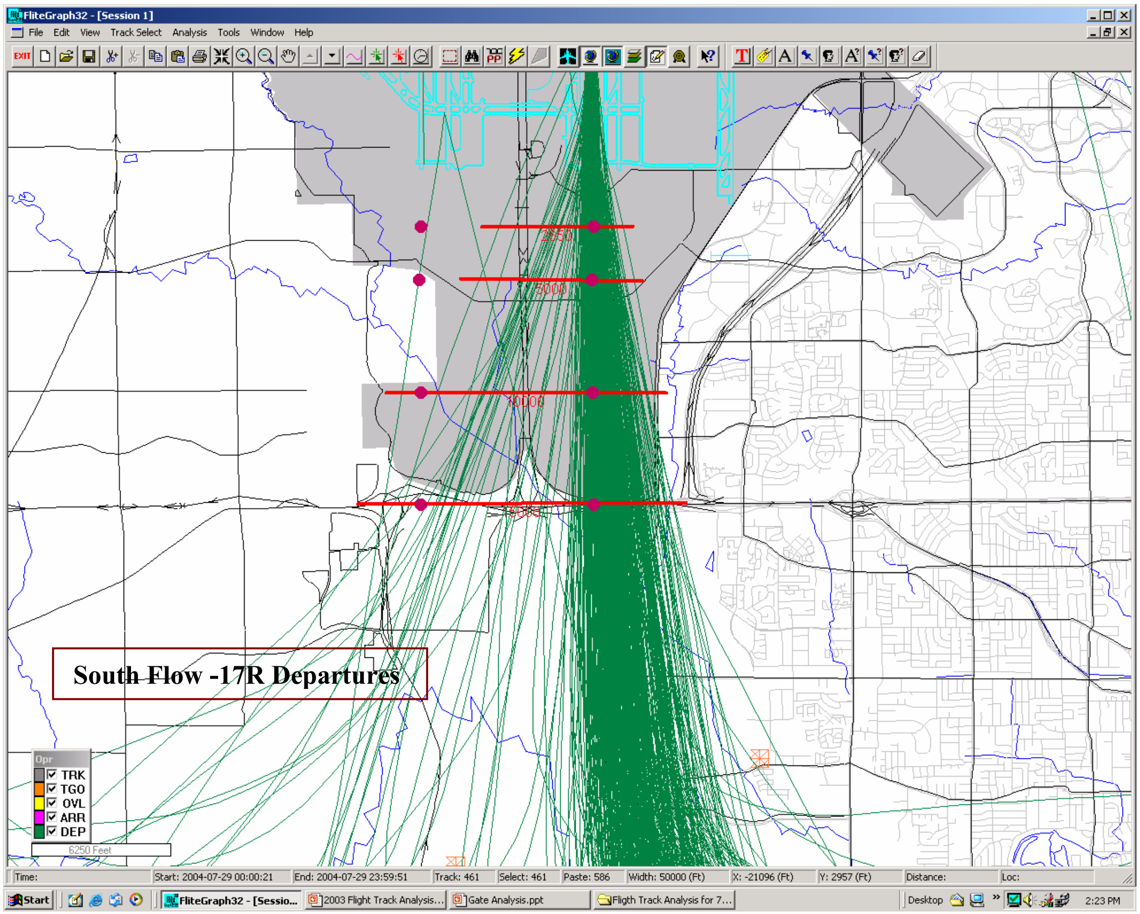


Figure 32 South Flow Runway 17R departures showing the location of gates

Figure 32 shows the departing aircraft flight path in green during South Flow operations at DFW. The gates are placed at 2,650, 5,000, 10,000, and 15,000 feet from the end of runway 17R, which is one of the primary departure runways at DFW. The flight data obtained from FliteGraph® facilitate the analysis of the aircraft height at different distances from the end of the runway during departure. The gates can be placed at any distance from the end of the runway to determine the height of aircraft above DFW ground level (GL)

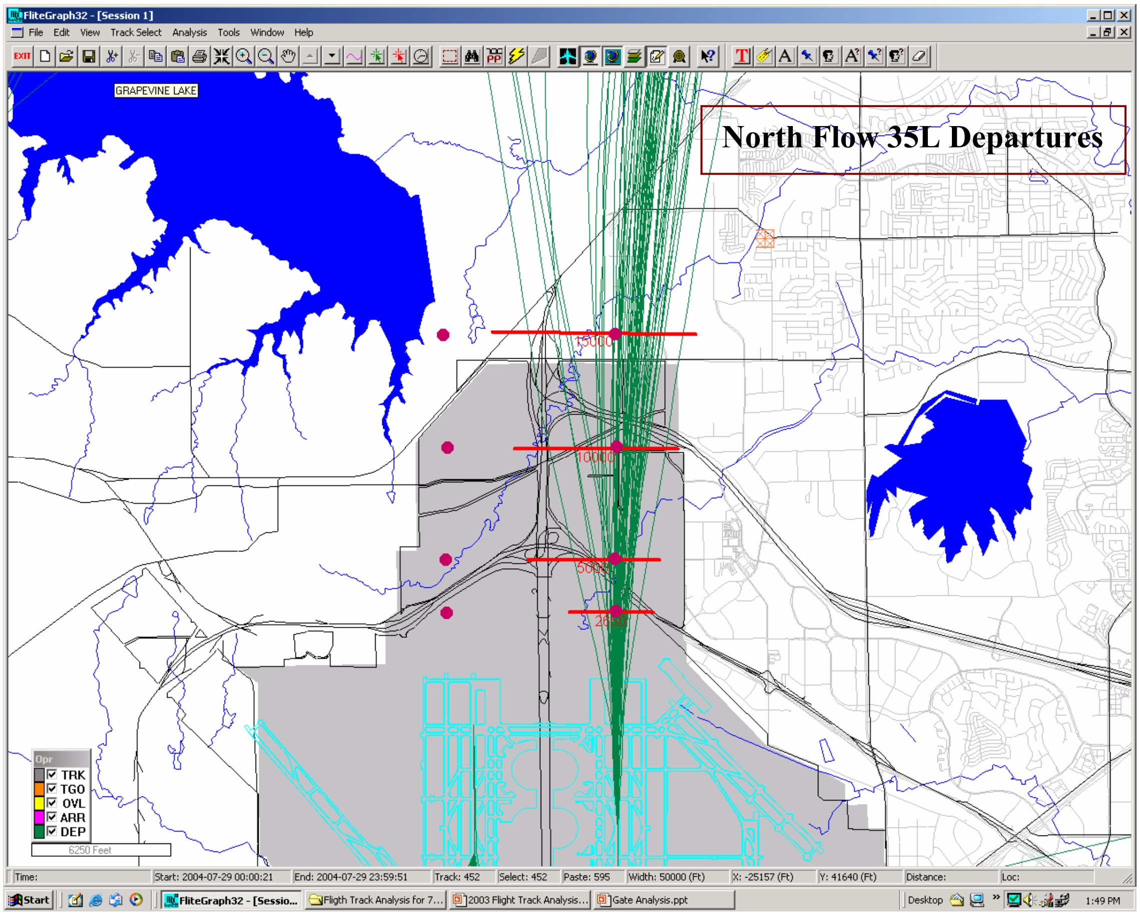


Figure 33 North Flow runway 35L departures showing location of gates

Figure 33 shows the location of gates at 2,650, 5,000, 10,000, and 15,000 feet from the end of runway 35L, one of the primary runways for North Flow departures.

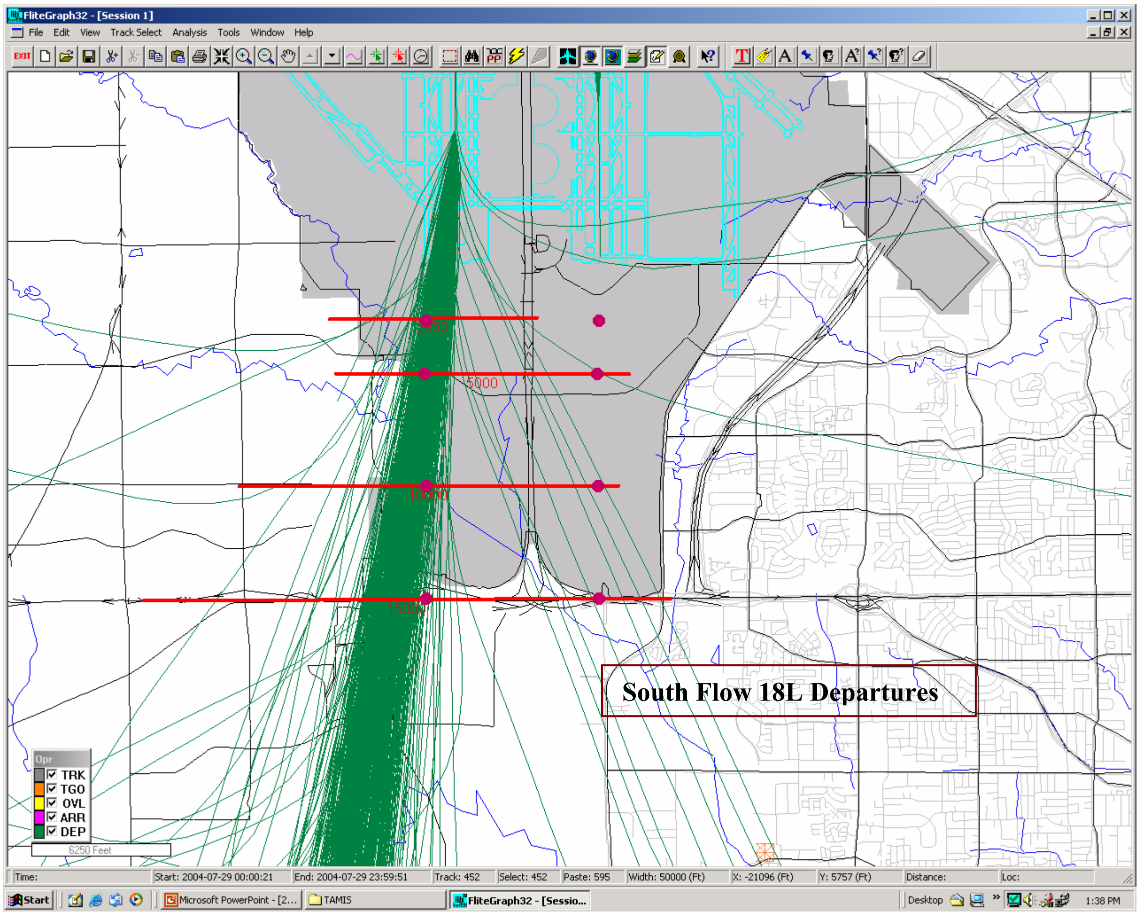


Figure 34 South Flow runway 18L departures showing the location of gates

Figure 34 shows the location of gates at 2,650, 5,000, 10,000, and 15,000 feet from the end of runway 18L, the other primary runway for South Flow departures. The flight data obtained from FliteGraph® facilitates the analysis of aircraft height at different distances from the end of the runway during departure.

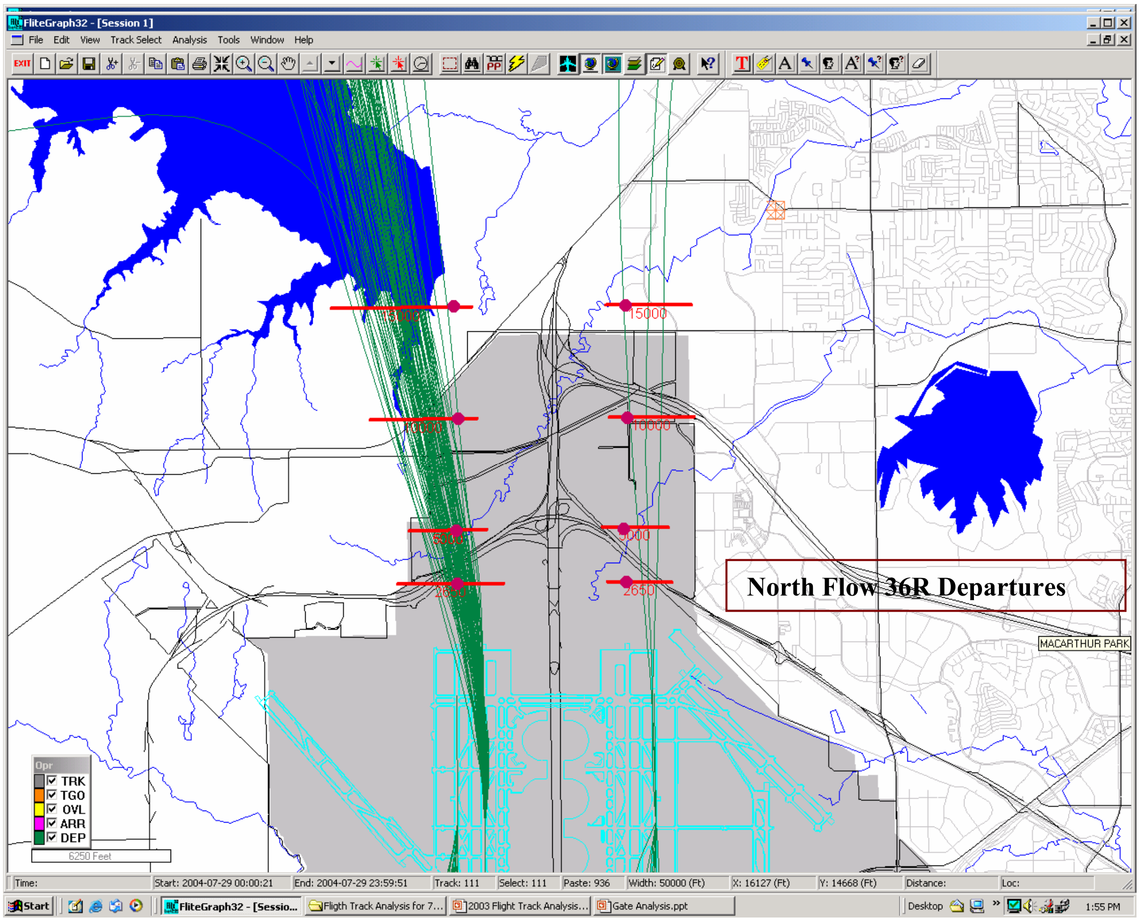


Figure 35 North Flow runway 36R showing the location of gates

Figure 35 shows the location of gates at 2,650, 5,000, 10,000, and 15,000 feet from the end of runway 36R, the primary runway for North Flow departures. The flight data obtained from FliteGraph® facilitates the analysis of the height of aircraft at different distances from the end of the runway during departure.

7.2 Statistical evaluation of flight data

This section evaluates of the flight path and aircraft height where it crosses the centerline of the PT at a distance of 2,650 feet from the end of the runway on the north side and south side using actual flight data obtained from DFW/EAD. This is the first time a research analysis has been attempted to establish the height of an aircraft along the centerline of a runway during the arrival and departure state in an airport using real time historical data. The typical data format is shown in Appendix K. Individual dates were analyzed for South Flow flights arriving on runway 17C and 18R and for North Flow arriving on Runway 35C and 36L. The data is analyzed to determine the maximum, minimum, mean, median, and mode of the aircraft height above the centerline of the PT. A statistical analysis is performed by combining the data for all five selected dates to compute the maximum, minimum, mean, mode, median, standard deviation, standard error, and average variation of the height. In the statistical analysis, the outliers are not eliminated while performing the test to determine the distribution of the observed height data. The numbers of outliers were few and they were well above the minimum specified by the FAA and did not affect the safety aspect of the analysis undertaken in this section. Chi-square goodness-of fit test is performed to ascertain the type of distribution of the height data at 2,650 feet from the end of the runway for South Flow and North flow.

7.2.1 Description of the flight track data

The height data obtained from FliteGraph® are discrete and independent of each other. The aircraft height in the approach path is dependent on the type of aircraft, speed of travel, weight of aircraft, where the aircraft will touch down on the runway, separation between successive aircraft, the visibility, wind direction and speed. The height of each aircraft is independent of the other aircraft in the arrival stream. Similarly, on the departure path, the aircraft heights depends on the aircraft's weight, speed and climb rate of, the wind direction and speed, visibility, navigational fix, designated flight path and preceding aircraft's flight path, direction and travel speed. The height information obtained from FliteGraph® is unique and independent of each aircraft in the departure flight path.

The analysis is performed on the presumption that the height data obtained from EAD has an accuracy of ± 20 ft [11] with reference to the actual position of an aircraft in space. Therefore, the data used in the analysis is appropriate to determine the aircraft height above the centerline of PT on the approach and departure paths.

7.3 Definition of statistical terms used in the analysis

The arithmetic mean of a sample of an independent variable, the height, is given by the equation,

$$\text{Mean} = \bar{x} = \sum_{i=1}^{n} X_i$$

Maximum = the maximum value for the independent variable, the height data

Minimum = the minimum value for the independent variable, of the height data

Mode = repetition of the value in the independent variable in the height data

The sample variance of data set consisting of values $x_1, x_2, x_3, \ldots x_n$ is given by,

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

Standard deviation $\mathbf{s} = +\sqrt{s^2}$

Standard error = $\frac{\mathbf{s^2}}{\sqrt{\mathbf{n}}}$

Scatter Plot: Five year combined height data for each runway for arrivals and departures is plotted with the mean, upper control limit (UCL) and lower control limit (LCL) super imposed on the chart.

UCL = $\bar{x}$ + 3 s where $\bar{x}$ = mean and s = standard deviation

LCL = $\bar{x}$ – 3 s

If a data set has an approximately mound-shaped symmetric distribution, then almost all measurements will lie within 3 standard deviations of their mean (within the UCL and LCL) as can be seen in the scatter plots.

Histogram: The histogram is a traditional way of displaying the shape of the height data obtained from flight track. It is constructed from a frequency distribution of the height data, where choices on the number of intervals and interval width have been made. These choices can drastically affect the shape of the histogram. The ideal shape to look for in the case of normality is a bell-shaped symmetrical distribution. The histogram is a graph of the frequency distribution in which the vertical axis represents the count (frequency) and the horizontal axis represents the possible range of the data values.

To compute the Chi-square test statistic, the height data is standardized (z-value) by subtracting the mean and dividing each by the standard deviation of the height. Then the height data was divided into ten bins of z-values: (<-2), (-2, -1.5), (-1.5, -1.0), (-1.0, -0.5), (-0.5, 0.0), (0.0, 0.5), (0.5, 1.0), (1.0, 1.5), (1.5, 2.0), (>2). The corresponding normal probabilities and the expected number of height observations for each runway data set are computed. The Chi-square goodness-of-fit test is used to test whether the distribution of a data set follows a particular pattern. For example, the goodness-of-fit, Chi-square may be used to test whether a set of values follow the normal distribution.

H_0: The data follow a specific distribution, in this case normal distribution

H_A: The data do not follow the normal distribution

Test statistic: for the Chi-square goodness-of-fit computation, the data are divided into k bins and the test statistic is defined as: $\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$ where O_i is the observed frequency for bin i and E_i is the expected frequency for bin i.

The expected frequency is

$E_i = N\,(F\,(Y_u) - F\,(Y_l))$ where F is the cumulative distribution function for the distribution being tested. Y_u is the upper limit for class i and Y_l is the lower limit for class i, and N is the sample size.

The statistical analysis is performed for South Flow and North Flow separately. Results for arrivals on runway 18R and 17C, 35C and 36L are presented first. The results for departures on 17R, 18L, 35L and 36R are posted second. It is found that nearly 90% of the data lie between the UCL and LCL in the scatter plot for the arrival and departure runway data.

There are a total of eight tables for the statistics of arrivals and departures. In the arrival statistics tables, the FAA defined arrival path at a 34:1 slope is shown to indicate the minimum height of 72 feet required from the PT centerline for clearance of an aircraft taxiing on the PT. The 34:1 slope begins at 200 feet from the end of the runway as shown in Figure 61 in Section 7.14.

The departure slope is defined by the FAA at 40:1 from the end of the runway. The table shows the minimum height of 66.25 feet above the PT center line. This is the minimum clearance required for a departing aircraft to fly safely over an aircraft taxiing on the PT as shown in Figure 60 in Section 7.13. The FAA/AOSC has reduced this height to 65 ft in the final approval document for PT construction at DFW [3].

7.4 Runway 18R arrival height statistical evaluation

Table 16 Statistics of runway 18R flight track data

DISTANCE FROM END OF RUNWAY	**2650**	**5000**	**10000**	**15000**
COUNT	**1340**	**1340**	**1340**	**1340**
34:1 ARRIVAL SLOPE (FAA)	**72**	**141**	**288**	**435**
MAXIMUM	**549**	**778**	**1288**	**1796**
MINIMUM	**148**	**183**	**410**	**613**
MEAN	**255**	**350**	**612**	**890**
MODE	**269**	**404**	**580**	**876**
MEDIAN	**253**	**349**	**603.5**	**866**
STANDARD DEVIATION	**41**	**68**	**101**	**144**
STANDARD ERROR	**1.1**	**1.9**	**2.8**	**3.9**
AVERAGE VARIATION	**31.1**	**55.5**	**76.5**	**101.6**

A total of 1,340 observations were obtained by combining the height data for the five dates for the five years selected. The statistical analysis yielded the results shown above in Table 15. The frequency distribution and the normal curve are shown in Figure 36.

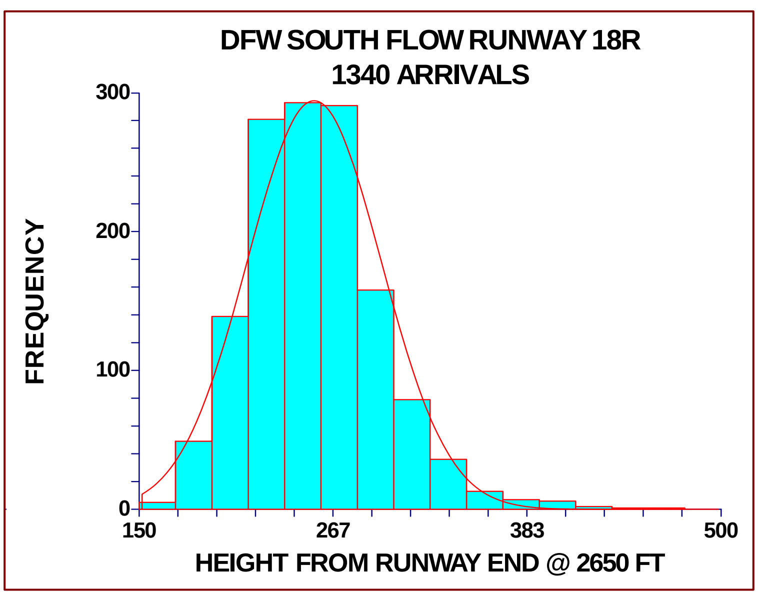


Figure 36 Frequency distribution of arrivals on runway 18R

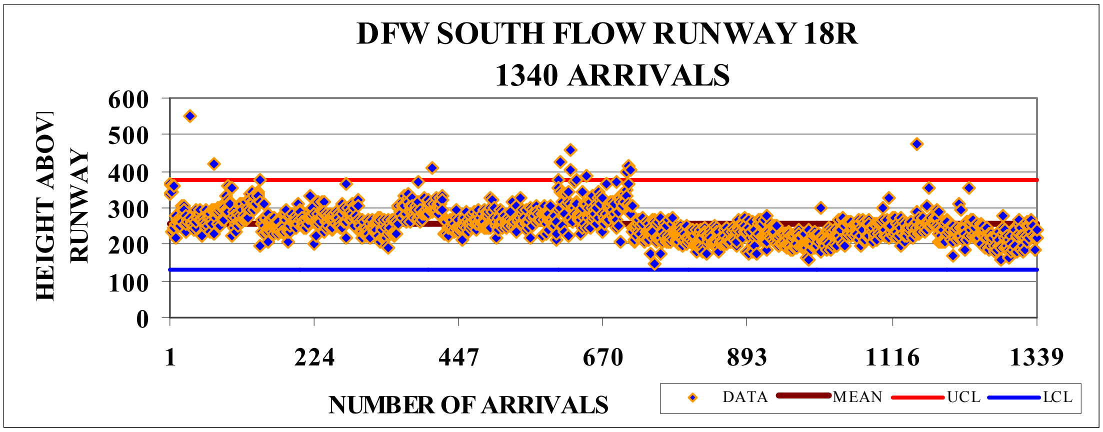


Figure 37 Runway 18R arrival data scatter plot

The data scatter plot in Figure 37 shows the arrival aircraft elevation above GL at a distance of 2,650 feet from end of the runway 18R is shown in Figure 36. There were a combined total of 1,340 arrivals for the five dates selected in 2001, 2002, 2003, 2004 and 2005. The mean of the arrival height is 255 feet above GL.

Table 17 Frequency distribution of runway 18R data

DFW SOUTH FLOW RUNWAY 18R-ARRIVALS HEIGHT @ 2650'				
COMBINED DATA		Cum		Cum
	Count	Count	Percent	Percent
140 To 165	5	5	0.37	0.37
165 To 190	43	48	3.21	3.58
190 To 215	145	193	10.82	14.4
215 To 240	318	511	23.73	38.13
240 To 265	348	859	25.97	64.1
265 To 290	254	1113	18.96	83.06
290 To 315	140	1253	10.45	93.51
315 To 340	50	1303	3.73	97.24
340 To 365	19	1322	1.42	98.66
365 To 390	8	1330	0.6	99.25
390 To 415	5	1335	0.37	99.63
415 To 440	2	1337	0.15	99.78
440 To 465	1	1338	0.07	99.85
465 To 490	1	1339	0.07	99.93
540 To 565	1	1340	0.07	100

Table 18 Runway 18R parametric estimates

PRAMETER ESTIMATES RUNWAY 18R ARRIVALS				
PRAMETER	ESTIMATE	STANDARD ERROR	LOWER (95%) CONFIDENCE BOUND	UPPER (95%) CONFIDENCE BOUND
MEAN	255.11	1.12	252.92	257.31
STANDARD DEVIATION	40.99	1.84	39.50	42.61
VARIANCE	1,680.45	106.58	1,560.08	1,815.37

Confidence intervals, for mean, standard deviation and variance are shown Table 17. The population mean height is expected to be 252.92<x<257.31 feet. The calculated mean height is 255.11 feet. The Chi-square test computation is shown in Table 19.

Table 19 Runway 18R arrivals height Chi square test

18R chi square test					
Z value	Observed count	Noraml Prob	Exp Count	(Ob-Ex)	χ^2
(<-2.0)	8	0.023	31	-23	16.90
(-2.0, -1.5)	47	0.044	59	-12	2.43
(-1.5, -1.0)	133	0.092	123	10	0.77
(-1.0, -0.5)	247	0.150	201	46	10.53
(-0.5, 0.0)	270	0.191	256	14	0.77
(0.0, 0.5)	304	0.191	256	48	9.02
(0.5, 1.0)	142	0.150	201	-59	17.32
(1.0, 1.5)	105	0.092	123	-18	2.71
(1.5,2.0)	38	0.044	59	-21	7.45
(>2.0)	46	0.023	31	15	7.48
	1340	1	1340		75.37

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RUNWAY 18R ARRIVALS

CHI-SQUARE GOODNESS-OF-FIT TEST

NULL HYPOTHESIS H_0: DISTRIBUTION FITS THE DATA

ALTERNATE HYPOTHESIS H_A: DISTRIBUTION DOES NOT FIT THE DATA

DISTRIBUTION: NORMAL DISTRIBUTION

SAMPLE

NUMBER OF OBSERVTIONS = 1340

TEST

CHI-SQUARE TEST STATISTIC = 75.37

DEGREES OF FREEDOM = 9

ALPHA LEVEL	CUTOFF	CONCLUSION
10%	14.6840	REJECT H_0
5%	16.9190	REJECT H_0
1%	21.6660	REJECT H_0

Figure 38 Chi-square Goodness-of-fit test Runway 18R arrivals

In Figure 38, Chi-square goodness-of-fit test shows that the data is not normally distributed. The data is bunched together at a certain elevation; hence, the null hypothesis is rejected.

7.5 Runway 17C arrival height statistical evaluation

Table 20 Runway 17C flight track data

DISTANCE FROM END OF RUNWAY	2650	5000	10000	15000
COUNT	1363	1363	1363	1363
34:1 ARRIVAL SLOPE (FAA)	72	141	288	435
MAXIMUM	597	896	1418	1953
MINIMUM	150	202	395	601
MEAN	260	359	629	916
MODE	251	348	579	896
MEDIAN	255	354	613	883
STANDARD DEVIATION	40	59	96	151
STANDARD ERROR	4.7	5.0	5.7	7.3
AVERAGE VARIATION	28.1	42.4	61.7	98.8

A total of 1,363 observations were obtained by combining the height data for the five data dates for the five years selected. The statistical analysis yielded the results shown above in Table 20. The frequency distribution and the normal curve are shown in Figure 39.

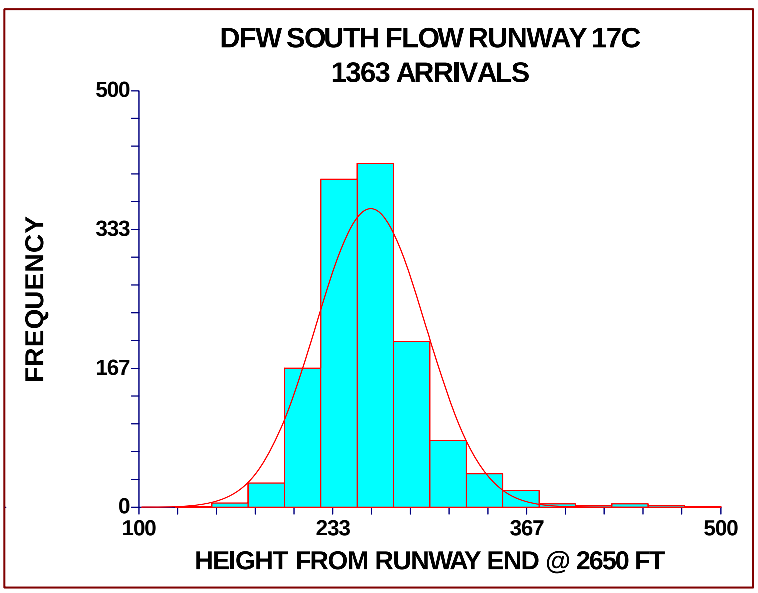

Figure 39 Frequency distribution of arrivals on runway 17C

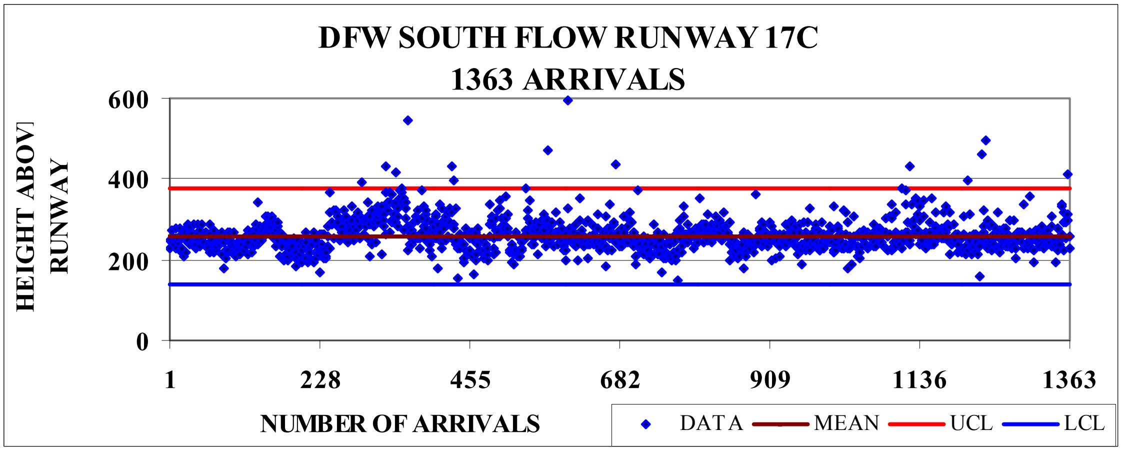

Figure 40 Runway 17C arrival data scatter plot

The data scatter plot for the arrival aircraft elevation above GL at a distance of 2,650 feet from end of the runway 17C is shown in Figure 40. There were a combined total of 1,363 arrivals for the five dates selected in 2001, 2002, 2003, 2004 and 2005. The mean of the arrival height is 260 feet above GL.

Table 21 Frequency distribution of runway 17C data

DFW SOUTH FLOW RUNWAY 17C-ARRIVALS HEIGHT @ 2650'				
COMBINED DATA		Cum		Cum
	Count	Count	Percent	Percent
125 To 150	1	1	0.07	0.07
150 To 175	5	6	0.37	0.44
175 To 200	29	35	2.13	2.57
200 To 225	167	202	12.25	14.82
225 To 250	394	596	28.91	43.73
250 To 275	413	1009	30.3	74.03
275 To 300	199	1208	14.6	88.63
300 To 325	80	1288	5.87	94.5
325 To 350	40	1328	2.93	97.43
350 To 375	20	1348	1.47	98.9
375 To 400	4	1352	0.29	99.19
400 To 425	2	1354	0.15	99.34
425 To 450	4	1358	0.29	99.63
450 To 475	2	1360	0.15	99.78
475 To 500	1	1361	0.07	99.85
525 To 550	1	1362	0.07	99.93
575 To 600	1	1363	0.07	100

Table 22 Runway 17C parametric estimates

PRAMETER ESTIMATES RUNWAY 17C ARRIVALS				
PRAMETER	ESTIMATE	STANDARD ERROR	LOWER (95%) CONFIDENCE BOUND	UPPER (95%) CONFIDENCE BOUND
MEAN	259.79	1.07	257.68	261.89
STANDARD DEVIATION	39.67	2.46	38.23	41.22
VARIANCE	1,573.65	138.28	1,461.83	1,698.86

Confidence intervals, for mean, standard deviation and variance are shown Table 22. The population mean height is expected to be between $257.68<x<261.89$ feet. The calculated mean height is 259.79 feet. The Chi-square test computation is shown in Table 23.

Table 23 Runway 17C arrivals height chi square test

17C chi square test					
Z value	Observed count	Noraml Prob	Exp Count	(Ob-Ex)	χ^2
(<-2.0)	10	0.023	31	-21	14.54
(-2.0, -1.5)	25	0.044	60	-35	20.39
(-1.5, -1.0)	111	0.092	125	-14	1.65
(-1.0, -0.5)	256	0.150	204	52	13.00
(-0.5, 0.0)	355	0.191	260	95	34.42
(0.0, 0.5)	288	0.191	260	28	2.94
(0.5, 1.0)	156	0.150	204	-48	11.48
(1.0, 1.5)	74	0.092	125	-51	21.07
(1.5,2.0)	41	0.044	60	-19	6.00
(>2.0)	47	0.023	31	16	7.81
	1363	1	1363		133.31

RUNWAY 17C ARRIVALS
CHI-SQUARE GOODNESS-OF-FIT TEST
NULL HYPOTHESIS H_0: DISTRIBUTION FITS THE DATA
ALTERNATE HYPOTHESIS H_A: DISTRIBUTION DOES NOT FIT THE DATA
DISTRIBUTION: NORMAL DISTRIBUTION

SAMPLE
NUMBER OF OBSERVTIONS = 1363

TEST
CHI-SQUARE TEST STATISTIC = 133.31
DEGREES OF FREEDOM = 9

ALPHA LEVEL	CUTOFF	CONCLUSION
10%	14.6840	REJECT H_0
5%	16.9190	REJECT H_0
1%	21.6660	REJECT H_0

Figure 41 Chi-square Goodness-of-fit test Runway 17C arrivals

In Figure 41, the Chi-square goodness-of-fit test shows that the data is not normally distributed. The data is bunched together at a certain elevation; hence, the null hypothesis is rejected.

7.6 Runway 35C arrival height statistical evaluation

Table 24 Runway 35C flight track data

DISTANCE FROM END OF RUNWAY	2650	5000	10000	15000
COUNT	1276	1276	1276	1276
34:1 ARRIVAL SLOPE (FAA)	72	141	288	435
MAXIMUM	750	898	1329	1682
MINIMUM	105	171	326	594
MEAN	206	273	521	793
MODE	207	253	509	775
MEDIAN	204	267	512	786
STANDARD DEVIATION	32	40	63	87
STANDARD ERROR	0.9	1.1	1.8	2.4
AVERAGE VARIATION	22.6	28.7	45.6	59.4

A total of 1,276 observations were obtained by combining the height data for the five dates for the five years selected. The statistical analysis yielded the results shown above in Table 24. The frequency distribution and the normal curve are shown in Figure 42.

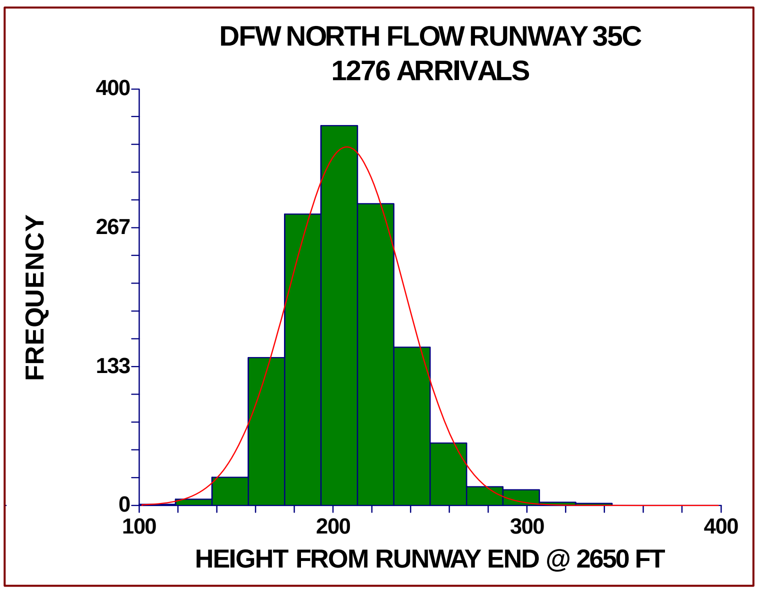

Figure 42 Frequency distribution of arrivals on runway 35C

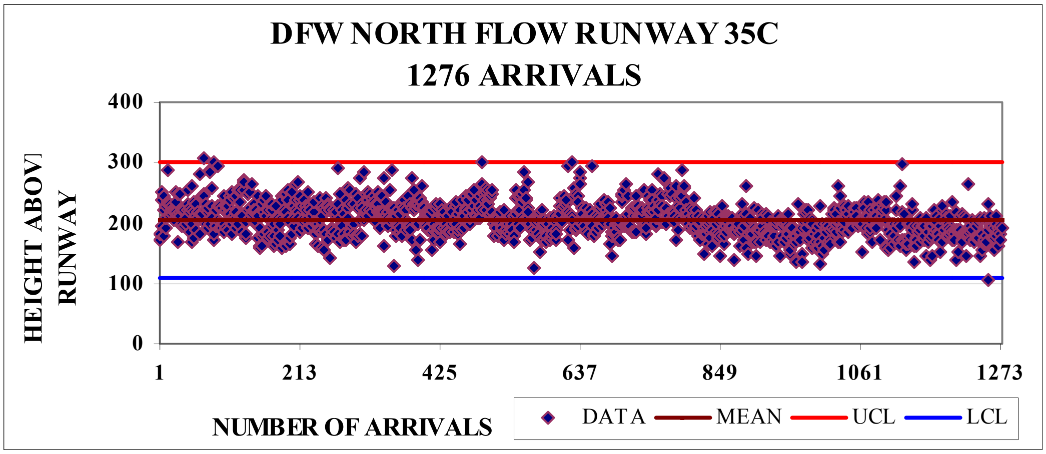

Figure 43 Runway 35C arrival data scatter plot

The data scatter plot for the arrival aircraft elevation above GL at a distance of 2,650 feet from end of the runway 35C is shown in Figure 43. There were a combined total of 1,276 arrivals for the five dates selected in 2001, 2002, 2003, 2004 and 2005. The mean of the arrival height is 206 feet above GL

Table 25 Frequency distribution of runway 35C data

DFW NORTH FLOW RUNWAY 35C-ARRIVALS HEIGHT @ 2650'				
COMBINED DATA		Cum		Cum
	Count	Count	Percent	Percent
100 To 150	25	25	1.96	1.96
150 To 200	556	581	43.57	45.53
200 To 250	621	1202	48.67	94.2
250 To 300	70	1272	5.49	99.69
300 To 350	3	1275	0.24	99.92
700 To 750	1	1276	0.08	100

Table 26 Runway 35C parametric estimates

PRAMETER ESTIMATES RUNWAY 35C ARRIVALS				
PRAMETER	ESTIMATE	STANDARD ERROR	LOWER (95%) CONFIDENCE BOUND	UPPER (95%) CONFIDENCE BOUND
MEAN	205.86	0.90	204.11	207.62
STANDARD DEVIATION	32.04	5.17	30.84	33.33
VARIANCE	1,026.43	234.15	951.19	1,111.01

Confidence interval for mean, standard deviation and variance is shown Table 26. The population mean height is expected to be between 204.11<x<207.62. The calculated mean height is 205.86 feet. The Chi-square test computation is shown in Table 27

Table 27 Runway 35C arrivals height chi square test

35C chi square test					
Z value	Observed count	Noraml Prob	Exp Count	(Ob-Ex)	χ^2
(<-2.0)	11	0.023	29	-18	11.47
(-2.0, -1.5)	28	0.044	56	-28	14.11
(-1.5, -1.0)	120	0.092	117	3	0.06
(-1.0, -0.5)	211	0.150	191	20	2.01
(-0.5, 0.0)	290	0.191	244	46	8.79
(0.0, 0.5)	276	0.191	244	32	4.28
(0.5, 1.0)	174	0.150	191	-17	1.58
(1.0, 1.5)	101	0.092	117	-16	2.29
(1.5,2.0)	38	0.044	56	-18	5.86
(>2.0)	27	0.023	29	-2	0.19
	1276	1	1276		50.63

RUNWAY 35C ARRIVALS
CHI-SQUARE GOODNESS-OF-FIT TEST
NULL HYPOTHESIS H_0: DISTRIBUTION FITS THE DATA
ALTERNATE HYPOTHESIS H_A: DISTRIBUTION DOES NOT FIT THE DATA
DISTRIBUTION: NORMAL DISTRIBUTION

SAMPLE
NUMBER OF OBSERVTIONS = 1276

TEST
CHI-SQUARE TEST STATISTIC = 50.6325
DEGREES OF FREEDOM = 9

ALPHA LEVEL	CUTOFF	CONCLUSION
10%	14.6840	REJECT H_0
5%	16.9190	REJECT H_0
1%	21.6660	REJECT H_0

Figure 44 Chi-square Goodness-of-fit test Runway 35C arrivals

In Figure 44, the Chi-square goodness-of-fit test shows that the data is not normally distributed. The data is bunched together at certain elevation; hence, the null hypothesis is rejected

7.7 Runway 36L arrival height statistical evaluation

Table 28 Runway 36L flight track data

DISTANCE FROM END OF RUNWAY	**2650**	**5000**	**10000**	**15000**
COUNT	**1086**	**1086**	**1086**	**1086**
34:1 ARRIVAL SLOPE (FAA)	**72**	**141**	**288**	**435**
MAXIMUM	**396**	**532**	**791**	**999**
MINIMUM	**95**	**144**	**401**	**574**
MEAN	**209**	**275**	**523**	**784**
MODE	**209**	**260**	**519**	**807**
MEDIAN	**209**	**270**	**518**	**780**
STANDARD DEVIATION	**27**	**36**	**49**	**59**
STANDARD ERROR	**0.8**	**1.1**	**1.5**	**1.8**
AVERAGE VARIATION	**20.3**	**27.9**	**38.0**	**45.5**

A total of 1,086 observations were obtained by combining the height data for the five dates for the five years selected. The statistical analysis yielded the results shown above in Table 28. The frequency distribution and the normal curve is shown in Figure 45.

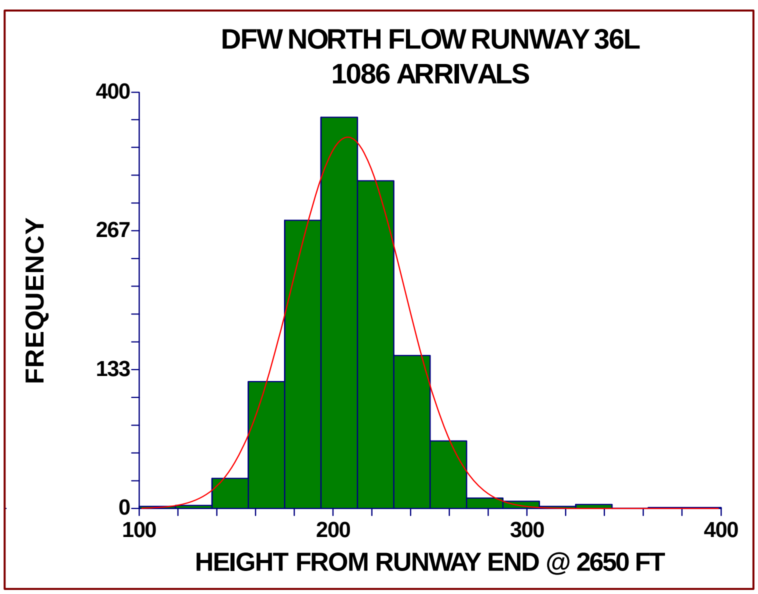

Figure 45 Frequency distribution of arrivals on runway 36L

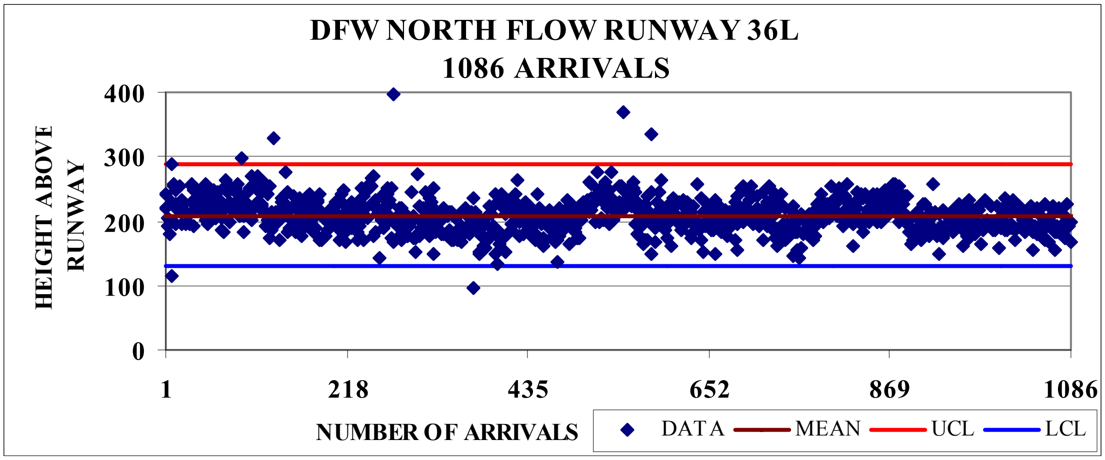

Figure 46 Runway 36L arrival data scatter plot

The data scatter plot shows the arrival aircraft elevation above GL at a distance of 2,650 feet from end of the runway 36L is shown in Figure 46. There were a combined total of 1,086 arrivals for the five dates selected in 2001, 2002, 2003, 2004 and 2005. The mean of the arrival height is 209 feet above GL

Table 29 Frequency distribution of runway 36L arrival data

DFW NORTH FLOW RUNWAY 36L-ARRIVALS HEIGHT @ 2650'				
COMBINED DATA	Count	Cum Count	Percent	Cum Percent
50 To 100	1	1	0.09	0.09
100 To 150	13	14	1.2	1.29
150 To 200	400	414	36.83	38.12
200 To 250	610	1024	56.17	94.29
250 To 300	58	1082	5.34	99.63
300 To 350	2	1084	0.18	99.82
350 To 400	2	1086	0.18	100

Table 30 Runway 36L parametric estimates

PRAMETER ESTIMATES RUNWAY 36L ARRIVALS				
PRAMETER	ESTIMATE	STANDARD ERROR	LOWER (95%) CONFIDENCE BOUND	UPPER (95%) CONFIDENCE BOUND
MEAN	208.73	0.81	207.15	210.32
STANDARD DEVIATION	26.61	1.39	25.54	27.78
VARIANCE	708.13	52.23	652.13	771.71

Confidence intervals, for mean, standard deviation and variance are shown Table 30. The population mean height is expected to be between 207.15<x<210.32. The calculated mean height is 208.73 feet. The Chi-square test computation is shown in Table 31

Table 31 Runway 36L arrivals height chi square test

36L chi square test					
Z value	Observed count	Noraml Prob	Exp Count	(Ob-Ex)	χ^2
(<-2.0)	22	0.023	25	-3	0.36
(-2.0, -1.5)	21	0.044	48	-27	15.01
(-1.5, -1.0)	117	0.092	100	17	2.92
(-1.0, -0.5)	179	0.150	163	16	1.59
(-0.5, 0.0)	195	0.191	207	-12	0.74
(0.0, 0.5)	263	0.191	207	56	14.89
(0.5, 1.0)	135	0.150	163	-28	4.78
(1.0, 1.5)	81	0.092	100	-19	3.58
(1.5,2.0)	56	0.044	48	8	1.41
(>2.0)	17	0.023	25	-8	2.55
	1086	1	1086		47.83

RUNWAY 36L ARRIVALS		
CHI-SQUARE GOODNESS-OF-FIT TEST		
NULL HYPOTHESIS H_0: DISTRIBUTION FITS THE DATA		
ALTERNATE HYPOTHESIS H_A: DISTRIBUTION DOES NOT FIT THE		
DISTRIBUTION: NORMAL DISTRIBUTION		
SAMPLE		
NUMBER OF OBSERVTIONS =	COUNT	1086
TEST		
CHI-SQUARE TEST STATISTIC =		47.83
DEGREES OF FREEDOM =		9
ALPHA LEVEL	CUTOFF	CONCLUSION
10%	14.6840	REJECT H_0
5%	16.9190	REJECT H_0
1%	21.6660	REJECT H_0

Figure 47 Chi-square Goodness-of-fit test Runway 36L arrivals

In Figure 47, the Chi-square goodness-of-fit test shows that the data is not normally distributed. The data is bunched together at a certain elevation; hence, the null hypothesis is rejected.

7.8 Runway 17R departure height statistical evaluation

Table 32 Runway 17R flight track data

DISTANCE FROM END OF RUNWAY	**2650**	**5000**	**10000**	**15000**
COUNT	**2155**	**2154**	**2152**	**2152**
40:1 DEPARTURE SLOPE (FAA)	**66.25**	**125**	**250**	**375**
MAXIMUM	**2597**	**2154**	**2152**	**2152**
MINIMUM	**365**	**557**	**902**	**1113**
MEAN	**1258**	**1452**	**1827**	**2225**
MODE	**1223**	**1385**	**1871**	**2063**
STANDARD DEVIATION	**294**	**309**	**387**	**483**
AVERAGE DEVIATION	**223.3**	**231.2**	**290.9**	**370.5**
STANDARD ERROR	**6.3**	**6.7**	**8.4**	**10.4**
MEDIAN	**1237**	**1416**	**1778**	**2175**

A total of 2,155 observations were obtained by combining the height data for the five dates for the five years selected. The statistical analysis yielded the results shown above in Table 32. The frequency distribution and the normal curve is shown in Figure 48.

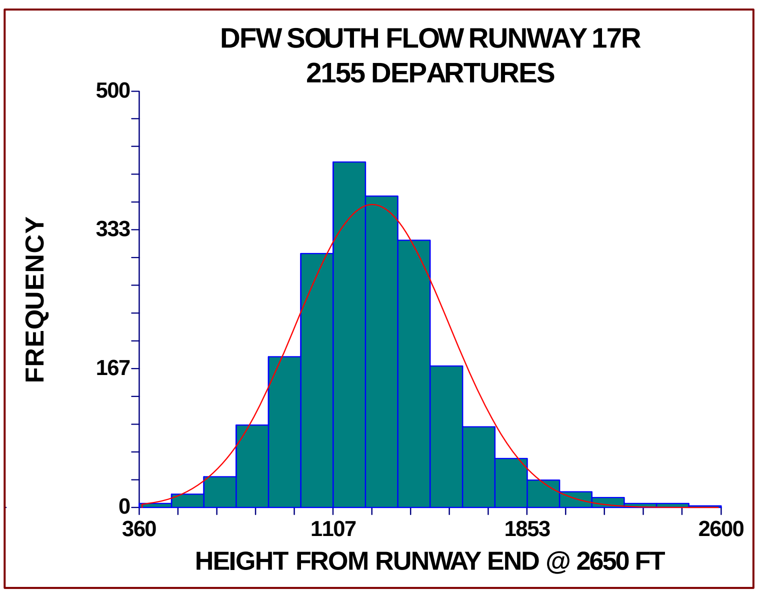

Figure 48 Frequency distribution of departures on runway 17R

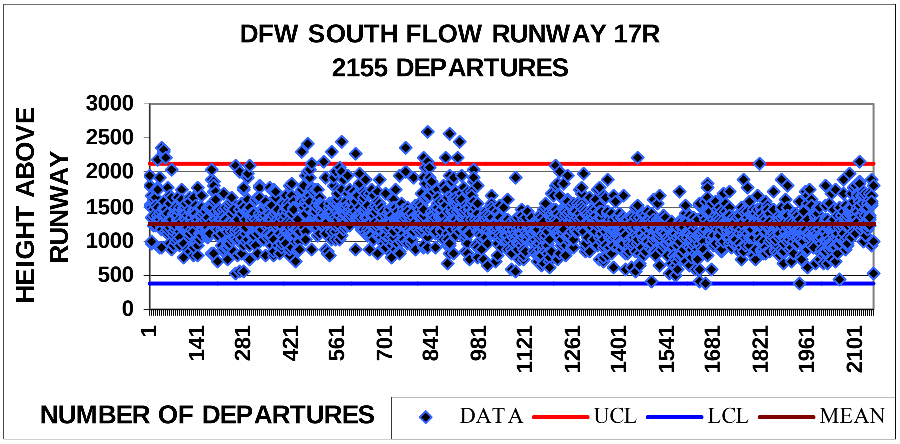

Figure 49 Runway 17R departure data scatter plot

The data scatter plot for the departure aircraft elevation above GL at a distance of 2,650 feet from end of the runway 17R is shown in Figure 49. There were a combined total of 2,155 departures for the five dates selected in 2001, 2002, 2003, 2004 and 2005. The mean of the departure aircraft height is 1,258 feet above GL.

Table 33 Frequency distribution 17R departures

DFW SOUTH FLOW RUNWAY 17R-DEPARTURES HEIGHT @ 2650'				
COMBINED DATA		Cum		Cum
	Count	Count	Percent	Percent
300 To 400	2	2	0.09	0.09
400 To 500	4	6	0.19	0.28
500 To 600	13	19	0.6	0.88
600 To 700	26	45	1.21	2.09
700 To 800	54	99	2.51	4.59
800 To 900	114	213	5.29	9.88
900 To 1000	156	369	7.24	17.12
1000 To 1100	258	627	11.97	29.1
1100 To 1200	309	936	14.34	43.43
1200 To 1300	342	1278	15.87	59.3
1300 To 1400	294	1572	13.64	72.95
1400 To 1500	230	1802	10.67	83.62
1500 To 1600	117	1919	5.43	89.05
1600 To 1700	82	2001	3.81	92.85
1700 To 1800	60	2061	2.78	95.64
1800 To 1900	30	2091	1.39	97.03
1900 To 2000	27	2118	1.25	98.28
2000 To 2100	13	2131	0.6	98.89
2100 To 2200	7	2138	0.32	99.21
2200 To 2300	8	2146	0.37	99.58
2300 To 2400	4	2150	0.19	99.77
2400 To 2500	3	2153	0.14	99.91
2500 To 2600	2	2155	0.09	100
	2155		100.0	

Table 34 Runway 17R parametric estimates

PARAMETER ESTIMATES RUNWAY 17R DEPARTURES				
PARAMETER	ESTIMATE	STANDARD ERROR	LOWER (95%) CONFIDENCE BOUND	UPPER (95%) CONFIDENCE BOUND
MEAN	1,257.70	6.33	1,245.29	1,270.12
STANDARD DEVIATION	293.98	8.10	285.46	303.03
VARIANCE	86,425.69	3,367.06	81,487.75	91,828.76

Confidence intervals, for mean, standard deviation and variance are shown in Table 34. The population mean height is expected to be between 1245.29<x<1270.12. The calculated mean height is 1,257.70 feet. The Chi-square test computation is shown in Table 35

Table 35 Runway 17R departures height chi square test

17R chi square test					
Z value	Observed count	Noraml Prob	Exp Count	(Ob-Ex)	χ^2
(<-2.0)	35	0.023	50	-15	4.28
(-2.0, -1.5)	90	0.044	95	-5	0.25
(-1.5, -1.0)	181	0.092	198	-17	1.50
(-1.0, -0.5)	348	0.150	323	25	1.90
(-0.5, 0.0)	489	0.191	412	77	14.55
(0.0, 0.5)	438	0.191	412	26	1.69
(0.5, 1.0)	286	0.150	323	-37	4.29
(1.0, 1.5)	134	0.092	198	-64	20.83
(1.5,2.0)	77	0.044	95	-18	3.35
(>2.0)	77	0.023	50	27	15.19
	2155	1	2155		67.82

RUNWAY 17R DEPARTURES		
CHI-SQUARE GOODNESS-OF-FIT TEST		
NULL HYPOTHESIS H_0: DISTRIBUTION FITS THE DATA		
ALTERNATE HYPOTHESIS H_A: DISTRIBUTION DOES NOT FI		
DISTRIBUTION: NORMAL DISTRIBUTION		
SAMPLE		
NUMBER OF OBSERVTIONS =		**2155**
TEST		
CHI-SQUARE TEST STATISTIC =		**67.82**
DEGREES OF FREEDOM =		**9**
ALPHA LEVEL	**CUTOFF**	**CONCLUSION**
10%	**14.6840**	**REJECT H_0**
5%	**16.9190**	**REJECT H_0**
1%	**21.6660**	**REJECT H_0**

Figure 50 Chi-square Goodness-of-fit test Runway 17R departures

In Figure 50, the Chi-square goodness-of-fit test shows that the data is not normally distributed. The data is bunched together at a certain elevation; hence the null hypothesis is rejected.

7.9 Runway 18L departure height statistical evaluation

Table 36 Runway 18L flight track data

DISTANCE FROM END OF RUNWAY	2650	5000	10000	15000
COUNT	1730	1728	1723	1721
40:1 DEPARTURE SLOPE (FAA)	66.25	125	250	375
MAXIMUM	2616	3076	8153	8752
MINIMUM	323	523	852	1002
MEAN	1199	1424	1807	2208
MODE	1204	1375	1586	2025
STANDARD DEVAITION	277	288	394	481
AVERAGE DEVIATION	213.1	217.3	274.7	345.1
STANDARD ERROR	6.7	6.9	9.5	11.6
MEDIAN	1180	1387	1746	2136

A total of 1,730 observations were obtained by combining the height data for the five dates for the five years selected. The statistical analysis yielded the results shown above in Table 36. The frequency distribution and the normal curve are shown in Figure 51.

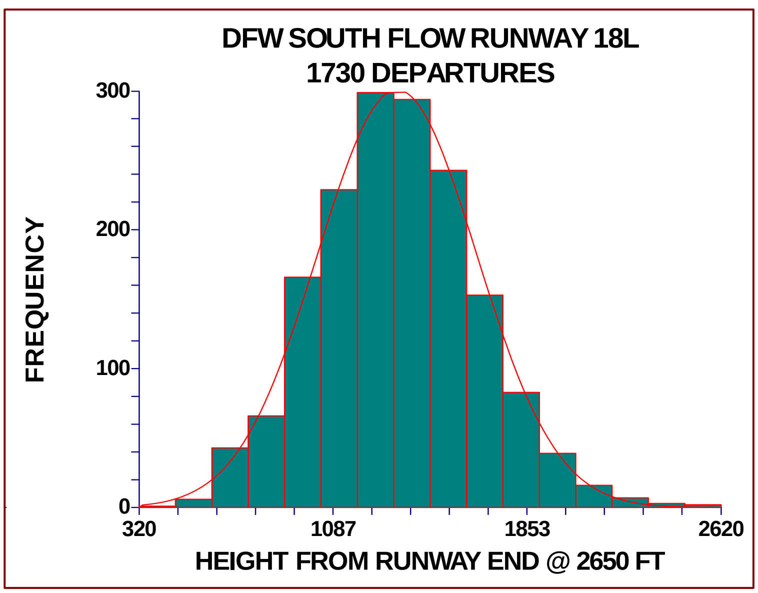

Figure 51 Frequency distribution of departures on runway 18L

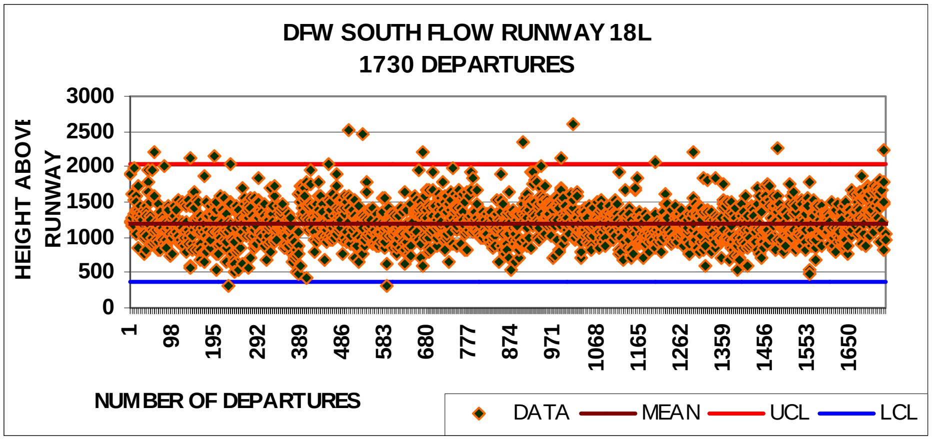

Figure 52 Runway 18L departure data scatter plot

The data scatter plot for the departure aircraft elevation above GL at a distance of 2,650 feet from end of the runway 18L is shown in Figure 52. There were a combined total of 1,730 departures for the five dates selected in 2001, 2002, 2003, 2004 and 2005. The mean of the departure aircraft height is 1,199 feet above GL.

Table 37 Runway 18L frequency distribution

DFW SOUTH FLOW RUNWAY 18L-DEPARTURES HEIGHT @ 2650'				
COMBINED DATA	Count	Cum Count	Percent	Cum Percent
300 To 400	2	2	0.12	0.12
400 To 500	4	6	0.23	0.35
500 To 600	12	18	0.69	1.04
600 To 700	24	42	1.39	2.43
700 To 800	53	95	3.06	5.49
800 To 900	117	212	6.76	12.25
900 To 1000	193	405	11.16	23.41
1000 To 1100	251	656	14.51	37.92
1100 To 1200	256	912	14.8	52.72
1200 To 1300	246	1158	14.22	66.94
1300 To 1400	217	1375	12.54	79.48
1400 To 1500	140	1515	8.09	87.57
1500 To 1600	96	1611	5.55	93.12
1600 To 1700	52	1663	3.01	96.13
1700 To 1800	27	1690	1.56	97.69
1800 To 1900	11	1701	0.64	98.32
1900 To 2000	12	1713	0.69	99.02
2000 To 2100	5	1718	0.29	99.31
2100 To 2200	3	1721	0.17	99.48
2200 To 2300	5	1726	0.29	99.77
2300 To 2400	1	1727	0.06	99.83
2400 To 2500	1	1728	0.06	99.88
2500 To 2600	1	1729	0.06	99.94
2600 To 2700	1	1730	0.06	100
	1730		100.0	

Table 38 Runway 18L parametric estimates

PARAMETER ESTIMATES RUNWAY 18L DEPARTURES				
PARAMETER	ESTIMATE	STANDARD ERROR	LOWER (95%) CONFIDENCE BOUND	UPPER (95%) CONFIDENCE BOUND
MEAN	1,198.96	6.65	1,185.92	1,212.00
STANDARD DEVIATION	276.74	8.79	267.81	286.28
VARIANCE	76,582.73	3,441.60	71,723.54	81,955.55

Confidence interval for mean, standard deviation and variance is shown Table 38. The population mean height is expected to be between 1185.92<x<1212.00. The calculated mean height is 1198.96 feet. The Chi-square test computation is shown in Table 39

Table 39 Runway 18L departures height chi square test

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18L chi square test					
Z value	Observed count	Noraml Prob	Exp Count	(Ob-Ex)	χ^2
(<-2.0)	26	0.023	40	-14	4.78
(-2.0, -1.5)	55	0.044	76	-21	5.86
(-1.5, -1.0)	164	0.092	159	5	0.15
(-1.0, -0.5)	295	0.150	260	36	4.86
(-0.5, 0.0)	366	0.191	330	36	3.83
(0.0, 0.5)	343	0.191	330	13	0.48
(0.5, 1.0)	237	0.150	260	-23	1.95
(1.0, 1.5)	133	0.092	159	-26	4.30
(1.5,2.0)	59	0.044	76	-17	3.85
(>2.0)	52	0.023	40	12	3.75
	1730	1	1730		33.80

RUNWAY 18L DEPARTURES		
CHI-SQUARE GOODNESS-OF-FIT TEST		
NULL HYPOTHESIS H_0: DISTRIBUTION FITS THE DATA		
ALTERNATE HYPOTHESIS H_A: DISTRIBUTION DOES NOT FIT THE I		
DISTRIBUTION: NORMAL DISTRIBUTION		
SAMPLE		
NUMBER OF OBSERVTIONS =		**1730**
TEST		
CHI-SQUARE TEST STATISTIC =		**33.80**
DEGREES OF FREEDOM =		**9**
ALPHA LEVEL	**CUTOFF**	**CONCLUSION**
10%	**14.6840**	**REJECT H_0**
5%	**16.9190**	**REJECT H_0**
1%	**21.6660**	**REJECT H_0**

Figure 53 Chi-square Goodness-of-fit test Runway 18L departures

In Figure 53 the Chi-square goodness-of-fit test shows that the data is not normally distributed. The data is bunched together at a certain elevation; hence, the null hypothesis is rejected

7.10 Runway 35L departure height statistical evaluation

Table 40 Runway 35L flight track data

DISTANCE FROM END OF RUNWAY	**2650**	**5000**	**10000**	**15000**
COUNT	**1652**	**1652**	**1651**	**1649**
40:1 DEPARTURE SLOPE (FAA)	**66.25**	**125**	**250**	**375**
MAXIMUM	**2649**	**2955**	**3766**	**4714**
MINIMUM	**357**	**539**	**914**	**1100**
MEAN	**1341**	**1543**	**1947**	**2382**
MODE	**1597**	**1586**	**2037**	**1988**
STANDARD DEVIATION	**318**	**322**	**395**	**495**
AVERAGE DEVIATION	**249.8**	**254.4**	**311.3**	**392.6**
STANDARD ERROR	**7.8**	**7.9**	**9.7**	**12.2**
MEDIAN	**1333**	**1519**	**1902**	**2326**

A total of 1,652 observations were obtained by combining the height data for the five dates for the five years selected. The statistical analysis yielded the results shown above in Table 40. The frequency distribution and the normal curve are shown in Figure 54.

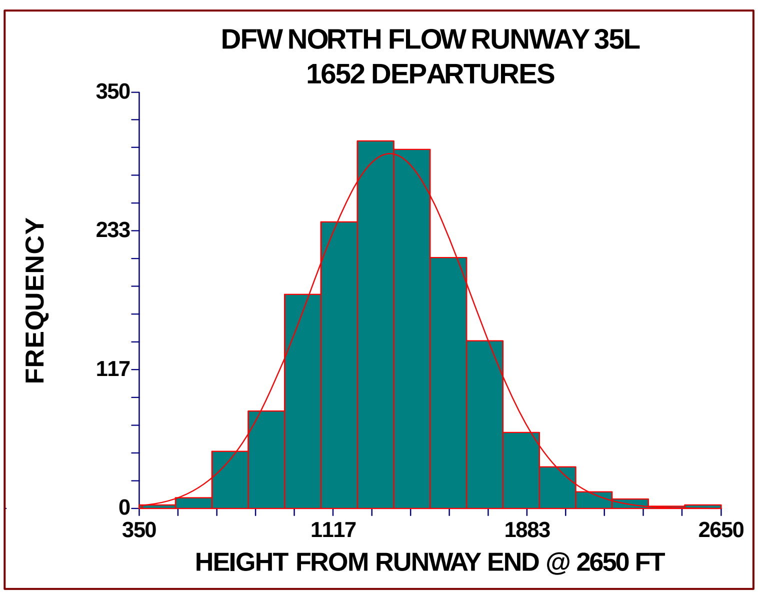

Figure 54 Frequency distribution of departures on runway 35L

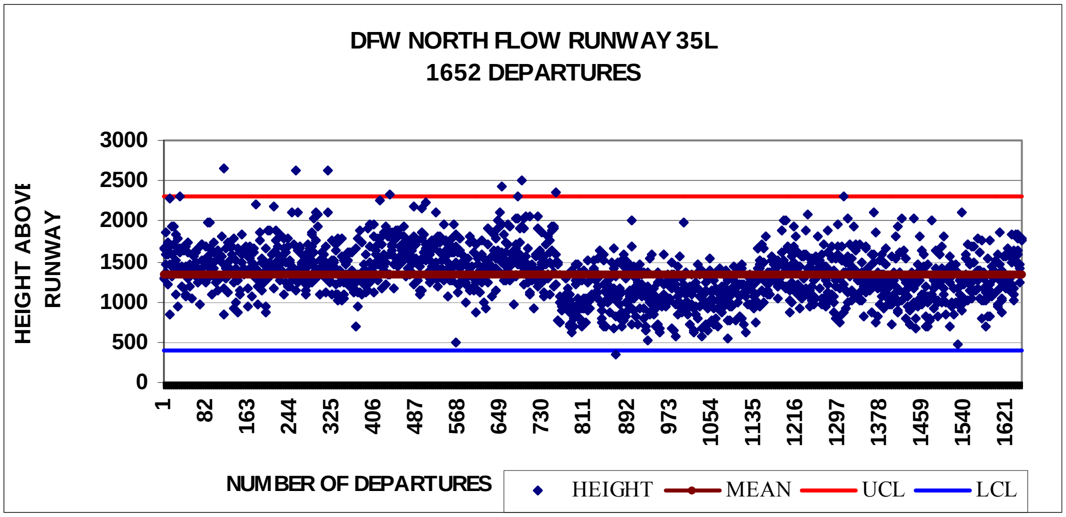

Figure 55 Runway 35L departure data scatter plot

The data scatter for the departure aircraft elevation above GL at a distance of 2,650 feet from end of the runway 35L is shown in Figure 55. There were a combined total of 1,652 departures for the five dates selected in 2001, 2002, 2003, 2004 and 2005. The mean of the departure aircraft height is 1,341 feet above GL.

Table 41 Runway 35L departures frequency distribution

DFW SOUTH FLOW RUNWAY 35L-DEPARTURES HEIGHT @ 2650'				
COMBINED DATA		Cum		Cum
	Count	Count	Percent	Percent
300 To 400	1	1	0.06	0.06
400 To 500	2	3	0.12	0.18
500 To 600	4	7	0.24	0.42
600 To 700	19	26	1.15	1.57
700 To 800	45	71	2.72	4.3
800 To 900	48	119	2.91	7.2
900 To 1000	116	235	7.02	14.23
1000 To 1100	148	383	8.96	23.18
1100 To 1200	157	540	9.5	32.69
1200 To 1300	215	755	13.01	45.7
1300 To 1400	214	969	12.95	58.66
1400 To 1500	205	1174	12.41	71.07
1500 To 1600	155	1329	9.38	80.45
1600 To 1700	130	1459	7.87	88.32
1700 To 1800	74	1533	4.48	92.8
1800 To 1900	50	1583	3.03	95.82
1900 To 2000	28	1611	1.69	97.52
2000 To 2100	18	1629	1.09	98.61
2100 To 2200	9	1638	0.54	99.15
2200 To 2300	5	1643	0.3	99.46
2300 To 2400	4	1647	0.24	99.7
2400 To 2500	2	1649	0.12	99.82
2600 To 2700	3	1652	0.18	100
	1652		100.0	

Table 42 Runway 35L parametric estimates

PARAMETER ESTIMATES RUNWAY 35L DEPARTURES				
PARAMETER	ESTIMATE	STANDARD ERROR	LOWER (95%) CONFIDENCE BOUND	UPPER (95%) CONFIDENCE BOUND
MEAN	1,340.83	7.81	1,325.52	1,356.14
STANDARD DEVIATION	317.53	8.63	307.06	328.74
VARIANCE	100,822.60	3,876.17	94,283.44	108,070.00

Confidence intervals, for mean, standard deviation and variance are shown Table 42. The population mean height is expected to be between 1,325.52<x<1,356.14. The calculated mean height is 1,340.83 feet. The Chi-square test computation is shown in Table 43.

Table 43 Runway 35L departures height chi square test

35L chi square test					
Z value	Observed count	Noraml Prob	Exp Count	(Ob-Ex)	χ^2
(<-2.0)	33	0.023	38	-5	0.66
(-2.0, -1.5)	69	0.044	73	-4	0.19
(-1.5, -1.0)	166	0.092	152	14	1.29
(-1.0, -0.5)	243	0.150	248	-5	0.09
(-0.5, 0.0)	332	0.191	316	16	0.86
(0.0, 0.5)	331	0.191	316	15	0.76
(0.5, 1.0)	232	0.150	248	-16	1.01
(1.0, 1.5)	136	0.092	152	-16	1.68
(1.5,2.0)	65	0.044	73	-8	0.81
(>2.0)	45	0.023	38	7	1.29
	1652	1	1652		8.64

RUNWAY 35L DEPARTURES

CHI-SQUARE GOODNESS-OF-FIT TEST

NULL HYPOTHESIS H_0: DISTRIBUTION FITS THE DATA

ALTERNATE HYPOTHESIS H_A: DISTRIBUTION DOES NOT FIT THE DATA

DISTRIBUTION: NORMAL DISTRIBUTION

SAMPLE

NUMBER OF OBSERVTIONS =	**1652**

TEST

CHI-SQUARE TEST STATISTIC =	**8.64**
DEGREES OF FREEDOM =	**9**

ALPHA LEVEL	**CUTOFF**	**CONCLUSION**
10%	**14.6840**	**ACCEPT H_0**
5%	**16.9190**	**ACCEPT H_0**
1%	**21.6660**	**ACCEPT H_0**

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Figure 56 Chi-square Goodness-of-fit test Runway 35L departures

In Figure 56, the Chi-square goodness-of-fit test shows that the data is normally distributed; hence, the null hypothesis is not rejected.

7.11 Runway 36R departure height statistical evaluation

Table 44 Runway 36R flight track data

DISTANCE FROM END OF RUNWAY	**2650**	**5000**	**10000**	**15000**
COUNT	**1475**	**1475**	**1474**	**1471**
40:1 DEPARTURE SLOPE (FAA)	**66.25**	**125**	**250**	**375**
MAXIMUM	**3004**	**3623**	**4827**	**5904**
MINIMUM	**456**	**734**	**1006**	**1196**
MEAN	**1371**	**1576**	**1988**	**2438**
MODE	**1549**	**1534**	**1787**	**2243**
STANDARD DEVIATION	**285**	**295**	**375**	**478**
AVERAGE DEVIATION	**220.3**	**224.9**	**284.6**	**368.2**
STANDARD ERROR	**7.4**	**7.7**	**9.8**	**12.5**
MEDIAN	**1363**	**1556**	**1947.5**	**2387**

A total of 1,475 observations were obtained by combining the height data for the five dates for the five years selected. The statistical analysis yielded the results shown above in Table 44. The frequency distribution and the normal curve are shown in Figure 57.

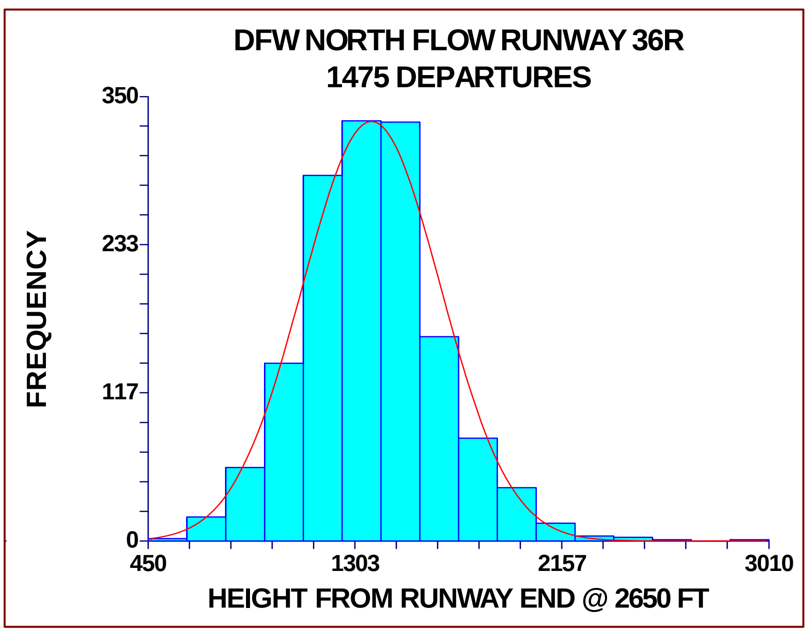

Figure 57 Frequency distribution of departures on runway 36R

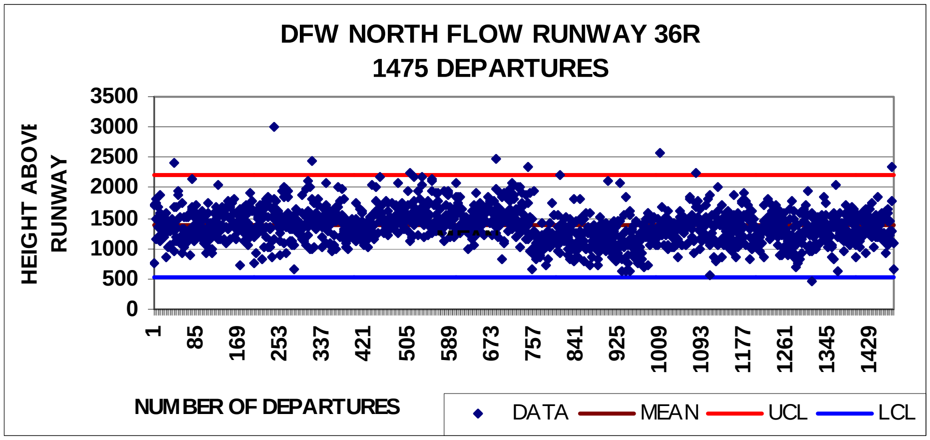

Figure 58 Runway 36R departure data scatter plot

The data scatter plot for the departure aircraft elevation above GL at a distance of 2,650 feet from end of the runway 36R is shown in Figure 58. There were a combined total of 1,475 departures for the five dates selected in 2001, 2002, 2003, 2004 and 2005. The mean of the departure aircraft height is 1,371 feet above GL.

Table 45 Runway 36R frequency distribution

DFW SOUTH FLOW RUNWAY 36R DEPARTURES HEIGHT @ 2650'				
	Count	Cum Count	Percent	Cum Percent
400 To 500	1	1	0.07	0.07
500 To 600	1	2	0.07	0.14
600 To 700	9	11	0.61	0.75
700 To 800	15	26	1.02	1.76
800 To 900	38	64	2.58	4.34
900 To 1000	54	118	3.66	8
1000 To 1100	114	232	7.73	15.73
1100 To 1200	169	401	11.46	27.19
1200 To 1300	204	605	13.83	41.02
1300 To 1400	207	812	14.03	55.05
1400 To 1500	220	1032	14.92	69.97
1500 To 1600	180	1212	12.2	82.17
1600 To 1700	95	1307	6.44	88.61
1700 To 1800	72	1379	4.88	93.49
1800 To 1900	35	1414	2.37	95.86
1900 To 2000	27	1441	1.83	97.69
2000 To 2100	16	1457	1.08	98.78
2100 To 2200	9	1466	0.61	99.39
2200 To 2300	2	1468	0.14	99.53
2300 To 2400	2	1470	0.14	99.66
2400 To 2500	3	1473	0.2	99.86
2500 To 2600	1	1474	0.07	99.93
3000 To 3100	1	1475	0.07	100
	1475		100.0	

Table 46 Runway 36R parametric estimates

PARAMETER ESTIMATES RUNWAY 36R DEPARTURES				
PARAMETER	ESTIMATE	STANDARD ERROR	LOWER (95%) CONFIDENCE BOUND	UPPER (95%) CONFIDENCE BOUND
MEAN	1,371.08	7.42	1,356.54	1,385.62
STANDARD DEVIATION	284.85	9.48	274.93	295.52
VARIANCE	81,141.92	3,818.35	75,588.25	87,334.13

Confidence intervals, for mean, standard deviation and variance are shown Table 46. The population mean height is expected to be between 1,356.54<x<1,385.62. The calculated mean height is 1,371.08 feet. The Chi-square test computation is shown in Table 47

Table 47 Runway 36R departures height chi square test

36R chi square test					
Z value	Observed count	Noraml Prob	Exp Count	(Ob-Ex)	χ^2
(<-2.0)	26	0.023	34	-8	1.85
(-2.0, -1.5)	60	0.044	65	-5	0.37
(-1.5, -1.0)	126	0.092	136	-10	0.69
(-1.0, -0.5)	250	0.150	221	29	3.74
(-0.5, 0.0)	288	0.191	282	6	0.14
(0.0, 0.5)	315	0.191	282	33	3.93
(0.5, 1.0)	204	0.150	221	-17	1.34
(1.0, 1.5)	108	0.092	136	-28	5.65
(1.5,2.0)	51	0.044	65	-14	2.98
(>2.0)	47	0.023	34	13	5.04
	1475	1	1475		25.74

RUNWAY 36R DEPARTURES

CHI-SQUARE GOODNESS-OF-FIT TEST

NULL HYPOTHESIS H_0: DISTRIBUTION FITS THE DATA

ALTERNATE HYPOTHESIS H_A: DISTRIBUTION DOES NOT FIT THE

DISTRIBUTION: NORMAL DISTRIBUTION

SAMPLE

NUMBER OF OBSERVTIONS =	**1475**

TEST

CHI-SQUARE TEST STATISTIC =	**25.74**
DEGREES OF FREEDOM =	**9**

ALPHA LEVEL	CUTOFF	CONCLUSION
10%	14.6840	REJECT H_0
5%	16.9190	REJECT H_0
1%	21.6660	REJECT H_0

Figure 59 Chi-square Goodness-of-fit-test Runway 36R departures

In Figure 59, the Chi-square goodness-of-fit test shows that the data is not normally distributed. The data is bunched together at a certain elevations; hence, the null hypothesis is rejected.

7.12 Normal distribution verification

The flight track data is verified to assess whether they follow a normal distribution for both arrival and departures using the Interquartile Range (IQR), and standard deviation 's'. IQR is the difference between the value at 75th and 25th percentiles. If the data sample is approximately normal then IQR divided by standard deviation (s) should equal 1.34. The frequency diagram in Figures 28, 31, 34, and 37 show that the normal curve is symmetrically placed over the mean value for the height of aircraft over PT for runways 18R, 17C, 35C and 36L for arrivals. Similarly, an inspection of Figures 40, 43, 46, and 49 show that the normal curve is symmetrically placed over the mean of the height of aircraft over runways 17R, 18L, 35L and 36R for departures. To verify that the data approximately follow a normal distribution, another check is done using the IQR/s method for runways 18R, 17C, 35C and 36L from arrival aircraft data and results are posted in Table 48.

Table 48 IQR data for runways 17C, 18R, 35C and 36L

17C ARRIVALS		**35C ARRIVALS**	
STANDARD DEVIATION	**40**	**STANDARD DEVIATION**	**32**
QUANTILE 75%	**277**	**QUANTILE 75%**	**223**
QUANTILE 25%	**236**	**QUANTILE 25%**	**186**
IQR	**41**	**IQR**	**37**
RATIO	**1.03**	**RATIO**	**1.15**
18R ARRIVALS		**36L ARRIVALS**	
STANDARD DEVIATION	**41**	**STANDARD DEVIATION**	**27**
QUANTILE 75%	**275**	**QUANTILE 75%**	**225**
QUANTILE 25%	**227**	**QUANTILE 25%**	**191**
IQR	**48**	**IQR**	**34**
RATIO	**1.17**	**RATIO**	**1.28**

All the IQR comparisons indicate that the arrival sample data's IQR values are close to the normal distribution's value in all cases, the IQR for the data is less than the normal distribution IQR. This indicates that the sample data is more closely concentrated near the mean than from the normal distribution. This is helpful for upcoming assumptions and analysis regarding the safety boundary because an assumption of normality will be conservative.

To verify that the data indeed follow a normal distribution, a check is done using the IQR/s, for runways 17R, 18L, 35L and 36R for departure aircraft and results are posted in Table 49.

Table 49 IQR data for runway 17R, 18L, 35L and 36R

17R DEPARTURES		**35L DEPARTURES**	
STANDARD DEVIATION	**294**	**STANDARD DEVAITION**	**318**
QUANTILE 75%	**1417**	**QUANTILE 75%**	**1545**
QUANTILE 25%	**1072**	**QUANTILE 25%**	**1119**
IQR	**345**	**IQR**	**426**
RATIO	**1.17**	**RATIO**	**1.34**
18L DEPARTURES		**36R DEPARTURES**	
STANDARD DEVAITION	**277**	**STANDARD DEVAITION**	**285**
QUANTILE 75%	**1366**	**QUANTILE 75%**	**1541**
QUANTILE 25%	**1014**	**QUANTILE 25%**	**1181**
IQR	**352**	**IQR**	**360**
RATIO	**1.27**	**RATIO**	**1.26**

The results for the departure data for IQR comparisons are similar to the arrival results where most of the values are close to the normal distribution but lower. However, the departure runway 35L IQR exactly matches the normal IQR. Runway 35L data has already passed the Chi square test, which indicated it is normally distributed.

The data obtained from EAD is used for noise monitoring and abatement near arrival and departure runways at DFW. The data obtained from EAD has been used to evaluate the aircraft flight pattern over the PT while approaching the four arrival runways. Similarly, the data is analyzed to evaluate how the departure aircraft gains altitude over the PT when they takeoff from the departure runways. Statistical analyses helps to determine the probability of flying below the threshold established by the FAA/AOSC for PT design and construction at DFW. Section 7.18 explains in detail the approach and method of computing the probability of an aircraft flying below the threshold established by the FAA for arrival and departure over PT.

7.13 Departure on 17R elevation computation

The height of aircraft during the departure phase is shown in Figure 60. The mean height above runway 17R is computed as 1,208 feet above runway elevation. The figure shows the actual elevation of the PT, elevation at the end of runway 17R, elevation of the visual barrier, and the elevation of the aircraft flying over the PT. A Category E aircraft is taxiing on the PT after landing on runway 17C. The thirteen feet high barrier proposed by the FAA/AOSC is also shown at a distance of 1,100 feet from the south end of runway 17R. Runway 17R is 13, 400 feet long and the PT centerline is at 2,650 feet from the south end of the runway. Therefore, the PT centerline is at 16,050 feet (3.04 miles) from the northern end of runway 17R. The difference in elevation between north end of runway and PT centerline is 11.5 feet.

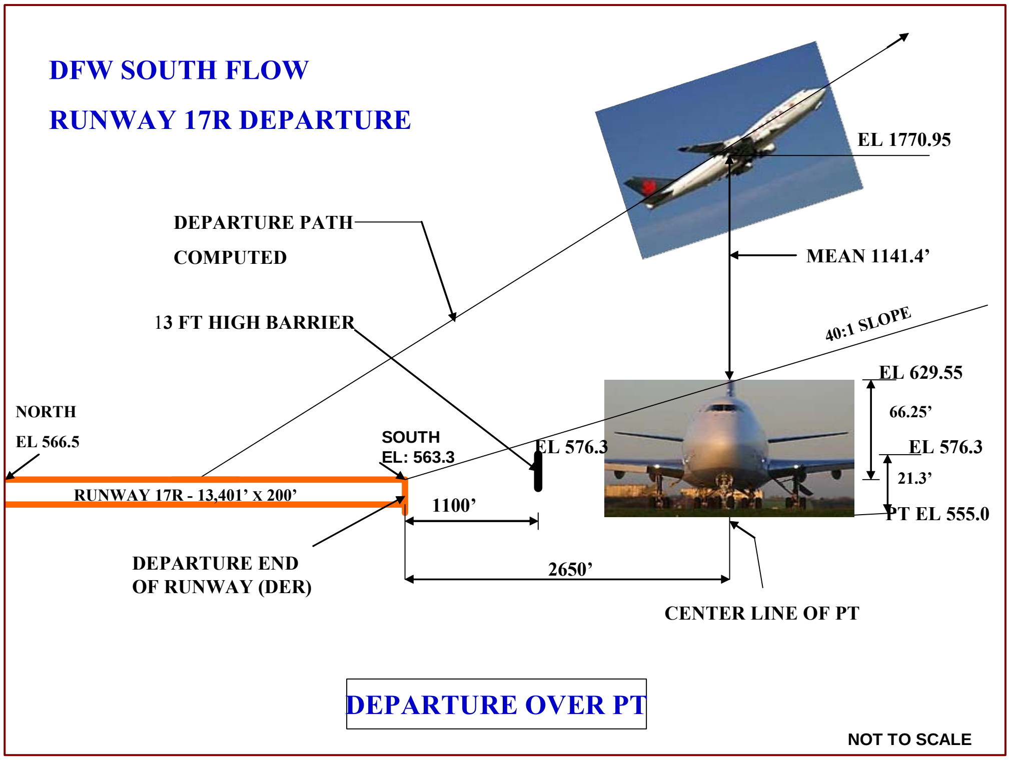

Figure 60 Departure path of an aircraft over the PT

7.14 Arrival on 17C elevation computation

The arrival path of an aircraft over runway 17C on the NE quadrant of the PT is shown in Figure 61. The actual elevation at the end of runway 17C, the elevation of the 34:1 slope at the center line of PT, and the thirteen feet high visual barrier top elevation is shown in the figure. A Category E aircraft is taxiing on the PT for take off from runway 17R after leaving from the NE freight apron area. The proposed thirteen feet high barrier by the FAA/AOSC at a distance of 1,100 feet from the north end of runway 17C is shown. The PT centerline is 2,650 feet from the north end of runway 17C. The aircraft is flying at a mean height of 208.56 feet above PT centerline.

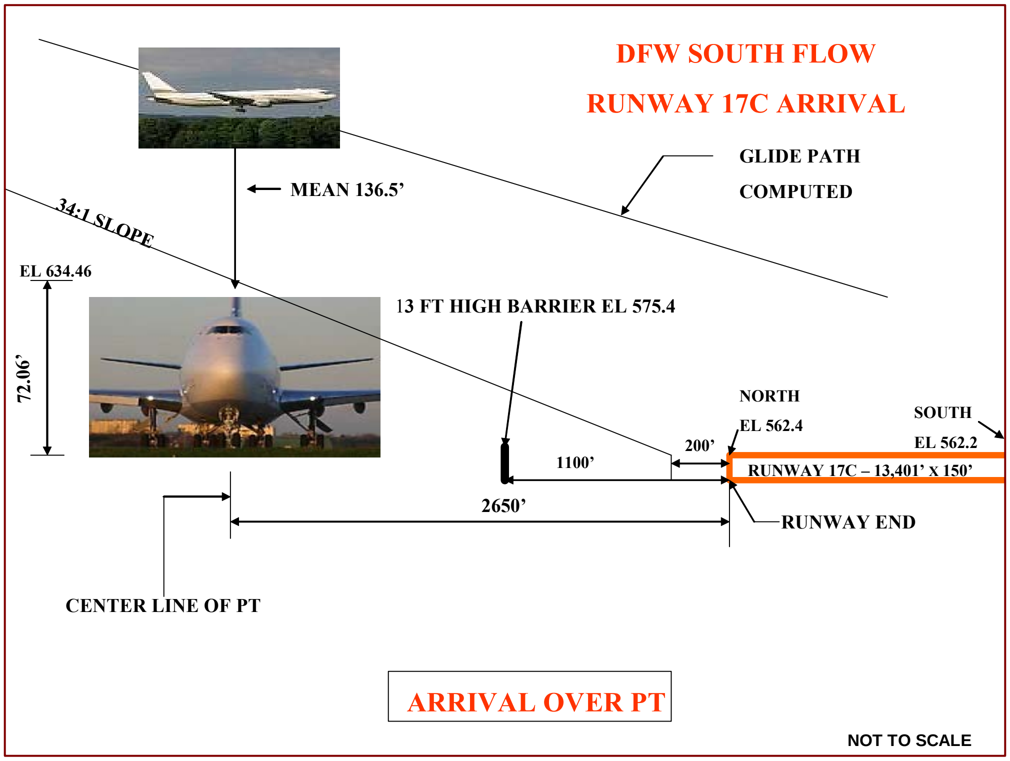

Figure 61 Arrival path of an aircraft over the PT

7.15 Comparison of arrival and departure heights over PT

Table 50 compares the height of the arrival aircraft over the PT center line on the four arrival runways 17C, 18R, (South Flow) 35C and 36L (North Flow) at DFW. The minimum height of 95 feet over the PT center line on runway 36L was recorded for a NW flight #403, a DC93, arriving at 14:05:39 on 23 December 2002. The other minimum height of 105 ft over the centerline of PT on runway 35C was recorded for AA flight #67, a B777-200, arriving at 20:03:13 on 2 August 2005.

Table 50 Comparison of arrival aircraft height on four runways

COMPARISON OF ARRIVAL HEIGHT ON 17C, 18R, 35C AND 36L 2650 FT FROM END OF RUNWAY				
	SOUTH FLOW		NORTH FLOW	
RUNWAY	**17C**	**18R**	**35C**	**36L**
MAXIMUM	**597**	**549**	**750**	**396**
MINIMUM	**150**	**148**	**105**	**95**
MEAN	**260**	**255**	**206**	**209**

Table 51 compares the height of the departure aircraft over the PT center line on the four departure runways 17R, 18L, (South Flow) 35L and 36R (North Flow) at DFW. The minimum height of 323 feet over the center line of PT on runway 18L was recorded for Delta flight #531, a B727, departing at 16:10:31 on 3 January 2001

Table 51 Comparison of departure aircraft height on four runways

COMPARISON OF DEPARTURE HEIGHT ON 17R, 18L, 35L AND 36R 2650 FT FROM END OF RUNWAY				
	SOUTH FLOW		NORTH FLOW	
RUNWAY	**17R**	**18L**	**35L**	**36R**
MAXIMUM	**2597**	**2616**	**2649**	**3004**
MINIMUM	**365**	**323**	**357**	**456**
MEAN	**1258**	**1199**	**1341**	**1371**

Table 52 shows the FAA designated aircraft approach categories and the aircraft design group classification that is used in the height determination for PT. The approach speed shown in the table is used in the VS simulation for various aircraft categories. The heights specified by the FAA in the above table will be useful to compare with the minimum aircraft height obtained from flight track analysis over the arrival and departure runways on the PT.

Table 52 The FAA airport reference codes for design [55]

FAA AIRPORT REFERENCE CODES				
Aircraft Approach Category	Aircraft Approach Speed (kts)	Airplane Design Group	Aircraft Wingspan (ft)	Tail Height (ft)
A	<91	I	<49	<20
B	91-121	II	49-<79	20-<30
C	121-141	III	79-<118	30-<45
D	141-166	IV	118-<171	45-<60
E	>166	V	171-<214	57-<66
F	-	VI	214-<262	66-<80

7.16 Comparison of minimum height over PT of arrival aircraft

Table 53 shows the minimum height of aircraft over PT during the arrival phase for the five data dates in years 2001, 2002, 2003, 2004, and 2005. The table also contains a count of the flight data collected for analysis for each year.

Table 53 Minimum height over PT of arrival aircraft

ARRIVALS MINIMUM HEIGHT CALCS @ 2650 FT								
YEAR	17C		18R		35C		36L	
	ARRIVALS	HEIGHT	ARRIVALS	HEIGHT	ARRIVALS	HEIGHT	ARRIVALS	HEIGHT
3/1/2001	353	159	276	198	349	143	261	115
7/17/2002	306	150	319	193	364	126	235	95
8/6/2003	190	182	119	208	253	137	190	148
7/29/2004	239	156	296	148	19	137	55	160
8/2/2005	275	168	330	160	291	105	345	142
MEAN		163		181		130		132
TOTAL	1363		1340		1276		1086	

7.17 Comparison of minimum height over PT of departure aircraft

Table 54 shows the minimum height reached by an aircraft on the departure path for the five data dates in years 2001, 2002, 2003, 2004 and 2005. The table also contains a count of the flight data collected for analysis for each year.

Table 54 Minimum height of aircraft on the departure path over PT

DEPARTURES MINIMUM HEIGHT CALCS @ 2650 FT								
YEAR	17R		18L		35L		36R	
	DEPARTURES	HEIGHT	DEPARTURES	HEIGHT	DEPARTURES	HEIGHT	DEPARTURES	HEIGHT
3/1/2001	449	514	386	323	332	836	365	671
7/17/2002	521	677	363	323	486	486	385	829
8/6/2003	224	567	148	545	366	357	231	616
7/29/2004	458	403	391	668	59	737	83	736
8/2/2005	503	503	442	494	466	476	411	456
MEAN		533		471		578		662
TOTAL	2155		1730		1709		1475	

7.18 Estimating the probability of flying below the minimum

Based on the earlier comparisons of the height data to the normal distribution, this section makes the assumption that the data is normally distributed for all runways. While most of the data is not normally distributed, this assumption is still being considered conservative because the data is concentrated closer to the mean and most of the outliers are on the upper end of the distribution. Table 55 show the computations for probability of aircraft height falling below FAA/AOSC standards for arrival runways, 17C, 18R, 35C and 36L. From the analysis of arrival data, the data indicates that the minimum height at which an aircraft is overflying the PT on the approach path is well above the 72 feet recommended by the FAA/AOSC. Therefore, the probability of flying below 72 feet over the PT is very close to zero, as shown in Table 55.

Table 55 Probability computations for arrival aircraft on four runways

DEFINITION	17C	18R	35C	36L
APPROACH PATH SLOPE	34:1	34:1	34:1	34:1
DISTANCE (2,650-200)	2,450	2,450	2,450	2,450
HEIGHT AT PT	72.06	72.06	72.06	72.06
μ	260	255	206	209
σ	39.6692	40.9932	32.0379	26.6107
Z	-4.7324	-4.4655	-4.1765	-5.1361
P(x<72.06)	1.1E-06	4.0E-06	1.5E-05	1.4E-07

Therefore, the PT is safe to operate under existing flight standards and guidelines established by the FAA for arrival aircraft. The lowest height at which any aircraft has flown over the centerline of PT is 95 ft in 2002.

Table 56 shows the computations for the probability of departure height on the four runways, 17R, 18L, 35L and 36R falling below the FAA/AOSC standards. The departure aircraft has been gaining altitude well above the 65 feet minimum established by the FAA/AOSC for all five data dates selected for analysis. The lowest altitude for an aircraft departing over the proposed PT is 323 ft in 2001 and 2002. The probability of not flying above the 65 feet is shown in Table 46 below for the four departure runways. Therefore, the PT is safe to operate for departures under the existing flight standards and guidelines established by the FAA/AOSC.

Table 56 Probability computations for departure aircraft on four runways

DEFINITION	17R	18L	35L	36R
ALL ENGINE OPERATION SLOPE	40:1	40:1	40:1	40:1
DISTANCE	2,650	2,650	2,650	2,650
HEIGHT AT PT	66.25	66.25	66.25	66.25
AOSC APPROVED ELEVATION	65	65	65	65
μ	1258	1199	1341	1371
σ	293.98	276.74	317.53	284.85
Z	-4.057	-4.179	-4.018	-4.585
P(X<65)	2.5E-05	1.5E-05	2.9E-05	2.3E-06

7.19 Statistical analysis of the minimum height over the PT for arrival aircraft

A different approach to the analysis can show that the mean of minimum height observation for the five year's data is significantly different from the greater than the recommended FAA/AOSC standard. This analysis does not require an assumption of normality for the entire distribution. The FAA/AOSC have specified a departure path slope of 40:1 on runway 17R, which will give a height of 66.25 feet at the centerline of the PT. However, the AOSC reduced the height to 65 ft at the PT centerline and approved the design and construction of the SE PT at DFW. Any aircraft with tail height of more than 65 ft is not permitted to taxi on the PT without specific approval from the ATC. For the arrival path, the slope is set at 34:1 which gives a height of 72 feet above the center line of PT. Table 56 shows the minimum height of aircraft over the PT during the arrival phase for the five data dates in years 2001, 2002, 2003, 2004, and 2005.

Table 57 Minimum height over PT of arrival aircraft

ARRIVALS MINIMUM HEIGHT CALCS @ 2650 FT				
YEAR	17C HEIGHT	18R HEIGHT	35C HEIGHT	36L HEIGHT
3/1/2001	159	198	143	115
7/17/2002	150	193	126	95
8/6/2003	182	208	137	148
7/29/2004	156	148	137	160
8/2/2005	168	160	105	142
MEAN	163	181	130	132

In the Table 57, all aircraft using the four runways are flying above the 72 feet minimum specified by the FAA along the approach slope of 34:1 beginning 200' from the end of the runway.

7.19.1 Runway 17C analysis

Statistical analysis of the height above the PT centerline for runway 17C shows that the minimum height specified by the FAA will be safely met by all arriving aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying above the AOSC specified height of 72 feet.

Number of observations = 5 t test statistic = 16.33 D. F. = 4

Probability level = 0.000041, Standard deviation s = 12.45

Mean of the minimum $\overline{x}$ = 163 ft Critical t value = 2.132 for α = 0.05

Test statistic t = $\frac{\overline{x}-\mu}{s/\sqrt{n}}$ test statistic t = $\frac{163-72}{12.45/\sqrt{5}}$=$\underline{16.33}$

H_O: $\mu = 72$ H_A: $\mu > 72$

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for runway 17C will be higher than the 72 feet specified by the FAA.

7.19.2 Runway 18R analysis

Statistical analysis of the height above the PT centerline for runway 18R shows that the minimum height specified by the FAA will be safely met by all arriving aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying below the AOSC specified height of 72 feet.

Number of observations = 5 t test statistic = 9.4 DF = 4

Probability level = 0.000352, Standard deviation s = 25.94

Mean of the minimum $\bar{x}$ = 181 ft   Critical t value = 2.132 for α = 0.05

Test statistic t = $\dfrac{\bar{x}-\mu}{s/\sqrt{n}}$ test statistic t = $\dfrac{181-72}{25.94/\sqrt{5}}$ =9.43

Critical value t = 2.132 for α = 0.05

H_O: μ = 72 H_A: μ > 72

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for runway 18R will be higher than the 72 feet specified by the FAA

7.19.3 Runway 35C analysis

Statistical analysis of the height above the PT centerline for runway 35C shows that the minimum height specified by the FAA will be safely met by all arriving aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying below the AOSC specified height of the 72 feet.

Number of observations = 5   t test statistic = 8.61   DF = 4

Probability level = 0.000513,   Standard deviation s = 15.06

Mean of the minimum $\bar{x}$ = 129.6 ft   Critical t value = 2.132 for α = 0.05

Test statistic t = $\dfrac{\bar{x}-\mu}{s/\sqrt{n}}$ test statistic t = $\dfrac{129.6-72}{15.06/\sqrt{5}}$ =8.552

H_O: μ = 72 H_A: μ > 72

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for runway 35C will be higher than the 72 feet specified by the FAA

7.19.4 Runway 36L analysis

Statistical analysis of the height above the PT centerline for runway 36L shows that the minimum height specified by the FAA will be safely met by all arriving aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying below the AOSC specified height of 72 ft.

Number of observations = 5 t test statistic = 5.07 DF = 4

Probability level = 0.003558, Standard deviation s = 26.45

Mean of the minimum $\bar{x}$ = 132 ft Critical t value = 2.132 for α = 0.05

Test statistic t $= \dfrac{\bar{x} - \mu}{s / \sqrt{n}}$ test statistic t = $\dfrac{132 - 72}{26.45 / \sqrt{5}}$ =5.073

H_O: μ = 72 H_A: μ > 72

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for runway 36L will be higher than the 72 feet specified by the FAA

7.20 Statistical analysis of minimum height of departure aircraft over PT

Table 58 shows the minimum height reached by aircraft on the departure path for the five data dates in year 2001, 2002, 2003, 2004 and 2005.

Table 58 Minimum height of aircraft on the departure path over PT

DEPARTURES MINIMUM HEIGHT CALCS @ 2650 FT				
YEAR	17R HEIGHT	18L HEIGHT	35L HEIGHT	36R HEIGHT
3/1/2001	514	323	836	671
7/17/2002	677	323	486	829
8/6/2003	567	545	357	616
7/29/2004	403	668	737	736
8/2/2005	503	494	476	456
MEAN	533	471	578	662
TOTAL				

Table 58 shows the minimum height reached by aircraft over the PT during take off from the four departure runways. The AOSC has set a minimum height of 65 ft above the PT centerline for departures and all aircraft have reached well above the specified height during departures on various runways.

7.20.1 Runway 17R analysis

Statistical analysis of the height above the PT centerline for runway 17R shows that the minimum height specified by the FAA will be safely met by all departing aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying above the AOSC specified height of 65 feet.

Number of observations = 5; t statistic = 10.4534; DF = 4;

Probability level = 0.000237, Standard deviation s = 100.07

Mean of the minimum $\overline{X}$ = 532.8 ft Critical t value = 2.132 for α = 0.05

Test statistic $t = \dfrac{\bar{x} - \mu}{s / \sqrt{n}}$ t statistic = $\dfrac{532.8 - 65}{100.07 / \sqrt{5}}$ =<u>10.4534</u>

H_O: μ = 65 H_A: μ > 65

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for runway 17R will be higher than 65 feet specified by the FAA.

7.20.2 Runway 18L analysis

Statistical analysis of the height above the PT centerline for runway 18L shows that the minimum height specified by the FAA will be safely met by all departing aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying above the AOSC specified height of 65 feet.

Number of observations = 5; t statistic = 6.0932; DF = 4;

Probability level = 0.001835, Standard deviation s = 148.85

Mean of the minimum $\bar{x}$ = 470.6 ft Critical t value = 2.132 for α = 0.05

Test statistic $t = \dfrac{\bar{x} - \mu}{s / \sqrt{n}}$ t statistic = $\dfrac{470.6 - 65}{148.85 / \sqrt{5}}$ =6.0932

H_O: μ = 65 H_A: μ > 65

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for runway 18L will be higher than 65 feet specified by the FAA.

7.20.3 Runway 35L analysis

Statistical analysis of the height above the PT centerline for runway 35L shows that the minimum height specified by the FAA will be safely met by all departing aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying above the AOSC specified height of 65 feet.

Number of observations = 5; t statistic = 5.748 DF = 4;

Probability level = 0.002271, Standard deviation s = 199.72

Mean of the minimum $\bar{x}$ = 578.4 ft Critical t value = 2.132 for α = 0.05

Test statistic t = $\dfrac{\bar{x}-\mu}{s/\sqrt{n}}$ t statistic = $\dfrac{578.4-65}{199.72/\sqrt{5}} = \underline{5.748}$

H_O: $\mu = 65$ H_A: $\mu > 65$

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for runway 35L will be higher than 65 feet specified by the FAA.

7.20.4 Runway 36R analysis

Statistical analysis of the height above the PT centerline for runway 36R shows that the minimum height specified by the FAA will be safely met by all departing aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying above the AOSC specified height of 65 feet.

Number of observations = 5; t statistic = 9.5534 DF = 4;

Probability level = 0.000335, Standard deviation s = 139.64

Mean of the minimum $\overline{x}$ = 661.36 ft

Critical t value = 2.132 for α = 0.05

Test statistic t $= \dfrac{\overline{x} - \mu}{s / \sqrt{n}}$ t statistic = $\dfrac{661.36 - 65}{139.64 / \sqrt{5}}$ =$\underline{9.5534}$

H_O: μ = 65 H_A: μ > 65

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for runway 36R will be higher than 65 feet specified by the AOSC

Table 59 Mean of the minumum hieght for arrival and departues

	Arrival	Departure
	ALL RUNWAYS	ALL RUNWAYS
	159	514
	150	677
	182	567
	156	403
	168	503
	198	323
	193	323
	208	545
	148	668
	160	494
	143	836
	126	486
	137	357
	137	737
	105	476
	115	671
	95	829
	148	616
	160	736
	142	456
Mean	152	561

The composite elevation for arrivals on the four runways gives a mean height of 152 feet above the PT centerline. The composite for departures on the four runways gives a mean height of 561 feet above the PT centerline as shown in Table 59..

7.20.5 Analysis of arrivals on all runways

Statistical analysis of the height above the PT centerline for all runways shows that the minimum height specified by the FAA will be safely met by all arriving aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying above the AOSC specified height of 72 feet.

Number of observations = 20; t statistic = 12.0841 DF = 19;

Probability level = 0.0000001, Standard deviation s = 29.422

Mean of the minimum $\bar{x}$ = 151.35 Critical t value = 1.7291 for α = 0.05

Test statistic t $= \dfrac{\bar{x}-\mu}{s/\sqrt{n}}$ t statistic = $\dfrac{151.5-72}{29.422/\sqrt{20}}$ =12.0841

H_O: μ = 72 H_A: μ > 72

Reject null hypothesis, because t statistic is greater than critical t.

The population mean of the minimum height for all runways will be higher than 72 ft specified by the FAA/AOSC

7.20.6 Analysis of departures on all runways

Statistical analysis of the height above the PT centerline for all runways shows that the minimum height specified by the FAA will be safely met by all departing aircraft. To verify the hypothesis, a student t test is performed to establish the probability of flying above the FAA/AOSC specified height of 65 feet.

Number of observations = 20; t statistic = 14.0021 DF = 19;

Probability level = 0.0000001 Standard deviation s = 156.1336

Mean of the minimum $\bar{x}$ = 560.85 Critical t value = 1.7291 for α = 0.05

Test statistic $t = \dfrac{\bar{x} - \mu}{s / \sqrt{n}}$ t statistic = $\dfrac{560.85 - 65}{156.1336 / \sqrt{20}}$ =14.0021

H_O: $\mu = 65$ H_A: $\mu > 65$

Reject null hypothesis, because t statistic is greater than critical t. The population mean of the minimum height for all runways will be higher than the 65 feet specified by the FAA/AOSC

The statistical analysis performed shows that all aircraft can safely overfly the PT while an aircraft is taxiing on the PT during both the arrival and departure configuration at DFW. The tail height of an aircraft taxing on the PT does not hinder the operation of PT during both the arrival and departure conditions at DFW.

During unfavorable weather conditions at DFW it is recommended that the threshold on 17C and 18R could be shifted by 1,000 feet to the south, to provide adequate safe clearance over the aircraft taxiing on the PT. The aircraft height observed from the flight data shows that the arriving aircraft on 17C are maintaining a safe minimum height of 163 feet above the centerline of PT. On runway 18R the arriving aircraft maintains a safe minimum height of 181 feet above the centerline of PT.

CHAPTER 8

EVALUATION OF PERIMETER TAXIWAY OPERATIONS

The performance metrics used in the analysis of airport and runway efficiency are based on the FAA/APO method of measurement, which is explained in detail below. Runway efficiency is computed based on the total arrival and departure rates per hour and measured against the predicted rates established by ATC at DFW. The FAA assigned runway capacity for DFW is updated on an hourly basis considering the weather, visibility, wind speed, wind direction, and other activities at the airport.

8.1 Description of the FAA performance metrics

When using the System Airport Efficiency Rate (SAER) [57], the arrival efficiency rate is defined as the percentage of the time arrivals are greater than or equal to arrival demand or the facility-set arrival rate.

The percentage is determined by dividing actual arrivals by the lesser of the arrival demand or the arrival rate: The Arrival Efficiency Rate (AER) is a measure designed to determine how well the demand for arrivals is met, and is determined by three factors:

- Arrivals during a given quarter hour - how many aircraft actually landed during that quarter-hour.

- Arrival demand for a given quarter hour - how many aircraft wanted to land during the quarter-hour;
- Airport arrival rate - the facility-set airport arrival rate for that quarter hour.

The definition of departure efficiency rate as computed for SAER is as follows: The Departure Efficiency Rate (DER) is the percentage of time departures are greater than or equal to departure demand of the facility-set departure rate. The percentage is determined by dividing actual departures by the lesser of the departure demand or the departure rate. The DER is the measure designed to determine how well the demand for departures is met and is determined by three factors:

- Departure during a given quarter hour - how many aircraft actually departed during that quarter;
- Departure demand for a given quarter hour - how many aircraft wanted to depart during that quarter hour;
- Airport departure rate - the facility-set airport departure rate for that quarter hour.

The FAA/ATC computes the Airport Departure Rate (ADR) and Capacity Airport Arrival Rate (Cap AAR) every hour based on the visibility, weather, wind speed and direction, construction and maintenance operations and any other factor that may impede runway operations [58]. For the typical runway configuration in use for South Flow arrival on 13R, 18R, 17C, and 17L, the Cap AAR is 120 per hour maximum; for departures on 13L, 17R, 18L, and 18R, the ADR is 90 per hour maximum for a total of 210 operations per hour. Similarly, for the typical North Flow operations, departures on runways 35L, 36R, 36L, and 31L, the ADR is set at 90 per hour and for arrivals on runways 31R, 35R, 35C and 36L, the Cap AAR is set at 150 per hour for a total of 240 operations per hour. These are the factors used in the computation of the efficiency of each runway configuration (South and North flow) for the sixteen VS applications. Hourly runway efficiency computations, and maximum flights handled by each runway for arrival and departure are shown in Tables 68 to 75.

8.1.1 Simulation results validation

The VS simulation results are validated with actual statistics posted at the FAA/APO/ASPM website for the simulated. The results are tallied for runway efficiency, Taxi In time, Taxi Out time and overall DFW performance. Several tables are appended in this chapter that compares the results with the FAA actual observations and metrics. The FAA data are actual flight information obtained from the operating airlines and the ATC. This data is used to validate the simulation results by comparing them with actual historical operations at DFW.

The Taxi In time is the time elapsed between wheels down and arrival at the gate. Taxi Out time is the time elapsed between departure from the gate and the wheels off from the runway. The runway crossing delay is the waiting time for an aircraft to cross an arrival or departure runway.

8.2 Taxi In time analysis

Table 60 shows that the mean Taxi In time for 22 July 2004 for South Flow is 11.26 minutes without the PT for 1256 arrivals. The FAA/APO reports for the same date that the average Taxi In time is 10.88 minutes for 1144 arrivals as shown in Table 61. The FAA considers only the arrival of scheduled airlines, air taxi and cargo flights in their computation of Taxi In time. GA, military, and some commercial/international flights are excluded in the metric's computation.

Table 60 Mean Taxi In time for the sixteen applications

DFW MEAN TAXI IN TIME IN MINUTES						
			SOUTH FLOW		NORTH FLOW	
SIMULATION	OPERATIONS/ DAY	NUMBER OF ARRIVALS	WITHOUT PT	WITH PT	WITHOUT PT	WITH PT
6-Mar-04	1647	818	10.53	18.59	9.16	16.88
25-Jun-04	2284	1122	11.59	18.70	10.64	16.85
22-Jul-04	2477	1256	11.26	17.35	10.66	16.93
YEAR 2010	2808	1418	11.42	16.70	10.36	17.22

Table 61 FAA/APO Taxi In time data for the three dates chosen for simulation

DFW MEAN TAXI IN TIME IN MINUTES FAA/APO/ASPM ACTUAL DATA					
		SOUTH FLOW	SOUTH FLOW	NORTH FLOW	NORTH FLOW
SIMULATION	OPERATIONS/ DAY	NUMBER OF ARRIVALS	WITHOUT PT	NUMBER OF ARRIVALS	WITHOUT PT
6-Mar-04	1647	544	10.08	434	9.13
25-Jun-04	2284	468	13.15	595	23.68
25-Jun-04	2284	45	54.67	0	0.00
22-Jul-04	2477	1144	10.88	0	0.00

Table 60, shows that for 25-Jun-04 the average Taxi In time for 45 flights is 54.67 minutes during South Flow and the remaining 468 flights experienced a Taxi In time of 13.15 minutes. When the wind direction shifted from south to north for the same day, the mean Taxi In time for 595 flights is 23.68 minutes for North Flow.

Table 62 Taxi In time in minutes

TAXI IN TIME STATISTICS IN MINUTES					
TRAFFIC		WITH OUT PT		WITH PT	
FLOW/DAY	DATA	SOUTH	NORTH	SOUTH	NORTH
2808	STDEV	3.7	4.4	3.5	3.0
	MEAN	11.4	10.4	16.7	17.2
	95% LCL	11.2	10.2	16.5	17.0
	95% UCL	11.6	10.6	16.9	17.4
2477	STDEV	3.6	3.3	2.9	3.3
	MEAN	11.3	10.7	17.4	16.9
	95% LCL	11.1	10.5	17.2	16.7
	95% UCL	11.5	10.9	17.6	17.1

Table 62 shows the confidence limits for the mean Taxi in time and standard deviation for various configurations in 2004 and 2010.

Table 63 Undelayed Taxi in time in minutes

DFW MEAN UNDELAYED TAXI IN TIME IN MINUTES						
			SOUTH FLOW		NORTH FLOW	
SIMULATION	OPERATIONS/ DAY	NUMBER OF ARRIVALS	WITHOUT PT	WITH PT	WITHOUT PT	WITH PT
6-Mar-04	1647	818	9.27	17.38	7.90	15.56
25-Jun-04	2284	1122	10.21	17.47	9.15	15.47
22-Jul-04	2477	1256	9.89	15.78	9.18	15.59
YEAR 2010	2808	1418	9.60	17.27	7.97	15.59

Table 63 shows the undelayed Taxi In time at DFW for various applications used in the simulation. The data shows the mean Taxi In time required for an aircraft to taxi to the gates without any runway crossing delay for the four data dates simulated.

The Taxi In time analysis provides a comparison between operation *without* and *with* PT to determine the impact pf PT operations.

8.3 Taxi Out time analysis

Table 64 shows that the mean Taxi Out in time for 22 July 2004 for South Flow is 11.08 minutes without PT for 1221 departures. FAA/APO reports for the same date that the average Taxi Out time is 18.35 minutes for 1162 departures as shown in Table 52. The FAA reports only the taxi out time of scheduled airlines flights, air taxi and cargo aircraft. The FAA excludes GA, military, some commercial/international flights in their Taxi Out time computation.

Table 64 Mean Taxi Out time for the sixteen applications

DFW MEAN TAXI OUT TIME IN MINUTES						
			SOUTH FLOW		NORTH FLOW	
SIMULATION	OPERATIONS/ DAY	NUMBER OF DEPARTURES	WITHOUT PT	WITH PT	WITHOUT PT	WITH PT
6-Mar-04	1647	829	8.29	8.50	8.72	9.00
25-Jun-04	2284	1162	10.77	8.64	9.81	9.53
22-Jul-04	2477	1221	11.08	8.66	9.74	9.65
YEAR 2010	2808	1390	10.62	9.66	9.20	9.83

Table 65: FAA/APO Mean Taxi Out time

DFW MEAN TAXI OUT TIME IN MINUTES FAA/APO/ASPM ACTUAL DATA					
		SOUTH FLOW	SOUTH FLOW	NORTH FLOW	NORTH FLOW
SIMULATION	OPERATIONS/ DAY	NUMBER OF DEPARTURES	WITHOUT PT	NUMBER OF DEPARTURES	WITHOUT PT
6-Mar-04	1647	544	10.83	449	9.13
25-Jun-04	2284	468	19.26	554	22.62
25-Jun-04	2284	94	35.22	0	0.00
22-Jul-04	2477	1162	18.35	0	0.00

On 25-Jun-04, 94 departing aircraft experienced a mean delay of 35.22 minutes and the remaining 468 flights experienced a mean delay of 19.26 minutes during the South Flow (refer Table 66).

Table 66 Taxi Out time in minutes

TAXI OUT TIME STATISTICS IN MINUTES					
TRAFFIC		WITH OUT PT		WITH PT	
FLOW/DAY	DATA	SOUTH	NORTH	SOUTH	NORTH
2808	STDEV	3.4	4.0	4.1	3.8
	MEAN	10.6	9.2	9.7	9.8
	95% LCL	10.4	9.0	9.5	9.6
	95% UCL	10.8	9.4	9.9	10.0
2477	STDEV	3.4	3.0	3.4	4.4
	MEAN	11.1	9.7	8.7	9.6
	95% LCL	10.9	9.5	8.5	9.4
	95% UCL	11.3	9.9	8.9	9.8

Table 66 shows the confidence limits for the mean Taxi Out time and standard deviation for various configurations in 2004 and 2010.

Table 67 Undelayed Taxi Out time in minutes

DFW MEAN UNDELAYED TAXI OUT TIME IN MINUTES						
			SOUTH FLOW		NORTH FLOW	
SIMULATION	OPERATIONS/ DAY	NUMBER OF DEPARTURES	WITHOUT PT	WITH PT	WITHOUT PT	WITH PT
6-Mar-04	1647	829	6.79	7.39	7.59	7.84
25-Jun-04	2284	1162	8.90	7.10	8.39	8.07
22-Jul-04	2477	1221	8.73	7.02	8.35	8.21
YEAR 2010	2808	1390	7.74	7.73	7.45	8.11

Table 67 shows the undelayed Taxi Out time at DFW for various applications used in the simulation. The data shows the mean Taxi Out time it took for an aircraft to taxi to the departure queue without any runway crossing delay for the four data dates simulated._The Taxi In time analysis provide a comparison between operation *without* and *with* PT to determine the impact pf PT operations

8.4 Runway Capacity and Efficiency computations

The runway efficiency and the hourly rate of runway use are computed for all sixteen applications. The arrivals and departures are tallied *without* and *with* the PT in place to determine the benefit of PT operations. Tables 68 to 75 summarize the runway performance for the eight applications, four for 2004 and four for 2010, used in the VS simulation.

Each table contains the VS data and the FAA/APO/ASPM data for comparison. The runway combination efficiency is computed using the FAA approved Cap AAR + ADR total operations for each hour to establish the operating efficiency of the airport in the VS simulation. Only the South Flow operations without the PT are considered for comparison and validation, because the data used in the simulation are from South Flow operations. North Flow hourly efficiency is calculated for VFR operations using the facility provided Cap AAR and ADR for 22 July 2004 and 2010 runway configurations.

Table 68 Runway performance South Flow without PT

DFW PERFORMANCE ON 7-22-04

SOUTH FLOW WITHOUT PT

Maximum arrivals and departures for a total of 2477 operations

	ARRIVALS = 1251								DEPARTURES = 1226												
Local hour	13R	17C	17L	17R	18L	18R	TOTAL ARR	FAA Cap AAR	13L	17C	17L	17R	18L	18R	TOTAL DEP	FAA ADR	TOTAL AAR+ADR	FAA ASPM TOTAL	FAA ADR + Cap AAR	% CAPACITY USED	FAA % CAPACITY USED
0	0	23	6	1	0	27	57	150	1	0	0	8	1	1	11	90	68	11	240	28.3	4.6
1	11	20	2	0	0	9	42	150	0	2	0	8	5	1	16	90	58	3	240	24.2	1.3
2	1	3	0	0	1	4	9	150	2	0	0	8	2	0	12	90	21	9	240	8.8	3.8
3	0	0	0	0	1	1	2	150	1	1	0	3	2	2	9	90	11	8	240	4.6	3.3
4	1	2	0	0	0	2	5	150	2	0	0	3	2	1	8	90	13	4	240	5.4	1.7
5	1	1	0	1	0	5	8	150	1	0	0	6	1	2	10	90	18	13	240	7.5	5.4
6	5	7	0	1	0	2	15	140	2	0	0	7	4	2	15	90	30	71	230	13.0	30.9
7	12	8	4	1	1	12	38	140	4	1	0	20	17	3	45	90	83	106	230	36.1	46.1
8	18	23	7	0	1	20	69	140	3	0	0	29	15	1	48	90	117	151	230	50.9	65.7
9	13	8	11	0	0	14	46	140	6	2	0	38	28	2	76	90	122	131	230	53.0	57.0
10	15	21	12	0	0	26	74	140	8	1	0	36	31	0	76	90	150	159	230	65.2	69.1
11	17	25	12	0	0	19	73	140	5	0	0	35	35	2	77	90	150	141	230	65.2	61.3
12	23	25	16	0	0	27	91	140	2	2	0	41	25	1	71	90	162	168	230	70.4	73.0
13	23	2	22	1	0	24	72	140	5	1	0	39	32	0	77	90	149	140	230	64.8	60.9
14	17	9	30	0	0	22	78	140	1	1	0	41	36	1	80	90	158	142	230	68.7	61.7
15	20	23	12	1	0	21	77	140	1	1	0	26	34	0	62	90	139	137	230	60.4	59.6
16	18	26	7	0	0	22	73	140	4	1	0	41	38	0	84	90	157	160	230	68.3	69.6
17	20	25	0	0	1	16	62	140	2	2	0	43	40	0	87	90	149	133	230	64.8	57.8
18	17	31	6	0	0	21	75	140	3	1	0	28	36	1	69	90	144	173	230	62.6	75.2
19	20	16	28	2	0	23	89	140	4	1	0	19	31	0	55	90	144	150	230	62.6	65.2
20	16	10	19	2	0	15	62	140	0	0	0	40	37	3	80	90	142	159	230	61.7	69.1
21	9	5	15	0	0	24	53	140	0	2	0	23	21	0	46	90	99	96	230	43.0	41.7
22	11	8	10	0	0	28	57	140	2	0	0	18	39	0	59	90	116	62	230	50.4	27.0
23	0	11	0	0	0	12	23	140	0	0	0	29	25	2	56	90	79	33	230	34.3	14.3
24	0	1	0	0	0	0	1	0	0	3	0	12	17	0	32	0	33	0	0	0.0	0.0
TOTAL	288	333	219	10	5	396	1251	3420	59	22	0	601	554	25	1261	2160	2512	2360	5580	45.0	42.3
INPUT DATA							1251	1251							1226	1261	2477				
							0	2169							35	899	35				

Table 69 Runway performance South Flow with PT

DFW PERFORMANCE ON 7-22-04

SOUTH FLOW WITH PT

Maximum arrivals and departures for a total of 2477 operations

	ARRIVALS = 1251								DEPARTURES = 1226												
Local hour	13R	17C	17L	17R	18L	18R	TOTAL ARR	FAA Cap AAR	13L	17C	17L	17R	18L	18R	TOTAL DEP	FAA ADR	TOTAL AAR+ADR	FAA ASPM TOTAL	FAA ADR + Cap AAR	% CAPACITY USED	FAA % CAPACITY USED
0	0	23	5	2	0	27	57	150	1	0	0	7	3	1	12	90	69		240	28.8	0.0
1	11	20	1	0	0	9	41	150	0	2	0	4	4	5	15	90	56		240	23.3	0.0
2	1	4	0	0	1	4	10	150	0	3	0	8	0	2	13	90	23		240	9.6	0.0
3	0	0	1	0	1	0	2	150	2	2	0	1	1	2	8	90	10		240	4.2	0.0
4	0	3	0	0	0	2	5	150	1	0	0	4	1	2	8	90	13		240	5.4	0.0
5	1	1	1	0	0	5	8	150	1	0	0	4	0	5	10	90	18		240	7.5	0.0
6	2	7	1	0	0	3	13	140	1	0	0	7	4	1	13	90	26		230	11.3	0.0
7	10	10	3	0	0	13	36	140	5	3	0	18	16	3	45	90	81		230	35.2	0.0
8	16	23	7	0	1	19	66	140	1	3	0	28	18	2	52	90	118		230	51.3	0.0
9	15	10	12	0	0	12	49	140	4	4	0	36	32	2	78	90	127		230	55.2	0.0
10	14	20	12	0	0	24	70	140	4	2	0	37	35	1	79	90	149		230	64.8	0.0
11	16	25	12	0	0	23	76	140	0	0	0	37	41	2	80	90	156		230	67.8	0.0
12	23	30	13	0	0	26	92	140	1	2	0	38	31	1	73	90	165		230	71.7	0.0
13	19	1	24	0	0	25	69	140	0	2	0	36	38	3	79	90	148		230	64.3	0.0
14	17	11	29	0	0	26	83	140	1	3	0	41	37	1	83	90	166		230	72.2	0.0
15	17	21	10	4	0	24	76	140	2	2	0	26	29	5	64	90	140		230	60.9	0.0
16	16	26	7	0	0	21	70	140	3	2	0	41	32	9	87	90	157		230	68.3	0.0
17	21	25	0	0	1	17	64	140	6	3	0	40	35	1	85	90	149		230	64.8	0.0
18	20	31	3	0	0	23	77	140	5	3	0	31	33	1	73	90	150		230	65.2	0.0
19	17	16	30	0	0	22	85	140	2	1	0	24	36	1	64	90	149		230	64.8	0.0
20	13	13	25	0	0	14	65	140	0	0	0	38	37	3	78	90	143		230	62.2	0.0
21	7	5	12	0	0	23	47	140	0	2	0	22	24	0	48	90	95		230	41.3	0.0
22	12	7	13	0	0	30	62	140	1	0	0	19	33	3	56	90	118		230	51.3	0.0
23	0	13	0	0	0	11	24	140	0	0	0	27	24	8	59	90	83		230	36.1	0.0
24	0	1	0	0	0	3	4	0	0	3	0	10	13	1	27	0	31		0	0.0	0.0
MAX	268	346	221	6	4	406	1251	3420	41	42	0	584	557	65	1289	2160	2540	0	5580	45.5	0.0
DATA							1251	1251							1226	1289	2477				
							0	2169							63	871	63				

Table 70 Runway performance North Flow without PT

DFW PERFORMANCE ON 7-22-04

NORTH FLOW WITHOUT PT

Maximum arrivals and departures for a total of 2477 operations

ARRIVALS = 1251 | DEPARTURES = 1226

Local hour	31R	35C	35L	35R	36L	36R	TOTAL ARR	FAA Cap AAR	31L	35C	35L	35R	36L	36R	TOTAL DEP	FAA ADR	TOTAL AAR+ADR	FAA ASPM TOTAL	FAA ADR + Cap AAR	% CAPACITY USED	FAA % CAPACITY USED
0	10	17	0	7	28	0	62	150	0	0	9	0	0	1	10	120	72		270	26.7	0.0
1	10	18	0	1	9	0	38	150	0	2	10	0	1	5	18	120	56		270	20.7	0.0
2	1	3	0	0	3	1	8	150	1	1	6	0	0	3	11	120	19		270	7.0	0.0
3	0	0	0	0	1	1	2	150	1	3	2	0	2	1	9	120	11		270	4.1	0.0
4	1	2	0	0	2	0	5	150	1	0	5	0	1	1	8	120	13		270	4.8	0.0
5	1	1	0	1	6	0	9	150	1	0	4	0	5	0	10	120	19		270	7.0	0.0
6	2	10	0	1	1	0	14	150	2	0	7	0	1	5	15	120	29		270	10.7	0.0
7	14	7	0	5	13	1	40	150	3	1	21	0	3	17	45	120	85		270	31.5	0.0
8	32	13	0	6	20	1	72	150	2	1	30	0	4	16	53	120	125		270	46.3	0.0
9	15	3	0	14	14	0	46	150	2	5	36	0	6	24	73	120	119		270	44.1	0.0
10	16	24	0	9	24	0	73	150	2	3	45	0	3	22	75	120	148		270	54.8	0.0
11	28	21	0	12	19	0	80	150	4	0	40	0	1	33	78	120	158		270	58.5	0.0
12	17	25	0	18	29	0	89	150	2	2	43	0	1	24	72	120	161		270	59.6	0.0
13	16	5	0	22	24	0	67	150	5	1	42	0	0	28	76	120	143		270	53.0	0.0
14	20	10	0	32	23	0	85	150	2	1	37	0	0	38	78	120	163		270	60.4	0.0
15	19	20	0	10	20	0	69	150	4	1	24	0	3	32	64	120	133		270	49.3	0.0
16	27	23	0	7	22	0	79	150	5	1	43	0	6	33	88	120	167		270	61.9	0.0
17	12	26	0	0	15	1	54	150	3	2	35	0	3	34	77	120	131		270	48.5	0.0
18	14	45	0	8	21	0	88	150	5	2	29	0	1	38	75	120	163		270	60.4	0.0
19	8	18	0	30	24	0	80	150	2	1	22	0	0	28	53	120	133		270	49.3	0.0
20	9	16	0	19	14	0	58	150	0	0	38	0	3	35	76	120	134		270	49.6	0.0
21	8	10	0	16	26	0	60	150	0	2	20	0	0	23	45	120	105		270	38.9	0.0
22	4	11	0	9	27	0	51	150	2	0	20	0	0	38	60	120	111		270	41.1	0.0
23	0	11	0	0	11	0	22	150	0	0	25	0	5	23	53	120	75		270	27.8	0.0
24	0	0	0	0	0	0	0	0	0	3	13	0	0	15	31	0	31		0	0.0	0.0
MAX	284	339	0	227	396	5	1251	3420	49	32	606	0	49	517	1253	2880	2504		6480	38.6	
DATA							1251	1251							1226	1253	2477				
							0	2169							27	1627	27				

Table 71 Runway performance North Flow with PT

DFW PERFORMANCE ON 7-22-04

NORTH FLOW WITH PT

Maximum arrivals and departures for a total of 2477 operations

	ARRIVALS = 1251								DEPARTURES = 1226											
Local hour	31R	35C	35L	35R	36L	36R	TOTAL ARR	FAA Cap AAR	31L	35C	35L	35R	36L	36R	TOTAL DEP	FAA ADR	TOTAL AAR+ADR	FAA ASPM TOTAL	FAA ADR + Cap AAR	% CAPACITY USED
0	0	18	1	5	18	1	43	150	1	1	7	0	0	1	10	120	53		270	19.6
1	10	19	0	2	21	0	52	150	3	2	4	0	1	5	15	120	67		270	24.8
2	1	5	0	0	6	1	13	150	4	0	6	0	0	1	11	120	24		270	8.9
3	0	0	0	0	0	2	2	150	3	2	1	0	1	3	10	120	12		270	4.4
4	1	1	0	0	2	0	4	150	2	0	3	0	2	1	8	120	12		270	4.4
5	1	2	0	1	5	0	9	150	1	0	4	0	4	0	9	120	18		270	6.7
6	2	8	0	1	2	0	13	150	3	0	8	0	2	4	17	120	30		270	11.1
7	10	9	0	4	12	1	36	150	9	2	13	0	2	15	41	120	77		270	28.5
8	15	20	0	6	19	1	61	150	5	2	28	0	2	18	55	120	116		270	43.0
9	15	13	0	12	14	0	54	150	8	1	37	0	4	27	77	120	131		270	48.5
10	15	17	0	12	22	0	66	150	10	1	35	0	2	29	77	120	143		270	53.0
11	14	24	0	12	23	0	73	150	2	0	42	0	2	33	79	120	152		270	56.3
12	15	23	0	14	22	0	74	150	4	2	37	0	1	22	66	120	140		270	51.9
13	15	17	0	22	22	1	77	150	5	1	43	0	2	32	83	120	160		270	59.3
14	15	15	0	21	23	0	74	150	4	1	40	0	1	34	80	120	154		270	57.0
15	15	20	0	21	22	0	78	150	5	2	27	0	1	30	65	120	143		270	53.0
16	16	23	0	11	23	0	73	150	3	2	41	0	5	32	83	120	156		270	57.8
17	15	23	0	0	22	1	61	150	4	2	37	0	0	37	80	120	141		270	52.2
18	15	23	0	3	17	0	58	150	2	2	31	0	1	35	71	120	129		270	47.8
19	15	23	0	22	23	0	83	150	1	3	18	0	0	31	53	120	136		270	50.4
20	16	23	0	21	15	0	75	150	2	0	41	0	1	36	80	120	155		270	57.4
21	15	12	0	22	20	1	70	150	0	2	22	0	0	25	49	120	119		270	44.1
22	15	6	0	14	22	0	57	150	0	2	21	0	0	39	62	120	119		270	44.1
23	6	14	0	0	24	1	45	150	1	3	38	0	4	42	88	120	133		270	49.3
Max	257	358	1	226	399	10	1251	3600	82	33	584	0	38	532	1269	2880	2520		6480	38.9
DATA							1251	1251							1226	1269	2477			
							0	2349							43	1611	43			

Table 72 Runway performance South Flow without PT

DFW PERFORMANCE IN 2010

SOUTH FLOW WITHOUT PT

Maximum arrivals and departures for a total of 2808 operations

ARRIVALS = 1418 **DEPARTURES = 1390**

Local hour	13R	17C	17L	17R	18L	18R	TOTAL ARR	FAA Cap AAR	13L	17C	17L	17R	18L	18R	TOTAL DEP	FAA ADR	TOTAL AAR+ADR	FAA ASPM TOTAL	FAA ADR + Cap AAR	% CAPACITY USED	FAA % CAPACITY USED
0	0	27	6	1	0	31	65	150	1	0	0	8	1	1	11	120	76		270	28.1	0.0
1	12	24	2	0	0	13	51	150	0	2	0	8	5	1	16	120	67		270	24.8	0.0
2	1	11	0	0	1	5	18	150	2	0	0	11	10	0	23	120	41		270	15.2	0.0
3	1	2	0	0	1	7	11	150	1	3	0	5	6	2	17	120	28		270	10.4	0.0
4	1	5	1	0	0	7	14	150	2	0	0	7	9	1	19	120	33		270	12.2	0.0
5	3	3	2	1	0	8	17	150	0	0	0	11	5	3	19	120	36		270	13.3	0.0
6	6	9	4	1	0	4	24	150	1	1	0	10	10	1	23	120	47		270	17.4	0.0
7	14	11	7	1	1	13	47	150	3	2	0	26	20	5	56	120	103		270	38.1	0.0
8	18	25	9	0	1	21	74	150	5	2	0	29	15	5	56	120	130		270	48.1	0.0
9	20	8	12	0	0	16	56	150	8	1	0	39	31	6	85	120	141		270	52.2	0.0
10	19	23	12	0	0	28	82	150	7	1	0	39	34	2	83	120	165		270	61.1	0.0
11	20	29	12	0	1	23	85	150	8	0	0	41	35	2	86	120	171		270	63.3	0.0
12	23	30	16	0	1	29	99	150	7	3	0	44	26	1	81	120	180		270	66.7	0.0
13	22	4	22	1	1	28	78	150	9	3	0	42	36	0	90	120	168		270	62.2	0.0
14	20	12	30	0	0	24	86	150	5	1	0	40	36	1	83	120	169		270	62.6	0.0
15	23	25	12	1	0	22	83	150	4	1	0	42	37	0	84	120	167		270	61.9	0.0
16	19	28	7	0	0	24	78	150	5	1	0	43	39	0	88	120	166		270	61.5	0.0
17	21	27	0	0	1	17	66	150	4	2	0	43	43	0	92	120	158		270	58.5	0.0
18	17	35	6	0	0	21	79	150	3	1	0	32	42	1	79	120	158		270	58.5	0.0
19	20	18	28	2	0	25	93	150	4	1	0	21	32	0	58	120	151		270	55.9	0.0
20	16	12	19	2	0	17	66	150	0	0	0	41	38	3	82	120	148		270	54.8	0.0
21	8	7	15	0	0	26	56	150	0	2	0	23	26	0	51	120	107		270	39.6	0.0
22	13	10	10	0	0	29	62	150	2	0	0	20	42	1	65	120	127		270	47.0	0.0
23	1	13	0	0	0	10	24	150	0	3	0	33	31	1	68	120	92		270	34.1	0.0
24	0	1	0	0	0	3	4	0	0	3	0	12	17	0	32	0	36		0	0.0	0.0
TOTAL	318	399	232	10	8	451	1418	3600	81	33	0	670	626	37	1447	2880	2829		6480	43.7	0.0
DATA							1418	1418							1390	1447	2808				
							0	2182							57	1433	21				

Table 73 Runway performance South Flow with PT

DFW PERFORMANCE IN 2010

SOUTH FLOW WITH PT

Maximum arrivals and departures for a total of 2808 operations

ARRIVALS = 1418 **DEPARTURES = 1390**

Local hour	13R	17C	17L	17R	18L	18R	TOTAL ARR	FAA Cap AAR	13L	17C	17L	17R	18L	18R	TOTAL DEP	FAA ADR	TOTAL AAR+ADR	FAA ASPM TOTAL	FAA ADR + Cap AAR	% CAPACITY USED	FAA % CAPACITY USED
0	0	27	5	2	0	31	65	150	1	0	0	7	2	2	12	90	77		240	32.1	0.0
1	11	23	3	0	0	13	50	150	4	2	0	4	4	1	15	90	65		240	27.1	0.0
2	1	12	0	0	1	5	19	150	2	0	0	9	8	2	21	90	40		240	16.7	0.0
3	1	2	0	0	1	7	11	150	1	3	0	2	8	4	18	90	29		240	12.1	0.0
4	1	5	1	0	0	7	14	150	1	0	0	7	8	4	20	90	34		240	14.2	0.0
5	1	3	5	0	0	8	17	150	1	0	0	11	4	5	21	90	38		240	15.8	0.0
6	3	11	5	0	0	5	24	140	2	1	0	11	9	1	24	90	48		230	20.9	0.0
7	12	12	7	0	0	15	46	140	6	3	0	24	17	4	54	90	100		230	43.5	0.0
8	19	25	9	0	1	21	75	140	9	3	0	29	16	2	59	90	134		230	58.3	0.0
9	21	8	13	0	0	16	58	140	10	3	0	37	27	4	81	90	139		230	60.4	0.0
10	19	25	12	0	0	26	82	140	11	2	0	41	35	1	90	90	172		230	74.8	0.0
11	17	28	12	0	1	24	82	140	8	0	0	43	34	2	87	90	169		230	73.5	0.0
12	23	33	16	0	1	29	102	140	5	3	0	45	26	1	80	90	182		230	79.1	0.0
13	22	4	25	0	1	29	81	140	8	5	0	41	38	0	92	90	173		230	75.2	0.0
14	19	13	29	0	0	27	88	140	5	2	0	40	37	1	85	90	173		230	75.2	0.0
15	15	26	9	4	0	23	77	140	7	1	0	24	33	3	68	90	145		230	63.0	0.0
16	19	28	7	0	0	24	78	140	6	2	0	43	35	4	90	90	168		230	73.0	0.0
17	19	27	0	0	1	17	64	140	7	2	0	40	35	2	86	90	150		230	65.2	0.0
18	18	35	6	0	0	22	81	140	4	1	0	30	40	1	76	90	157		230	68.3	0.0
19	20	18	30	0	0	25	93	140	2	1	0	21	36	0	60	90	153		230	66.5	0.0
20	15	12	21	0	0	17	65	140	0	0	0	39	40	3	82	90	147		230	63.9	0.0
21	9	7	16	0	0	26	58	140	0	2	0	22	26	0	50	90	108		230	47.0	0.0
22	11	10	10	0	0	29	60	140	2	0	0	20	40	2	64	90	124		230	53.9	0.0
23	1	13	0	0	0	12	26	140	0	0	0	30	24	5	59	90	85		230	37.0	0.0
24	0	1	0	0	0	1	2	0	0	3	0	10	13	0	26	0	28		0	0.0	0.0
MAX	297	408	241	6	7	459	1418	3420	102	39	0	630	595	54	1420	2160	2838		5580	50.9	0.0
DATA							1418	1418							1390	1420	2808				
							0	2002							30	740	30				

Table 74 Runway performance North Flow without PT

DFW PERFORMANCE IN 2010

NORTH FLOW WITHOUT PT

Maximum arrivals and departures for a total of 2808 operations

ARRIVALS = 1418 **DEPARTURES = 1390**

Local hour	31R	35C	35L	35R	36L	36R	TOTAL ARR	FAA Cap AAR	31L	35C	35L	35R	36L	36R	TOTAL DEP	FAA ADR	TOTAL AAR+ADR	FAA ASPM TOTAL	FAA ADR + Cap AAR	% CAPACITY USED	FAA % CAPACITY USED
0	10	21	0	7	32	0	70	150	0	0	9	0	0	1	10	120	80		270	29.6	0.0
1	11	23	0	1	13	0	48	150	0	2	11	0	1	5	19	120	67		270	24.8	0.0
2	1	11	0	0	4	1	17	150	1	0	9	0	4	7	21	120	38		270	14.1	0.0
3	1	2	0	0	7	1	11	150	1	2	5	0	4	5	17	120	28		270	10.4	0.0
4	1	5	0	1	7	0	14	150	1	1	10	0	1	6	19	120	33		270	12.2	0.0
5	3	3	0	3	8	0	17	150	1	0	12	0	5	3	21	120	38		270	14.1	0.0
6	3	12	0	6	3	0	24	150	3	1	11	0	3	5	23	120	47		270	17.4	0.0
7	16	10	0	8	14	1	49	150	8	2	24	0	1	17	52	120	101		270	37.4	0.0
8	37	14	0	7	21	1	80	150	7	3	35	0	2	17	64	120	144		270	53.3	0.0
9	20	4	0	14	17	0	55	150	14	1	40	0	2	23	80	120	135		270	50.0	0.0
10	20	27	0	10	26	0	83	150	14	1	45	0	0	25	85	120	168		270	62.2	0.0
11	28	24	0	12	24	1	89	150	9	0	44	0	0	34	87	120	176		270	65.2	0.0
12	17	32	0	17	30	1	97	150	7	3	44	0	0	29	83	120	180		270	66.7	0.0
13	16	9	0	23	28	1	77	150	6	3	47	0	0	36	92	120	169		270	62.6	0.0
14	20	13	0	31	24	0	88	150	6	1	42	0	0	33	82	120	170		270	63.0	0.0
15	18	24	0	11	22	0	75	150	7	1	24	0	2	34	68	120	143		270	53.0	0.0
16	26	26	0	7	24	0	83	150	8	2	44	0	3	34	91	120	174		270	64.4	0.0
17	13	28	0	0	16	1	58	150	4	7	36	0	1	35	83	120	141		270	52.2	0.0
18	13	46	0	8	21	0	88	150	5	1	31	0	0	39	76	120	164		270	60.7	0.0
19	8	24	0	30	26	0	88	150	4	3	23	0	0	30	60	120	148		270	54.8	0.0
20	9	18	0	19	16	0	62	150	0	0	40	0	0	42	82	120	144		270	53.3	0.0
21	9	12	0	16	27	0	64	150	0	2	21	0	0	28	51	120	115		270	42.6	0.0
22	4	13	0	9	29	0	55	150	2	0	21	0	0	41	64	120	119		270	44.1	0.0
23	1	11	0	0	10	0	22	150	1	0	16	0	4	13	34	120	56		270	20.7	0.0
24	0	1	0	0	3	0	4	0	0	3	13	0	0	15	31	0	35		0	0.0	0.0
TOTAL	305	413	0	240	452	8	1418	3600	109	39	657	0	33	557	1395	2880	2778		6480	42.9	
DATA							1418	1418							1390	1395	2808				
							0	2182							5	1485	-30				

Table 75 Runway performance North Flow with PT

DFW PERFORMANCE IN 2010

NORTH FLOW WITH PT

Maximum arrivals and departures for a total of 2808 operations

ARRIVALS = 1418 **DEPARTURES = 1390**

Local hour	31R	35C	35L	35R	36L	36R	TOTAL ARR	FAA Cap AAR	31L	35C	35L	35R	36L	36R	TOTAL DEP	FAA ADR	TOTAL AAR+ADR	FAA ASPM TOTAL	FAA ADR + Cap AAR	% CAPACITY USED	FAA % CAPACITY USED
0	0	24	1	6	27	1	59	150	1	0	8	0	0	1	10	120	69		270	25.6	0.0
1	12	21	0	1	21	0	55	150	0	1	10	0	1	5	17	120	72		270	26.7	0.0
2	0	13	0	0	6	1	20	150	3	0	8	0	4	5	20	120	40		270	14.8	0.0
3	1	2	0	0	6	2	11	150	1	2	5	0	3	7	18	120	29		270	10.7	0.0
4	1	5	0	1	7	0	14	150	1	0	8	0	2	7	18	120	32		270	11.9	0.0
5	3	3	0	3	8	0	17	150	1	0	12	0	5	3	21	120	38		270	14.1	0.0
6	3	11	0	5	4	0	23	150	2	0	8	0	4	5	19	120	42		270	15.6	0.0
7	12	12	0	7	13	1	45	150	5	5	18	0	7	18	53	120	98		270	36.3	0.0
8	22	23	0	8	21	1	75	150	9	3	31	0	2	17	62	120	137		270	50.7	0.0
9	20	11	0	13	16	0	60	150	13	2	39	0	4	27	85	120	145		270	53.7	0.0
10	19	22	0	12	27	0	80	150	11	2	39	0	2	33	87	120	167		270	61.9	0.0
11	18	30	0	12	23	2	85	150	7	0	43	0	2	34	86	120	171		270	63.3	0.0
12	22	30	0	16	29	1	98	150	5	3	45	0	1	28	82	120	180		270	66.7	0.0
13	18	13	0	22	27	2	82	150	9	3	45	0	2	33	92	120	174		270	64.4	0.0
14	18	17	0	29	24	0	88	150	3	2	41	0	1	36	83	120	171		270	63.3	0.0
15	14	26	0	15	23	0	78	150	8	1	26	0	2	36	73	120	151		270	55.9	0.0
16	20	27	0	7	24	0	78	150	9	2	43	0	4	35	93	120	171		270	63.3	0.0
17	18	27	0	0	18	1	64	150	5	6	35	0	0	31	77	120	141		270	52.2	0.0
18	21	30	0	5	21	0	77	150	2	5	33	0	1	36	77	120	154		270	57.0	0.0
19	11	30	0	29	25	0	95	150	2	3	21	0	0	30	56	120	151		270	55.9	0.0
20	13	15	0	23	16	0	67	150	1	1	36	0	1	37	76	120	143		270	53.0	0.0
21	11	8	0	14	23	1	57	150	1	2	27	0	0	32	62	120	119		270	44.1	0.0
22	9	10	0	11	31	0	61	150	0	2	20	0	0	47	69	120	130		270	48.1	0.0
23	1	13	0	0	10	1	25	150	1	3	29	0	4	28	65	120	90		270	33.3	0.0
24	0	1	0	0	3	0	4	0	0	3	14	0	0	17	34	0	38		0	0.0	0.0
MAX	287	424	1	239	453	14	1418	3600	100	51	644	0	52	588	1435	2880	2853		6480	44.0	0
DATA							1418	1418							1390	1435	2808		2853		
							0	2182							45	1445	45		3627		

Figure 62 shows the comparison of hourly operations rate between 2004 and 2010 for South Flow configuration without PT.

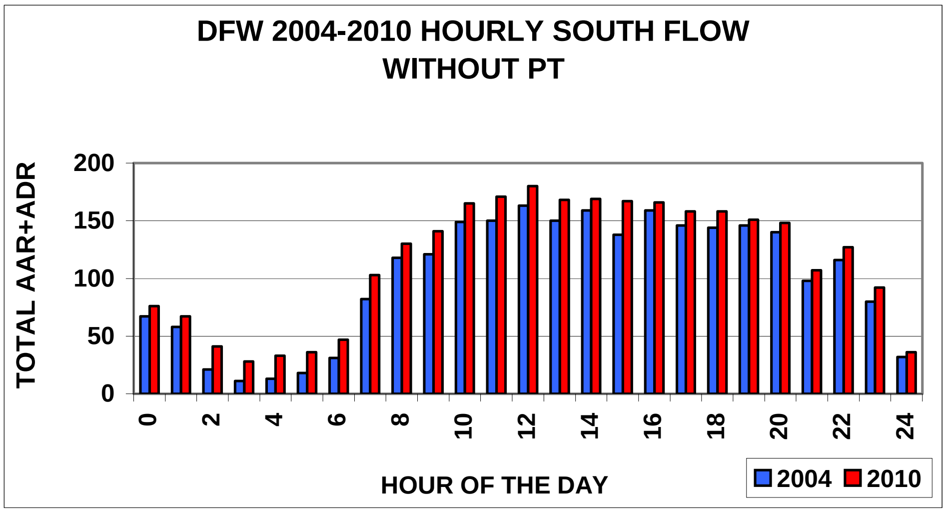

Figure 62 South flow hourly flows without PT

Figure 63 shows the comparison of hourly operations between 2004 and 2010 for North Flow configuration without PT.

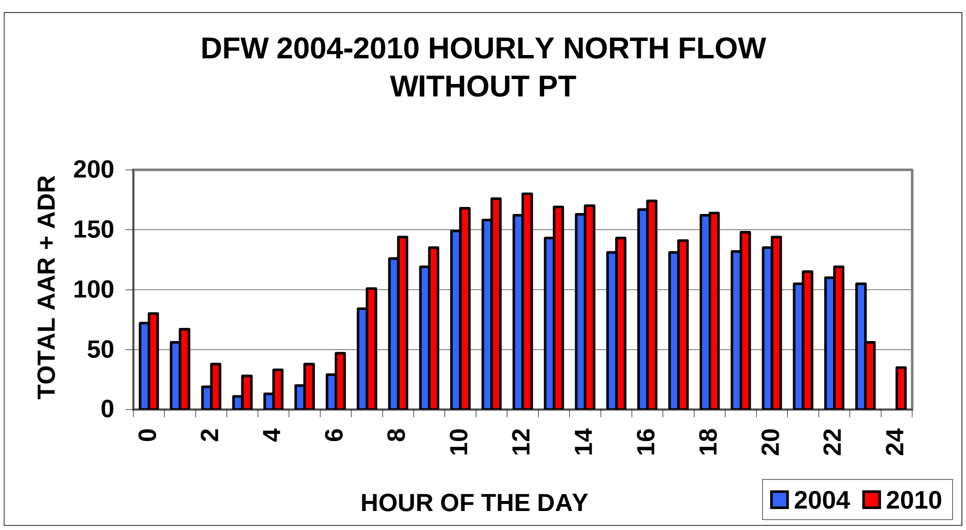

Figure 63 North Flow hourly flows without PT

Figure 64 shows the comparison of hourly operations between 2004 and 2010 for South Flow configuration with PT.

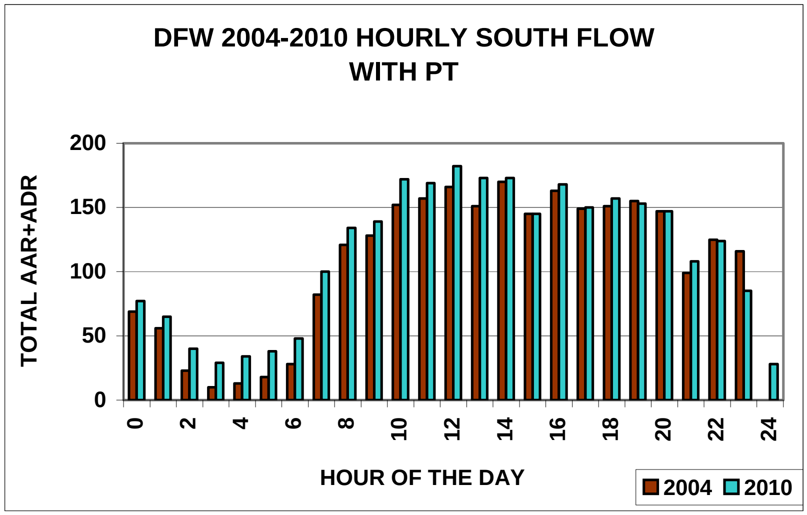

Figure 64 South Flow hourly flows with PT

Figure 65 shows the comparison of hourly operations between 2004 and 2010 for North Flow configuration with PT.

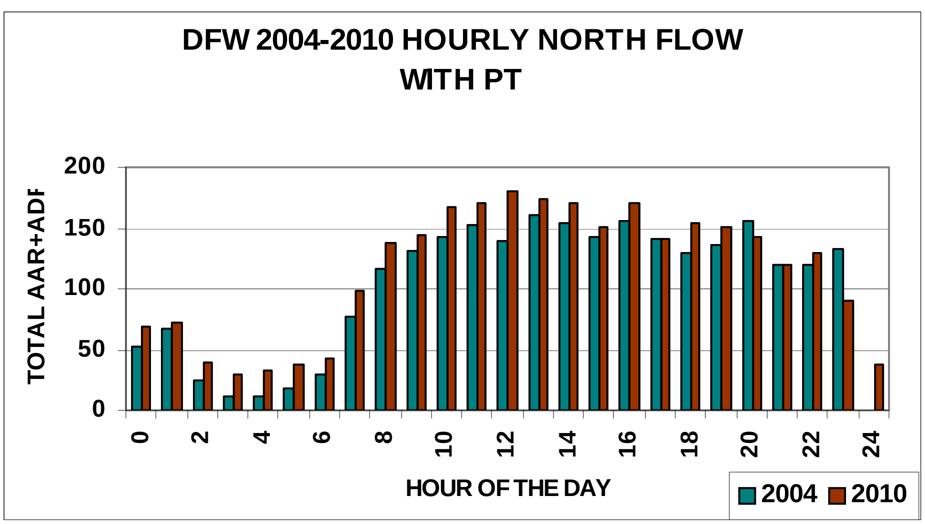

Figure 65 North Flow hourly flows with PT

The total operations per hour with and without the PT during the South Flow configuration for year 2004, with 2,477 operations per day are shown in Figure 66.

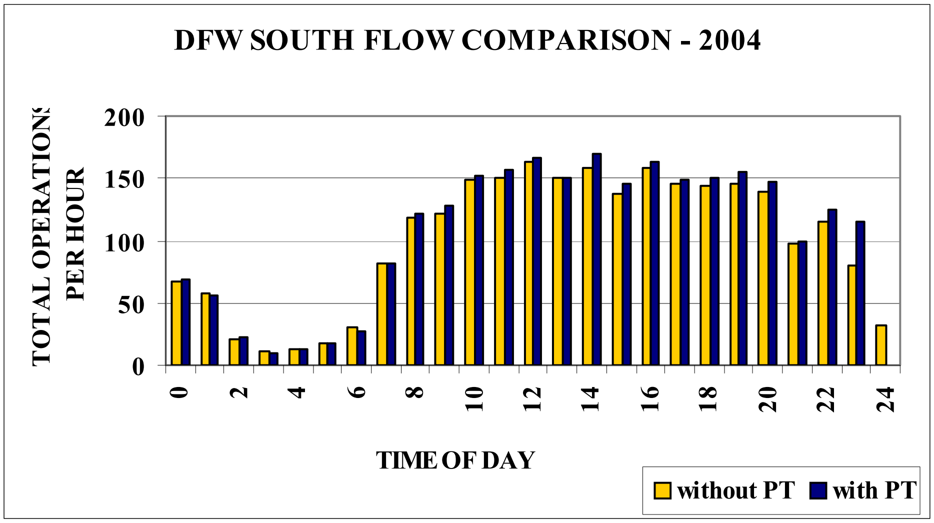

Figure 66 South Flow-DFW 2004 hourly operations comparison

The total operations per hour with and without the PT during the North Flow configuration for year 2004, with 2,477 operations per day are shown in Figure 67.

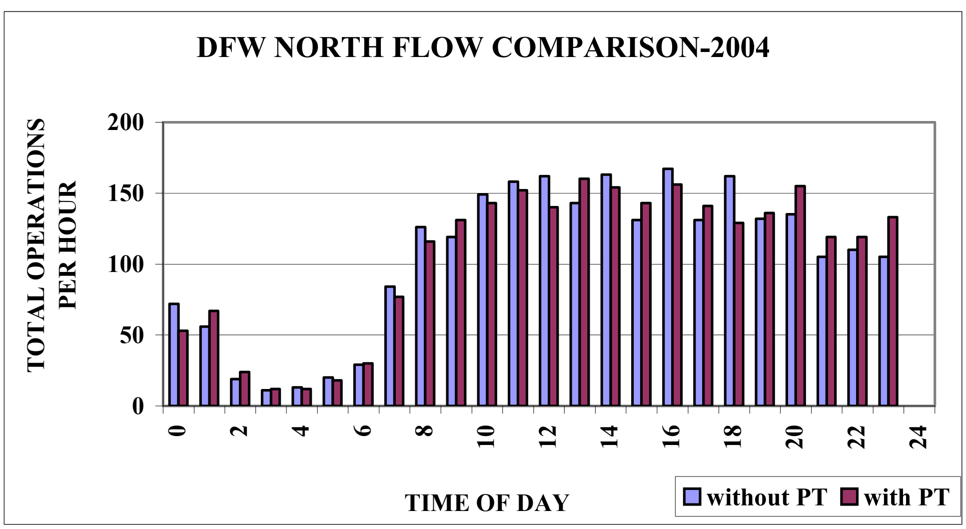

Figure 67 North Flow-DFW 2004 hourly operations comparison

The total operations per hour with and without the PT during the South Flow configuration for year 2010, with 2,808 operations per day are shown in Figure 68.

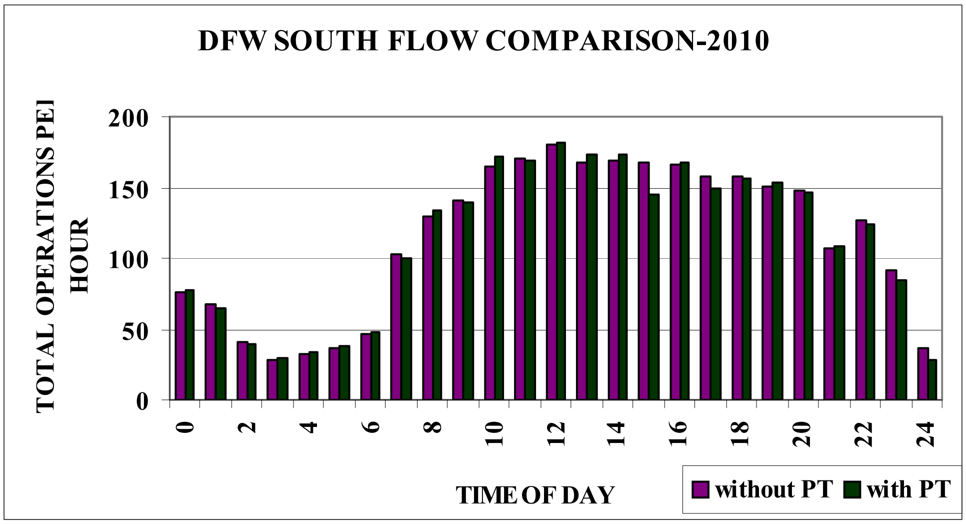

Figure 68 South Flow-DFW 2010 hourly operations comparison

The total operations per hour with and without the PT during the North Flow configuration for year 2010, with 2,808 operations per day are shown in Figure 69.

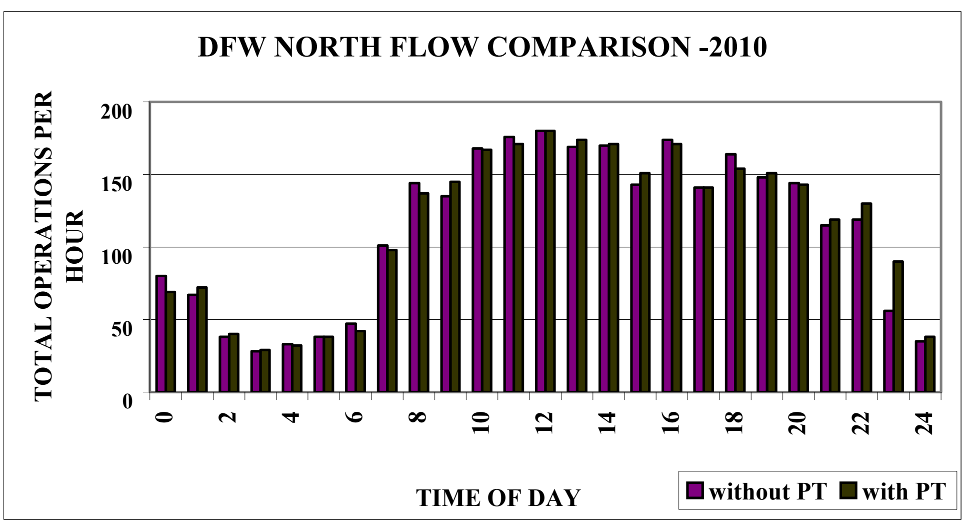

Figure 69 North Flow-DFW 2010 hourly operations comparison

Total hourly departures during the South Flow configuration in 2010 are shown in Figure 70. The introduction of the PT did not significantly increase the departure rate as expected in the initial assumption.

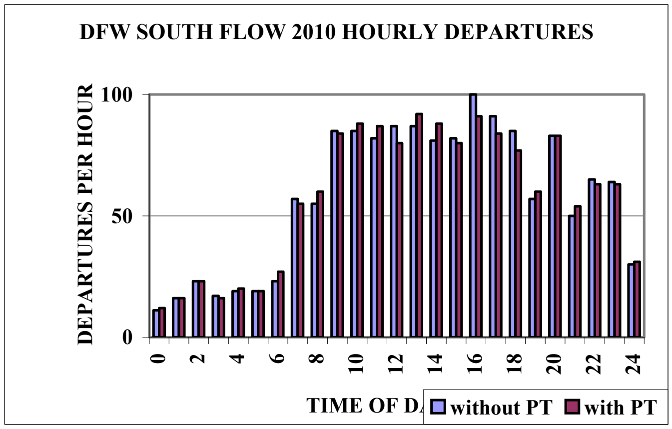

Figure 70 DFW South Flow departures per hour comparison 2010

The reason being that the operation of the airport with five terminals, GA apron, and cargo aprons on the east and west side had altered the departure sequence and the time it takes for the flights to reach the departure queue. The North Flow departures in 2010 are shown in Figure 71.

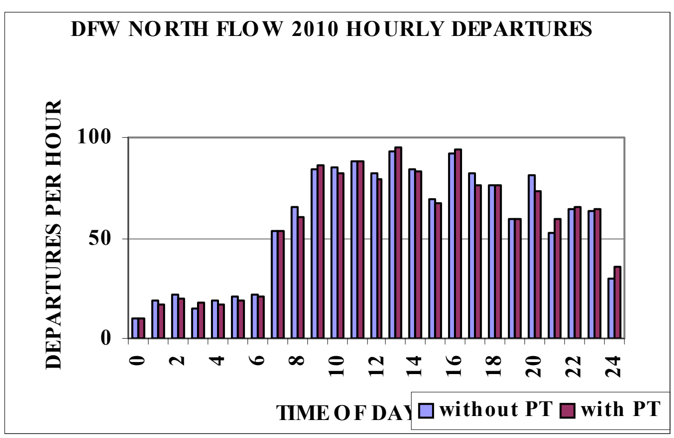

Figure 71 DFW North Flow departures per hour comparison 2010

<u>8.5 Runway crossing delay analysis</u>

Runway crossing delay experienced by an arriving aircraft and the departing aircraft is evaluated in this section. The tables list the delay for arriving and departing aircraft while waiting to cross the departure runways to reach the terminals or the departure runways. Table 76 gives the runway crossing delay for the 2004 baseline arrival statistics for the 1,251 arrivals during the South Flow configuration. Only 538 (43%) flights have incurred runway crossing delay while crossing an active runway to reach their respective assigned gates or cargo aprons. Average delay incurred is 0.6 minutes and the maximum delay experienced equals 1.3 minutes.

Table 76 Runway crossing delay-South Flow arrivals-2004

DFW RUNWAY CROSSING DELAY							
2004 OPERATIONS							
TOTAL ARRIVALS 2004 = 1251							
			RUNWAY CROSSING TIME IN MINUTES				
RUNWAY CROSSING DESCRIPTION	TO TERMINAL	ARRIVAL RUNWAY	AVERAGE	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF FLIGHTS
RUNWAY CROSSING BY ARRIVING AIRCRAFT							
SOUTH FLOW							
RUNWAY 18R/18L	A	13R	0.72	0.48	1.87	0.02	28.00
RUNWAY 18R/18L	B	13R	0.7	0.4	2.0	0.0	42
RUNWAY 18R/18L	C	13R	0.9	0.4	1.9	0.3	32
RUNWAY 18R/18L	E	13R	0.9	0.5	2.1	0.3	47
RUNWAY 18R/18L	GA	13R	0.8	0.4	1.9	0.2	17
RUNWAY 18R/18L/17R/17C	EAST CARGO	13R	0.3	0.2	0.6	0.0	4
RUNWAY 17R	A	17C	0.5	0.2	0.9	0.1	31
RUNWAY 17R	B	17C	0.5	0.2	0.9	0.2	20
RUNWAY 17R	C	17C	0.6	0.3	1.1	0.1	26
RUNWAY 17R	E	17C	0.4	0.3	1.2	0.0	29
RUNWAY 17R	GA	17C	0.5	0.5	1.1	0.2	4
RUNWAY 17R/17C	EAST CARGO	17C	0.6	0.0	0.6	0.6	2
RUNWAY 17R/18L/18R	WEST CARGO	17C	0.4	0.0	0.4	0.4	2
RUNWAY 17C/17R	A	17L	0.6	0.4	1.5	0.1	28
RUNWAY 17C/17R	B	17L	0.7	0.3	1.8	0.2	22
RUNWAY 17C/17R	C	17L	0.7	0.3	1.5	0.2	23
RUNWAY 17C/17R	E	17L	0.8	0.4	1.9	0.3	25
RUNWAY 17C/17R	GA	17L	0.8	0.1	0.8	0.7	2
RUNWAY 17C/17R/18L/18R	WEST CARGO	17L	0.6	0.3	0.8	0.3	3
RUNWAY 18R/18L	A	18R	0.7	0.3	1.4	0.1	39
RUNWAY 18R/18L	B	18R	0.5	0.3	1.2	0.1	26
RUNWAY 18R/18L	C	18R	0.7	0.3	1.2	0.1	40
RUNWAY 18R/18L	E	18R	0.6	0.3	1.2	0.0	24
RUNWAY 18R/18L	GA	18R	0.5	0.3	1.1	0.0	11
RUNWAY 18R/18L/17R/17C	EAST CARGO	18R	0.6	0.3	0.8	0.3	3
RUNWAY 18R/18L	WEST CARGO	18R	0.8	0.6	2.1	0.1	8
ALL RUNWAYS	ALL	ALL	0.6	0.3	1.3	0.2	538.00

PERCENTAGE OF ARRIVALS THAT EXPERIENCED RUNWAY CROSSING DELAY = 43.0%

Table 77 depicts the runway crossing delay for arrivals during the North Flow configuration for baseline 2004 data for a total of 1,251 flights. Only 371 (29.7%) flights have incurred runway crossing delay while crossing the active runway to reach their respective assigned gates or cargo aprons. The mean delay incurred is 0.8 minutes and the maximum delay experienced equals 3.1 minutes.

Table 77 Runway crossing delay-North Flow arrivals-2004

DFW RUNWAY CROSSING DELAY							
2004 OPERATIONS							
TOTAL ARRIVALS 2004 = 1251							
			RUNWAY CROSSING TIME IN MINUTES				
RUNWAY CROSSING DESCRIPTION	TO TERMINAL	ARRIVAL RUNWAY	AVERAGE	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF FLIGHTS
RUNWAY CROSSING BY ARRIVING AIRCRAFT							
NORTH FLOW							
RUNWAY 35L/35C	A	31R	0.6	0.3	1.2	0.2	15
RUNWAY 35L/35C	B	31R	1.2	2.8	16.3	0.2	32
RUNWAY 35L/35C	C	31R	0.8	0.4	1.6	0.4	8
RUNWAY 35L/35C	E	31R	1.5	2.1	11.0	0.0	34
RUNWAY 35L/35C	GA	31R	1.5	1.9	7.1	0.2	16
RUNWAY 31R	EAST CARGO	31R	1.0	0.0	1.0	1.0	2
RUNWAY 35L	A	35C	0.5	0.2	0.8	0.2	16
RUNWAY 35L	B	35C	0.4	0.1	0.7	0.2	13
RUNWAY 35L	C	35C	0.4	0.1	0.6	0.2	22
RUNWAY 35L	E	35C	0.3	0.2	0.6	0.1	15
RUNWAY 35L	GA	35C	0.0	0.0	0.0	0.0	0
RUNWAY 31R	EAST CARGO	35C	2.0	1.5	3.4	0.4	4
RUNWAY 35L/36R/36L	WEST CARGO	35C	1.1	0.3	1.3	0.7	3
RUNWAY 35L	A	35R	1.3	1.0	3.9	0.4	16
RUNWAY 35L	B	35R	1.4	2.4	11.5	0.2	21
RUNWAY 35L	C	35R	1.0	1.1	5.2	0.2	21
RUNWAY 35L	E	35R	0.7	0.7	2.4	0.1	24
RUNWAY 35L	GA	35R	1.1	1.3	2.6	0.3	3
RUNWAY 35L/36R/36L	WEST CARGO	35R	0.0	0.0	0.0	0.0	0
RUNWAY 36R	A	36L	0.5	0.2	0.9	0.2	29
RUNWAY 36R	B	36L	0.6	0.2	1.0	0.2	24
RUNWAY 36R	C	36L	0.6	0.2	1.0	0.2	22
RUNWAY 36R	E	36L	0.4	0.2	0.6	0.2	16
RUNWAY 36R	GA	36L	0.4	0.2	0.7	0.1	9
RUNWAY 36R/35L/35C	WEST CARGO	36L	0.9	0.6	1.9	0.2	6
ALL RUNWAYS	ALL	ALL	0.8	0.7	3.1	0.2	371
PERCENTAGE OF ARRIVALS THAT EXPERIENCED RUNWAY CROSSING DELAY =					29.7%		

Table 78 shows the runway crossing delay statistics for departures for baseline year 2004 for a total of 1,226 flights. Only 40(3.3%) flights have incurred runway crossing delay while crossing the active runway to reach their respective assigned departure queue. The mean delay incurred is 0.5 minutes and the maximum delay experienced equals 0.7 minutes.

Table 78 Runway crossing delay- South Flow departures-2004

DFW RUNWAY CROSSING DELAY							
2004 OPERATIONS							
TOTAL DEPARTURES 2004 = 1226							
			RUNWAY CROSSING TIME IN MINUTES				
RUNWAY CROSSING DESCRIPTION	FROM TERMINAL	DEPARTURE RUNWAY	AVERAGE	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF FLIGHTS
RUNWAY CROSSING BY DEPARTING AIRCRAFT							
SOUTH FLOW							
RUNWAY 18R/18L	B	13L	0.5	0.4	0.9	0.1	3
RUNWAY 18R/18L	E	13L	0.6	0.3	1.0	0.3	5
RUNWAY 18R/18L	GA	13L	0.6	0.4	1.5	0.0	18
RUNWAY 17R	B	17C	0.7	0.0	0.7	0.7	1
RUNWAY 17R	E	17C	0.6	0.0	0.6	0.6	2
RUNWAY 17R/18L/18R	WEST CARGO	17C	0.2	0.0	0.2	0.2	1
RUNWAY 17C	EAST CARGO	17R	0.5	0.1	0.6	0.4	3
RUNWAY 18L/18R	WEST CARGO	17R	0.6	0.0	0.6	0.6	1
RUNWAY 18L	C	18R	0.3	0.0	0.3	0.3	1
RUNWAY 18R	WEST CARGO	18L	0.4	0.1	0.5	0.3	2
RUNWAY 17R/17C	EAST CARGO	18L	0.5	0.0	0.5	0.5	1
RUNWAY 18R	WEST CARGO	18L	0.7	0.0	0.7	0.7	2
ALL RUNWAYS	ALL	ALL	0.5	0.1	0.7	0.4	40
PERCENTAGE OF DEPARTURES THAT EXPERIENCED RUNWAY CROSSING DELAY =							3.3%

Table 79 shows the runway crossing delay for North Flow departures on the baseline year 2004 for a total of 1,226 flights. Only 52 (4.2%) flights have incurred runway crossing delay while crossing the active runway to reach their respective assigned departure queue. The mean delay incurred is 0.8 minutes and the maximum delay experienced equals 1.2 minutes.

Table 79 Runway crossing delay North Flow departures-2004

DFW RUNWAY CROSSING DELAY							
2004 OPERATIONS							
TOTAL DEPARTURES 2004 =1226							
			RUNWAY CROSSING TIME IN MINUTES				
RUNWAY CROSSING DESCRIPTION	FROM TERMINAL	DEPARTURE RUNWAY	AVERAGE	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF FLIGHTS
RUNWAY CROSSING BY DEPARTING AIRCRAFT							
NORTH FLOW							
RUNWAY 36R/36L	B	31L	0.8	0.7	1.7	0.3	5
RUNWAY 35L/36R/36L	C	31L	0.8	0.0	0.8	0.8	1
RUNWAY 35L/36R/36L	E	31L	0.6	0.3	1.2	0.1	18
RUNWAY 36R/36L	GA	31L	0.7	0.5	2.3	0.1	18
RUNWAY 35L	C	35C	0.1	0.0	0.1	0.1	1
RUNWAY 35L	E	35C	0.2	0.1	0.3	0.2	2
RUNWAY 31R	EAST CARGO	35C	0.7	0.0	0.7	0.7	1
RUNWAY 31R/35C	EAST CARGO	35L	2.5	2.1	4.0	1.0	2
RUNWAY 36R/36L	WEST CARGO	35L	1.1	0.0	1.1	1.1	1
RUNWAY 36R	A	36L	0.8	0.0	0.8	0.8	1
RUNWAY 36R	B	36L	0.8	0.0	0.8	0.8	1
RUNWAY 36L	WEST CARGO	36R	0.9	0.0	0.9	0.9	1
ALL RUNWAYS	ALL	ALL	0.8	0.3	1.2	0.6	52
PERCENTAGE OF DEPARTURES THAT EXPERIENCED RUNWAY CROSSING DELAY =							4.2%

Table 80 shows the runway crossing delay statistics for future operations in 2010 for a total of 1,418 arrivals during South Flow configuration. Only 628 (44.3%) flights have incurred runway crossing delay while crossing the active runway to reach their respective assigned gates or cargo aprons. The mean delay incurred is 0.7 minutes and the maximum delay experienced equals 1.7 minutes.

Table 80 Runway crossing delay South Flow arrivals-2010 without PT

DFW RUNWAY CROSSING DELAY							
2010 OPERATIONS							
TOTAL ARRIVALS 2010 = 1418							
			RUNWAY CROSSING TIME IN MINUTES				
RUNWAY CROSSING DESCRIPTION	TO TERMINAL	ARRIVAL RUNWAY	AVERAGE	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF FLIGHTS
RUNWAY CROSSING BY ARRIVING AIRCRAFT							
SOUTH FLOW							
RUNWAY 18R/18L	A	13R	0.8	0.5	1.9	0.2	23
RUNWAY 18R/18L	B	13R	1.0	0.6	3.9	0.0	50
RUNWAY 18R/18L	C	13R	0.8	0.5	2.0	0.2	24
RUNWAY 18R/18L	D	13R	0.9	0.3	1.3	0.3	10
RUNWAY 18R/18L	E	13R	1.0	0.6	3.4	0.2	53
RUNWAY 18R/18L	GA	13R	0.9	0.5	2.7	0.2	31
RUNWAY 18R/18L/17R/17C	EAST CARGO	13R	0.6	0.3	1.0	0.4	4
RUNWAY 17R	A	17C	0.5	0.3	1.1	0.2	18
RUNWAY 17R	B	17C	0.4	0.2	0.9	0.0	24
RUNWAY 17R	C	17C	0.4	0.2	0.9	0.1	35
RUNWAY 17R	D	17C	0.5	0.3	1.0	0.1	10
RUNWAY 17R	E	17C	0.6	0.3	1.3	0.1	39
RUNWAY 17R	GA	17C	0.4	0.3	0.6	0.1	4
RUNWAY 17R/17C	EAST CARGO	17C	0.7	0.4	1.4	0.4	4
RUNWAY 17R/18L/18R	WEST CARGO	17C	0.9	0.2	1.0	0.8	2
RUNWAY 17C/17R	A	17L	0.8	0.5	2.2	0.1	25
RUNWAY 17C/17R	B	17L	0.9	0.5	2.1	0.4	32
RUNWAY 17C/17R	C	17L	1.1	1.0	5.4	0.2	29
RUNWAY 17C/17R	D	17L	0.9	0.4	1.5	0.5	9
RUNWAY 17C/17R	E	17L	1.1	0.5	2.7	0.2	31
RUNWAY 17C/17R	GA	17L	1.1	0.6	1.5	0.7	2
RUNWAY 17C/17R/18L/18R	WEST CARGO	17L	0.3	0.0	0.3	0.2	3
RUNWAY 18R/18L	A	18R	0.6	0.3	1.3	0.1	25
RUNWAY 18R/18L	B	18R	0.5	0.3	1.0	0.0	32
RUNWAY 18R/18L	C	18R	0.6	0.3	1.6	0.1	40
RUNWAY 18R/18L	D	18R	0.6	0.3	1.0	0.2	9
RUNWAY 18R/18L	E	18R	0.5	0.3	1.0	0.0	26
RUNWAY 18R/18L	GA	18R	0.5	0.4	1.7	0.2	13
RUNWAY 18R/18L/17R/17C	EAST CARGO	18R	1.2	0.4	1.5	0.7	3
RUNWAY 18R/18L	WEST CARGO	18R	0.7	0.4	1.4	0.1	18
ALL RUNWAYS	ALL	ALL	0.7	0.4	1.7	0.2	628
PERCENTAGE OF ARRIVALS THAT EXPERIENCED RUNWAY CROSSING DELAY =					44.3%		

Table 81 shows the runway crossing delay statistics for the future 2010 operations during the North Flow for a total 1,418 flights. Only 472 (33.3%) flights have incurred runway crossing delay while crossing the active runway to reach their respective assigned gates or cargo aprons. The mean delay incurred is 1.2 minutes and the maximum delay experienced equals 4.8 minutes.

Table 81 Runway crossing delay North Flow arrivals 2010 without PT

DFW RUNWAY CROSSING DELAY							
2010 OPERATIONS							
TOTAL ARRIVALS 2010 = 1418							
			RUNWAY CROSSING TIME IN MINUTES				
RUNWAY CROSSING DESCRIPTION	TO TERMINAL	ARRIVAL RUNWAY	AVERAGE	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF FLIGHTS
RUNWAY CROSSING BY ARRIVING AIRCRAFT							
NORTH FLOW							
RUNWAY 35L/35C	A	31R	1.6	1.1	3.9	0.2	11
RUNWAY 35L/35C	B	31R	2.9	6.3	42.8	0.2	47
RUNWAY 35L/35C	C	31R	1.0	1.1	4.2	0.2	14
RUNWAY 35L/35C	D	31R	1.6	0.4	2.0	1.3	3
RUNWAY 35L/35C	E	31R	1.6	1.6	6.9	0.2	41
RUNWAY 35L/35C	GA	31R	1.4	1.5	7.6	0.1	29
RUNWAY 31R	EAST CARGO	31R	1.1	0.0	1.1	1.1	2
RUNWAY 35L	A	35C	0.4	0.1	0.6	0.2	22
RUNWAY 35L	B	35C	0.5	0.1	0.6	0.2	11
RUNWAY 35L	C	35C	0.4	0.2	1.1	0.1	29
RUNWAY 35L	D	35C	0.5	0.1	0.6	0.2	6
RUNWAY 35L	E	35C	0.4	0.2	0.7	0.1	24
RUNWAY 35L	GA	35C	0.5	0.0	0.5	0.5	1
RUNWAY 31R	EAST CARGO	35C	2.2	1.7	4.9	0.5	6
RUNWAY 35L/36R/36L	WEST CARGO	35C	2.1	1.5	4.8	0.6	7
RUNWAY 35L	A	35R	1.6	2.2	9.1	0.2	15
RUNWAY 35L	B	35R	1.2	0.9	3.6	0.2	25
RUNWAY 35L	C	35R	2.3	2.3	8.8	0.2	28
RUNWAY 35L	D	35R	1.2	0.5	1.9	0.6	5
RUNWAY 35L	E	35R	1.4	2.1	11.4	0.0	30
RUNWAY 35L	GA	35R	2.1	1.7	3.9	0.6	3
RUNWAY 35L/36R/36L	WEST CARGO	35R	1.5	1.5	2.6	0.4	2
RUNWAY 36R	A	36L	0.5	0.2	0.8	0.2	18
RUNWAY 36R	B	36L	0.5	0.3	1.1	0.1	27
RUNWAY 36R	C	36L	0.5	0.2	0.8	0.2	24
RUNWAY 36R	D	36L	0.5	0.2	0.7	0.3	4
RUNWAY 36R	E	36L	0.5	0.2	0.8	0.2	18
RUNWAY 36R	GA	36L	0.5	0.6	1.9	0.0	7
RUNWAY 36R/35L/35C	WEST CARGO	36L	2.1	2.3	8.2	0.2	13
ALL RUNWAYS	ALL	ALL	1.2	1.1	4.8	0.3	472
PERCENTAGE OF ARRIVALS THAT EXPERIENCED RUNWAY CROSSING DELAY =					33.3%		

Table 82 shows the runway crossing delay statistics for the future 2010 operations during South Flow configuration for a total 1,390 flights. Only 75 (5.4%) flights have incurred runway crossing delay while crossing the active runway to reach their respective assigned departure queue. The mean delay incurred is 2.3 minutes and the maximum delay experienced equals 3.8 minutes.

Table 82 Runway crossing delay South Flow departures-2010 without PT

DFW RUNWAY CROSSING DELAY							
2010 OPERATIONS							
TOTAL DEPARTURES 2010 = 1390							
			RUNWAY CROSSING TIME IN MINUTES				
RUNWAY CROSSING DESCRIPTION	FROM TERMINAL	DEPARTURE RUNWAY	AVERAGE	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF FLIGHTS
RUNWAY CROSSING BY DEPARTING AIRCRAFT							
SOUTH FLOW							
RUNWAY 17C/17R	B	13L	0.5	0.3	0.9	0.2	6
RUNWAY 17C/17R	D	13L	2.1	0.0	2.1	2.1	1
RUNWAY 17C/17R	E	13L	0.7	0.5	1.3	0.2	7
RUNWAY 17C/17R	GA	13L	1.0	0.7	3.5	0.0	27
RUNWAY 17R	A	17C	0.2	0.0	0.2	0.2	1
RUNWAY 17R	E	17C	0.3	0.0	0.3	0.3	3
RUNWAY 17R	GA	17C	0.2	0.0	0.2	0.2	1
RUNWAY 17R/18L/18R	WEST CARGO	17C	0.1	0.0	0.1	0.1	1
RUNWAY 17C	EAST CARGO	17R	0.6	0.5	1.0	0.0	3
RUNWAY 18L/18R	WEST CARGO	17R	1.0	0.7	1.4	0.2	3
RUNWAY 17C/17R	EAST CARGO	18L	3.5	5.4	9.8	0.3	3
RUNWAY 18R	WEST CARGO	18L	0.7	0.4	1.1	0.0	8
RUNWAY 18L	A	18R	0.4	0.0	0.4	0.4	1
RUNWAY 18L	B	18R	0.4	0.3	0.8	0.1	3
RUNWAY 18L	C	18R	0.7	0.0	0.7	0.7	1
RUNWAY 18L	GA	18R	26.5	10.9	39.0	19.2	3
RUNWAY 18R	WEST CARGO	18R	0.6	0.4	1.1	0.3	3
ALL RUNWAYS	ALL	ALL	2.3	1.2	3.8	1.4	75
PERCENTAGE OF DEPARTURES THAT EXPERIENCED RUNWAY CROSSING DELAY =							5.4%

Table 83 shows the runway crossing delay statistics for future 2010 operations during North Flow configuration for a total of 1,390 flights. Only 78 (5.6%) flights have incurred runway crossing delay while crossing the active runway to reach their respective assigned departure queue. The mean delay incurred is 1.1 minutes and the maximum delay experienced equals 2.0 minutes

Table 83 Runway crossing delay North Flow departures-2010 without PT

DFW RUNWAY CROSSING DELAY							
2010 OPERATIONS							
TOTAL DEPARTURES 2010 = 1390							
			RUNWAY CROSSING TIME IN MINUTES				
RUNWAY CROSSING DESCRIPTION	FROM TERMINAL	DEPARTURE RUNWAY	AVERAGE	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF FLIGHTS
RUNWAY CROSSING BY DEPARTING AIRCRAFT							
NORTH FLOW							
RUNWAY 36R/36L	A	31L	2.1	0.0	2.1	2.1	1
RUNWAY 36R/36L	B	31L	0.9	0.8	2.3	0.2	6
RUNWAY 36R/36L	C	31L	2.0	1.6	3.1	0.9	2
RUNWAY 36R/36L	D	31L	1.9	0.0	1.9	1.9	1
RUNWAY 36R/36L	E	31L	1.7	1.2	5.0	0.1	19
RUNWAY 36R/36L	GA	31L	1.5	1.2	4.4	0.1	31
RUNWAY 35L	B	35C	0.8	0.0	0.8	0.8	1
RUNWAY 35L	E	35C	0.3	0.0	0.3	0.3	1
RUNWAY 35L	GA	35C	0.3	0.0	0.3	0.2	2
RUNWAY 31R	EAST CARGO	35C	2.8	3.0	4.9	0.7	2
RUNWAY 35C	EAST CARGO	35L	2.4	1.6	3.4	0.6	3
RUNWAY 36R/36L	WEST CARGO	35L	0.2	0.0	0.2	0.2	1
RUNWAY 36R	A	36R	0.0	0.0	0.0	0.0	0
RUNWAY 36R	B	36L	0.6	0.0	0.6	0.6	1
RUNWAY 36R	C	36R	0.0	0.0	0.0	0.0	0
RUNWAY 36R	D	36R	0.0	0.0	0.0	0.0	0
RUNWAY 36R	E	36R	0.0	0.0	0.0	0.0	0
RUNWAY 35C/35L	EAST CARGO	36R	2.0	2.4	5.6	0.3	4
RUNWAY 36R	WEST CARGO	36R	1.2	1.5	2.9	0.1	3
ALL RUNWAYS	ALL	ALL	1.1	0.7	2.0	0.5	78
PERCENTAGE OF DEPARTURES THAT EXPERIENCED RUNWAY CROSSING DELAY =							5.6%

Table 84 shows the total runway crossing delay experienced for various applications. With PT, the delay has been reduced to zero minutes. These delays shown with PT operation for the South Flow are due to aircraft waiting to cross the departure runway 13L when a departing aircraft is taxiing on taxiway N, P, and R to take off. Similarly during the North Flow aircraft experiences delay on taxiway N due to arrivals on 31R when they exit from the East Airfield cargo apron for departures from the NE quadrant of airport to use runway 35C by taxiing on taxiway P.

Table 84 Runway crossing total delay in minutes for each simulation

DFW RUNWAY CROSSING TOTAL DELAY IN MINUTES					
		SOUTH FLOW		NORTH FLOW	
SIMULATION DATE	OPERATIONS/ DAY	WITHOUT PT	WITH PT	WITHOUT PT	WITH PT
6-Mar-04	1647	159.70	0.00	120.05	0.11
25-Jun-04	2284	351.47	0.18	283.81	6.76
22-Jul-04	2477	392.41	0.18	388.52	7.57
YEAR 2010	2808	530.15	1.15	744.86	8.74

A summary of the research analysis is shown in Table 85, for the 2004 data and 2010 data. The table shows the South Flow performance with and without PT, as well as North Flow performance with and without PT. The Measures Of Effectiveness (MOE) is compared for annual service volume (ASV), capacity of airport per hour, arrival per hour, departure per hour, runway crossing delay, Taxi In time for arrivals and Taxi Out time for departures.

8.6 Evaluation of the Measures of Effectiveness (MOE)

The annual service volume (ASV) is defined as a reasonable estimate of an airport's annual capacity (FAA Advisory Circular 150/5060-5-*Airport* C*apacity and Delay*). As the number of annual operations increases and approaches ASV, the average delay incurred by each operation increases [28]. When annual aircraft operations are equal to the ASV, the average delay per aircraft operations can be up to four minutes depending upon the mix of aircraft using the airport. When the number of annual operations exceeds the ASV, moderate to severe congestion will occur.

The hourly and daily airport capacity and ASV depends on the following as a minimum:

- Weather and visibility
- Aircraft mix
- Runway use
- Touch and go operation
- Percent arrivals
- Exit Taxiway locations

$ASV = C_w \times D \times H$

Where

C_w = Weighted hourly capacity of the runway components

D = Ratio of annual demand to average daily demand during the peak month

H = Ratio of average daily demand to average peak hour demand

$C_w = P \times C \times W$

Where

P = percent of time each runway-use configuration in use

C = Hourly capacity for each runway-use configuration

W= ASV weighting factor

The method of computing the weighting factors can be found in the FAA Advisory Circular 150/5060-5, *Airport Capacity and Delay.*

The computation of ASV using the above method for DFW is not within the scope of this research, therefore no attempt is made to derive a value for DFW. The analysis is performed using the facility reported ATC hourly rate for Cap AAR and ADR for DFW instead of the ASV method.

Table 85 presents the measures of effectiveness for various parameters considered in the simulation for the base line 2004 and future operations in 2010

The actual ASV for 2004 is 816,910 operations per year and for 2010 it is forecast at 1,004,191 operations per year as shown in Table 12 (Section 2.3). The maximum of 2,477 operations per day is considered in the simulation for 2004 and the mean daily traffic volume of 2,808 operations per day is forecast for 2010. Both cases are analyzed for operations *with* and *without* PT.

Maximum airport hourly capacity in 2004 and 2010 without PT

CAPACITY/HR	2004	2010
SOUTH FLOW	162	186
NORTH FLOW	167	179

Maximum airport hourly capacity in 2004 and 2010 with PT

CAPACITY/HR	2004	2010
SOUTH FLOW	169	182
NORTH FLOW	161	177

The reason for the reduction in North Flow capacity per hour is due to the longer distance aircraft have to travel from the terminal buildings to line-up in the departure queue of runway 35L and 36R for takeoff.

The arrival runways during the South Flow (13R, 17C, 17C and 17L) and North Flow (36L, 35C, 35R, and 31R) configuration experienced a maximum arrival rate per hour for 2004 and 2010 as shown below without PT.

ARRIVAL/HOUR	2004	2010
SOUTH FLOW	115	122
NORTH FLOW	139	147

Table 85 Summary of Research Analysis and results

SUMMARY OF RESEARCH ANALYSIS AND RESULTS									
		SCENARIOS							
MEASURES OF EFFECTIVENESS		2004		2010		2004		2010	
DESCRIPTIONS OF MEASURES	UNITS	1	2	3	4	5	6	7	8
		BASELINE		FORECAST		BASELINE		FORECAST	
		WITHOUT PT				WITH PT			
		SOUTH FLOW	NORTH FLOW	SOUTH FLOW	NORTH FLOW	SOUTH FLOW	NORTH FLOW	SOUTH FLOW	NORTH FLOW
ASV	OPERATIONS/YR	816,910	816,910	1,004,191	1,004,191	816,910	816,910	1,004,191	1,004,191
DAILY TRAFFIC VOLUME	OPERATIONS/DAY	2477	2477	2808	2808	2477	2477	2808	2808
CAPACITY OF AIRPORT-MAXIMUM	AIRCRAFT/HR	162	167	186	179	169	161	182	177
ARRIVAL									
RUNWAY 13R/31L	AIRCRAFT/HR	23		23		23		23	
RUNWAY 18R/36L	AIRCRAFT/HR	28	29	31	32	32	24	31	31
RUNWAY 18L/36R	AIRCRAFT/HR	1	1	1	1	1	2	1	2
RUNWAY 17R/35L	AIRCRAFT/HR	2	0	2	0	4	1	4	1
RUNWAY 17C/35C	AIRCRAFT/HR	31	45	35	46	32	24	35	30
RUNWAY 17L/35R	AIRCRAFT/HR	30	32	30	31	32	22	30	29
RUNWAY 13L/31R	AIRCRAFT/HR		32		37		16		22
TOTAL	AIRCRAFT/HR	115	139	122	147	124	89	124	115
DEPARTURE									
RUNWAY 13R/31L	AIRCRAFT/HR		5		7		8		10
RUNWAY 18R/36L	AIRCRAFT/HR	3	6	6	5	9	5	7	7
RUNWAY 18L/36R	AIRCRAFT/HR	40	38	44	41	41	40	40	43
RUNWAY 17R/35L	AIRCRAFT/HR	43	45	57	47	41	46	45	45
RUNWAY 17C/35C	AIRCRAFT/HR	3	5	3	7	4	3	5	6
RUNWAY 17L/35R	AIRCRAFT/HR	0	0	0	0	0	0	0	0
RUNWAY 13L/31R	AIRCRAFT/HR	8		6		6		8	
TOTAL	AIRCRAFT/HR	97	99	116	107	101	102	105	111
RUNWAY CROSSING DELAY- ARRIVALS									
Maximum	MINUTES/AIRCRAFT	2.10	16.32	5.41	42.83				
Minimum	MINUTES/AIRCRAFT	0.02	0.04	0.03	0.01				
Mean	MINUTES/AIRCRAFT	0.68	0.84	0.74	1.28				
RUNWAY CROSSING DELAY- DEPARTURES									
Maximum	MINUTES/AIRCRAFT	1.50	4.01	9.81	5.57				
Minimum	MINUTES/AIRCRAFT	0.04	0.06	0.01	0.06				
Mean	MINUTES/AIRCRAFT	0.53	0.71	0.85	1.57				
TAXI IN TIME									
Mean	MINUTES/AIRCRAFT	11.26	10.66	11.42	10.36	16.93	17.35	18.52	16.99
TAXI OUT TIME									
Mean	MINUTES/AIRCRAFT	11.08	9.74	10.62	9.32	9.65	9.10	9.66	9.80

The runway capacity per hour for arrival runways during the South Flow (13R, 18R, 17C and 17L) and North Flow (36L, 35C, 35R, and 31R) configuration. Total maximum arrival rate per hour for 2004 and 2010 is shown below with PT

ARRIVAL/HOUR	2004	2010
SOUTH FLOW	124	124
NORTH FLOW	89	115

In 2004 for the North Flow configuration, the arrival rate was 23 flights per hour for five hours on runway 35C in the simulation. Hence, the hourly maximum arrival rate is reduced to 89 per hour.

The runway capacity per hour for departure runways during the South Flow (18L, 17R, and 13L) and North Flow (36R, 35L, and 31L) configuration is shown below. The total maximum departure rate per hour for 2004 and 2010 is shown below without PT.

DEPARTURE/HOUR	2004	2010
SOUTH FLOW	97	116
NORTH FLOW	99	107

The runway capacity per hour for departure runways during the South Flow (18L, 17R, and 13L) and North Flow (36R, 35L, and 31L) configuration is shown below. The total maximum departure rate per hour for 2004 and 2010 is shown below with PT.

DEPARTURE/HOUR	2004	2010
SOUTH FLOW	101	105
NORTH FLOW	102	111

Taxi In time shows that the mean travel time has increased when the PT is introduced for arriving aircraft. This is due to the longer distance the arriving aircraft had to travel to the terminal gates by taxiing on the PT.

Taxi In time comparison between 2004 and 2010 without PT

ARRIVAL	2004	2010
SOUTH FLOW	11.26	11.42
NORTH FLOW	10.66	10.36

Taxi In time comparison between 2004 and 2010 with PT

ARRIVAL	2004	2010
SOUTH FLOW	16.93	18.52
NORTH FLOW	17.35	16.99

Taxi Out time comparison between 2004 and 2010 without PT

DEPARTURES	2004	2010
SOUTH FLOW	11.08	10.62
NORTH FLOW	9.74	9.32

Taxi Out time comparison between 2004 and 2010 with PT

DEPARTURES	2004	2010
SOUTH FLOW	9.65	9.66
NORTH FLOW	9.10	9.80

The Taxi Out time had a slight increase in 2010 PT operations between South Flow and North Flow due to increased wait time for departure aircraft from west side cargo aprons on Taxiway C to permit departing aircraft traveling to the departure queue on runway 31L during North Flow configuration. This wait time is likely to increase in the future when more cargo flights start serving DFW.

This chapter dealt in detail various aspects of DFW operations. Specifically, the simulation results were analyzed for delay experienced by the arrival aircraft without and with PT. Delay is a critical factor in operations, which impacts airlines, passengers, and operations personnel at the airport. Delay experienced by aircraft while idling causes fuel consumption and pollution of the area surrounding the airport [32].

CHAPTER 9

CRITICAL EVALUATION OF AIRFIELD GEOMETRY

In this chapter, a detailed evaluation of the DFW runway and taxiway geometry are performed to identify problems areas that may require further study or analysis to develop operating procedures and guidelines. The principal rationale in introducing the PT is to reduce runway incursions, improve safety, and significantly reduce delay to airlines and passengers. When completed, the PT as planned, designed, and constructed, is expected to improve operating efficiency and increase arrival and departure capacity at DFW. The analysis is performed for the four quadrants of the airport after the PT is in place and in operation to determine how the planned operations will improve runway efficiency and improve overall safety at DFW. The planned standard taxipath from arrival runway to terminals and cargo aprons are compared with animation of operations created from the VS simulation of DFW. Similarly, the departure on the standard taxi path from the terminals and cargo aprons are compared to determine how the taxiing to departure queue on the departure runway will impact operations.

9.1 Introduction

This research focuses on the viability of constructing PTs on all four quadrants of the airfield to underscore the benefits of a PT operation in the future. The FAA has approved the design and construction of the SE quadrant PT in September 2006. The full AOSC decision document can be found in Appendix D, which clearly expounds the reasons and restrictions on the use of PT on the SE quadrant. Final designs and construction drawings are developed identical to the layout used in this research. The PT centerline is kept at 2,650 ft from the end of the two north-south parallel runways, 17C and 17R. The contract has been awarded on 10 October 2006 at a cost of $66.7 million (FAA funding 75%) with completion expected in the fall of 2008 [5]. The SE quadrant PT has been approved by the FAA for departure only from runway 17R during peak period operations. Mr. Jim Crites, Executive VP of Operations at DFW stated, "This is a win-win-win situation. By installing a perimeter taxiway system, we will be providing a better and safer operating environment for both pilots and air traffic controllers who devote themselves to providing a safe and efficient operating environment. The system will also provide the traveling public with greater efficiency and a small amount of delay on the ground, getting them off the gate or to their gates faster than ever before" [5, 22]. The FAA/ATC staff at DFW, reveal that each arriving flight will be monitored with regard to their assigned runways, and terminals and evaluate the situation for efficient operation at that time to permit active departure runway crossing or to direct them to taxi on the PT to the terminals or vice versa to access the departure runways from the gates. No doubt this will likely increase the runway incursion potential when the operating guidelines are modified during flight operations to go from PT to non PT operations. Therefore these operational changes require due diligence and constant communication to avoid conflict and runway incursion at DFW.

9.2 Runway geometry

Currently, there are seven runways in use at DFW. Plans are under discussion for the construction of an eighth runway between 18R and 13R intersecting 13R as shown in Figure 72. The addition of a new runway is still in the planning study stage by the FAA. This research evaluates the use of existing runways in 2010 when the annual operations are expected to reach about 1 million. In 2006, the FAA has revised their forecast downward to 827,076 operations (Table 10) in 2010 and expects 1,127,139 operations by year 2025. This research demonstrates that the existing runways are capable of handling expected operations in 2010 as shown in Tables 68 to 75 (Section 8.4).

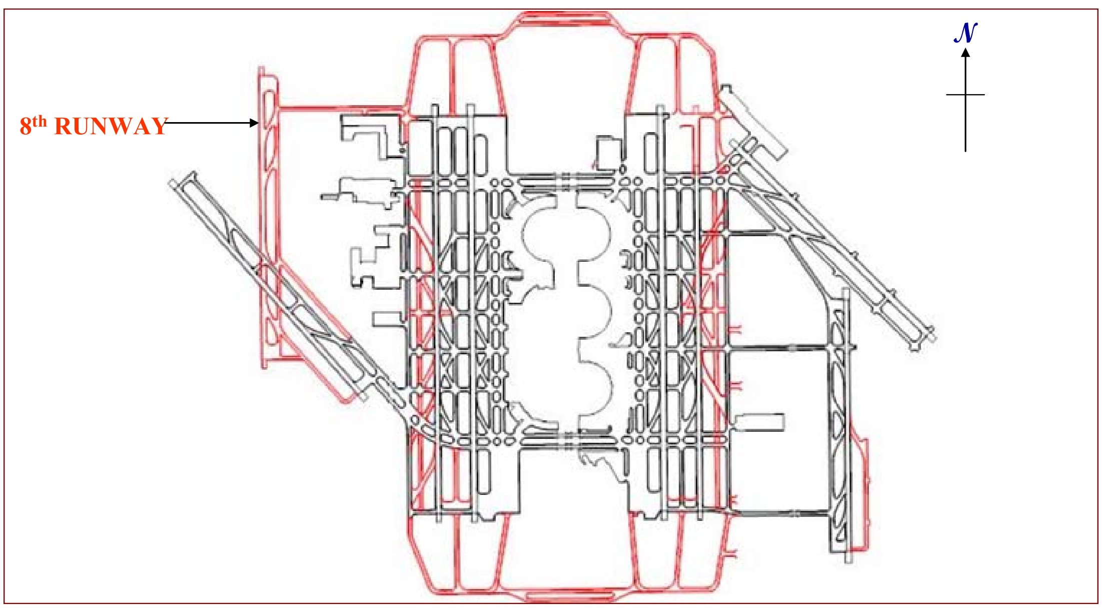

Figure 72 DFW layout showing the proposed eighth runway

DFW is not expected to reach one million plus operations for fifteen years based on the FAA's 2006 forecast [34]. There is a good possibility that the air cargo traffic may increase over the forecast years, which will depend on additional cargo apron and facilities being built at the airport. At present, there are many gates not in use at Terminals D and E [22]. Therefore, the airport will be able to handle additional passenger flights without substantial investment on new terminal buildings in the near future. The LAHSO is completely eliminated with the introduction of PT, as aircraft arriving on the arrival runways taxi on the PT without waiting.

Table 86 shows the comparison of DFW operational efficiency between the VS simulation and FAA/APO/ASPM established efficiency for the dates, 7-22-04 (2,477 operations), 6-25-04 (2,284 operations) and 3-6-04 (1,647 operations).

Table 86 DFW efficiency comparison between simulation and the FAA/APO/ASPM

DFW OVERALL AIRPORT EFFICIENCY

Scenario	Wind conditions	PT status	Operations per day	VS computed Efficiency	FAA/APO/ ASPM Efficiency
1	South flow	Without PT	2477	43.2	42.3
2	North flow	Without PT	2477	38.6	-
3	South flow	With PT	2477	44.6	-
4	North flow	With PT	2477	37.4	-
5	South flow	Without PT	2808	44.2	-
6	North flow	Without PT	2808	43.4	-
7	South flow	With PT	2808	50.8	-
8	North flow	With PT	2808	44.1	-
9	South flow	Without PT	2284	47.3	43.8
10	North flow	Without PT	2284	35.7	-
11	South flow	With PT	2284	45.1	-
12	North flow	With PT	2284	47.2	-
13	South flow	Without PT	1647	31.6	31.0
14	North flow	Without PT	1647	25.7	-
15	South flow	With PT	1647	25.7	-
16	North flow	With PT	1647	25.9	-

For the 2,477 operations per day on 7-22-04, VS had an efficiency of 43.2% and FAA/APO/ASPM had an efficiency of 42.3%. On 7-22-04, the airport was operating in a South Flow configuration throughout the day as the prevailing wind was from the South

For the 2,284 operations on 6-25-04 VS had an efficiency of 47.3% and FAA/APO/ASPM had 43.8%. On that day the airport was operating from midnight to 13:00 hrs in a South Flow configuration and the operating direction was changed to North Flow from 14:00 hrs until 23:00 hrs after the wind direction changed. In the VS simulation the airport only operated in a South Flow configuration throughout the day.

In the application with 1,647 operations per day, VS had an efficiency of 31.6% and FAA/APO/ASPM had an efficiency of 31%. On 3-6-04, the airport was operating from midnight until 12:00 hrs in a North Flow configuration and from 13:00 hrs to 23:00 hrs in a South Flow configuration when the wind direction changed. In VS, the operations were South Flow throughout the day.

In the three applications mentioned above, the airport was operating *without* PT in the South Flow configuration for comparison purposes. The criteria used in the simulation may vary to some extent from real life operations at DFW. For example, the mean Taxi Out time, obtained from VS was 11.1 minutes and the FAA/APO/ASPM report had a mean Taxi Out time of 19.3 minutes. The Taxi Out time was greater in real operations due to frequent communication with the tower, while in the VS simulation the aircraft Taxi Out time is only due to travel on the standard taxiway route to departure queue on the departure runway without any communication delays. Similarly the mean Taxi In time obtained from VS was 11.3 minutes versus 14.1 minutes from the FAA/APO/ASPM report for 7-22-04.

Table 87 shows the performance measures for DFW across all sixteen scenarios used to estimate the airport efficiency based on the FAA/ATC specified Cap AAR and ADR for DFW for different dates. The table shows in scenario 3, 9, 12 and 13 that the arrivals increased by 4.2%, 4.3%, 4.9% and 5.9%, respectively. On the departure side, all scenarios had an increase in the number of departures and the increase ranged from 0.1% to 8.3%. Overall airport efficiency was less than fifty percent as shown in Table 68 to 75 (Section 8.4) in all applications except in the South Flow configuration (Table 72) of DFW in 2010 where it was at 50.9% with PT. Therefore, there is sufficient room for growth to handle more flights than the forecast 2,808 operations per day in year 2010.

Table 87 DFW overall airport performance

DFW OVERALL AIRPORT PERFORMANCE											
				Scheduled		Computed		Difference		% change	
Scenario	Wind conditions	PT status	Operations per day	Arrivals	Departures	Arrivals	Departures	Arrivals	Departures	Arrivals	Departures
1	South flow	Without PT	2477	1251	1226	1251	1260	0	34	0.0%	2.8%
2	North flow	Without PT	2477	1251	1226	1251	1251	0	25	0.0%	2.0%
3	South flow	With PT	2477	1251	1226	1304	1290	53	64	4.2%	5.2%
4	North flow	With PT	2477	1251	1226	1251	1269	0	43	0.0%	3.5%
5	South flow	Without PT	2808	1418	1390	1418	1444	0	54	0.0%	3.9%
6	North flow	Without PT	2808	1418	1390	1418	1392	0	2	0.0%	0.1%
7	South flow	With PT	2808	1418	1390	1418	1417	0	27	0.0%	1.9%
8	North flow	With PT	2808	1418	1390	1418	1438	0	48	0.0%	3.5%
9	South flow	Without PT	2284	1122	1162	1177	1254	55	92	4.9%	7.9%
10	North flow	Without PT	2284	1122	1162	1122	1190	0	28	0.0%	2.4%
11	South flow	With PT	2284	1122	1162	1122	1191	0	29	0.0%	2.5%
12	North flow	With PT	2284	1122	1162	1177	1254	55	92	4.9%	7.9%
13	South flow	Without PT	1647	818	829	866	898	48	69	5.9%	8.3%
14	North flow	Without PT	1647	818	829	818	848	0	19	0.0%	2.3%
15	South flow	With PT	1647	818	829	818	850	0	21	0.0%	2.5%
16	North flow	With PT	1647	818	829	818	862	0	33	0.0%	4.0%

9.3 Taxiway geometry

The taxiway geometry and the links to the proposed PT require a critical evaluation from the Ground Controller's and Local Controller's point of view. Evaluation of the flow and movement of aircraft on the PT configuration for the South Flow and North Flow is performed separately to identify the areas that require further study to eliminate runway incursions and to facilitate collision avoidance. Pilots should have situational awareness and use extreme caution and keep sufficient distance between aircraft while traveling on the PT. The simulation uses the minimum separation between aircraft built-in the VS program based on the FAA criteria and the speed of travel is set at 15 mph on the taxiway. The simulation and the animation show that during the South Flow operations, large numbers of aircraft are using the SE quadrant of the PT following closely one behind the other to reach their respective assigned gates on the east and west terminals. A similar situation arises on the NE quadrant PT during the North Flow operations that require careful evaluation and the development of standard taxiway operational guidelines, procedures, and control. In the VS simulation the departure aircraft is not allowed to takeoff from the intersection of taxiway and runway, because no departure queue was provided at this location. At DFW, the ATC may occasionally permit an aircraft to takeoff during North Flow operation from the intersection of Taxiway A and runway 36R or 35L at the request of a pilot, but as a general rule the ATC does not encourage intersection takeoff at DFW, because of the complex nature of operations.

9.3.1 NE quadrant analysis

Figure 73 shows the movement of aircraft traveling to terminal A, C, E and general aviation area after landing on runways 35C, 35R and 31R during North Flow operations at DFW. The figure also shows a B767-300 departing from runway 35L overflying a B737-300 on the PT.

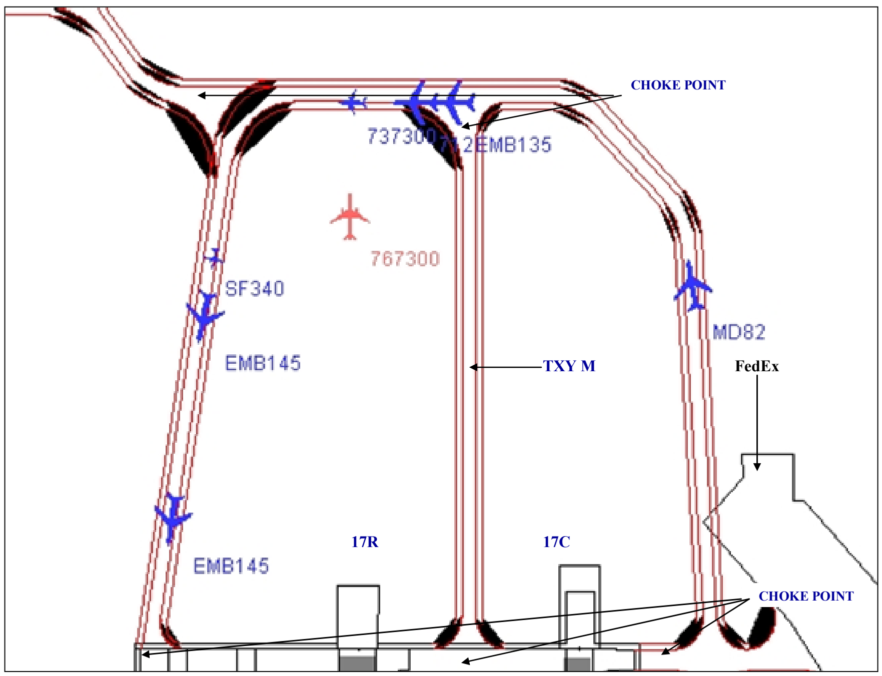

Figure 73 NE quadrant PT

This section of PT feeds five terminals and a large number of aircraft are moving on the PT during peak periods. There are aircraft exiting from the FedEx and east cargo area that take taxiway P, travel south to join the departure queue on the east side of 35C for take off to the north. The intersection of taxiways P, Q, R and N is a choke point where both arriving and departing aircraft meet during North Flow operations. Therefore, a detailed evaluation of this choke point needs to be done to properly regulate the movement of aircraft and develop detailed standard taxiway procedures and guidelines for pilots in addition to posting information on the navigational charts.

9.3.2 SE quadrant analysis

Figure 74 shows the operation of the SE quadrant PT during South Flow configuration. Aircraft arriving on 17L and 17C use taxiway P to taxi on the PT to reach terminal buildings on the east and west side. This is the busiest section of the PT that receives aircraft from runways 17C and 17L during South Flow operations

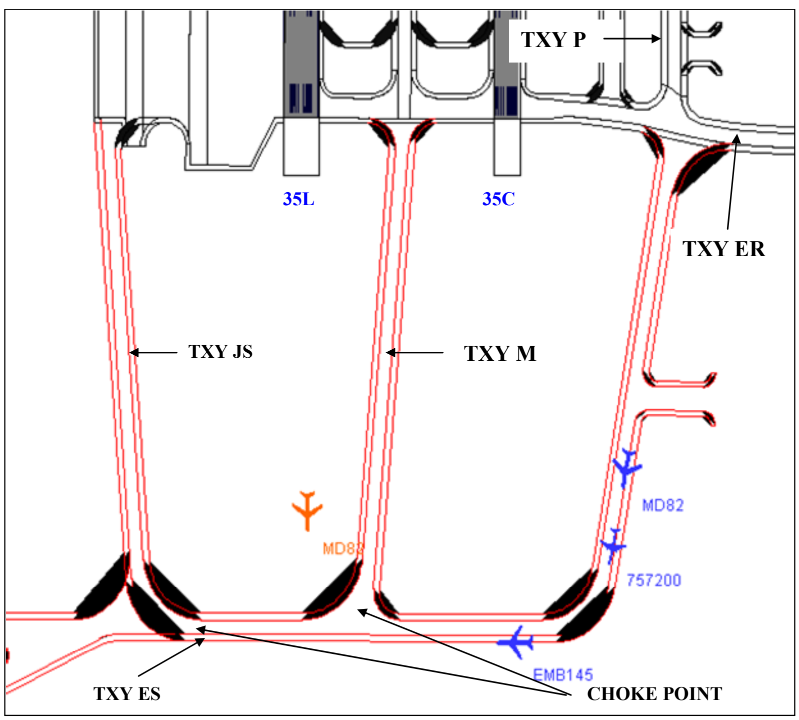

Figure 74 SE quadrant PT showing aircraft

The aircraft traveling south from Taxiway P will reach the choke point at the intersection of PT and Taxiway M. The Ground Controller will direct traffic at this choke point based on the standard taxiway procedures and guidelines Each aircraft will be given clearance to cross the choke point and allowed to taxi to the next hold point and wait for instruction from Ground Controllers to proceed further.

9.3.3 SW quadrant analysis

During the South Flow operations, the aircraft landing on 13R and 18R take the high speed exit and travel on the PT to reach terminals B and D on the west side. Aircraft traveling to terminals A, C and E use the Taxiway A bridge on the south side and turn left on Taxiway K to head north. This is shown in Figure 75.

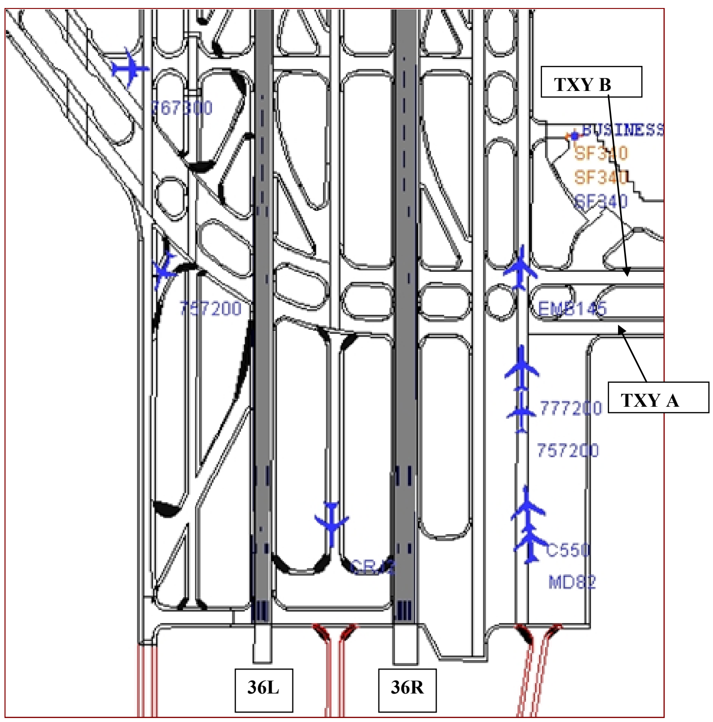

Figure 75 South Flow PT operations

During the North Flow operations, the aircraft departing from the UPS apron, and West air cargo aprons travel south on Taxiway C to join the departure queue for runway 36L from the west In the Figure 76, a B747-400 is heading south to runway 36L, aircraft, SF340, is entering the departure queue on runway 31L, another aircraft

SF340 is traveling north on taxiway C to runway 31L. This portion of Taxiway C is designated in VS as a Dynamic Single Direction (DSD) path allowing one aircraft only in the link from PT entrance to Taxiway WM.

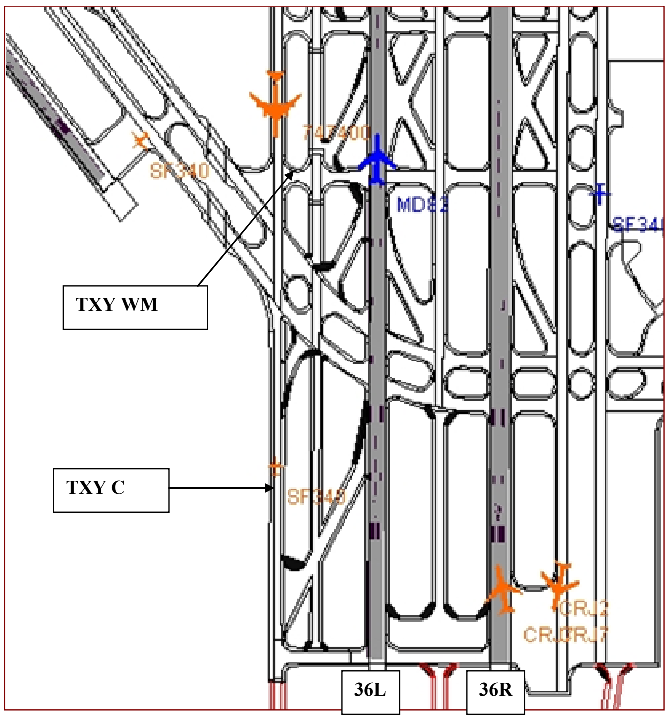

Figure 76 SW PT North Flow operations

9.3.4 West side Taxiway C analysis

In Figure 77, aircraft B777-200 landed on 36L, and existed on the high speed exit, but it had to come to a complete stop to allow the arriving B737-200 aircraft heading to the west cargo apron area pass the intersection.

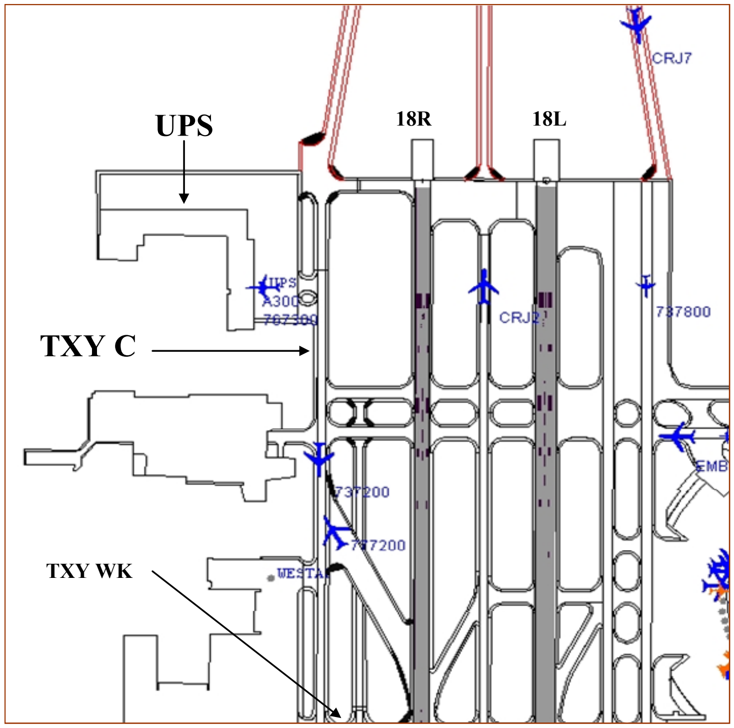

Figure 77 West side Taxiway C showing two arriving aircraft on North Flow

In the VS simulation, this section of Taxiway C has been designated as a DSD that permits only one aircraft on the specified link on Taxiway C from the UPS apron to Taxiway WK. There are departing flights from UPS that travel to the west side departure queue on Runway 36L for takeoff during North Flow operations. This part of Taxiway C requires a detailed evaluation and standard taxiway procedures and guidelines developed to control the movement of aircraft on this section of Taxiway C.

9.3.5 East side Taxiway P analysis

Figure 78, shows a B777-300 is exiting on the high speed exit from runway 17C to taxiway P traveling to terminal A. The requirement with the introduction of a PT is that heavy aircraft should take the high speed exit before the hangar on the east side on taxiway P and continue on taxiway P south to travel on the PT to terminal gates.

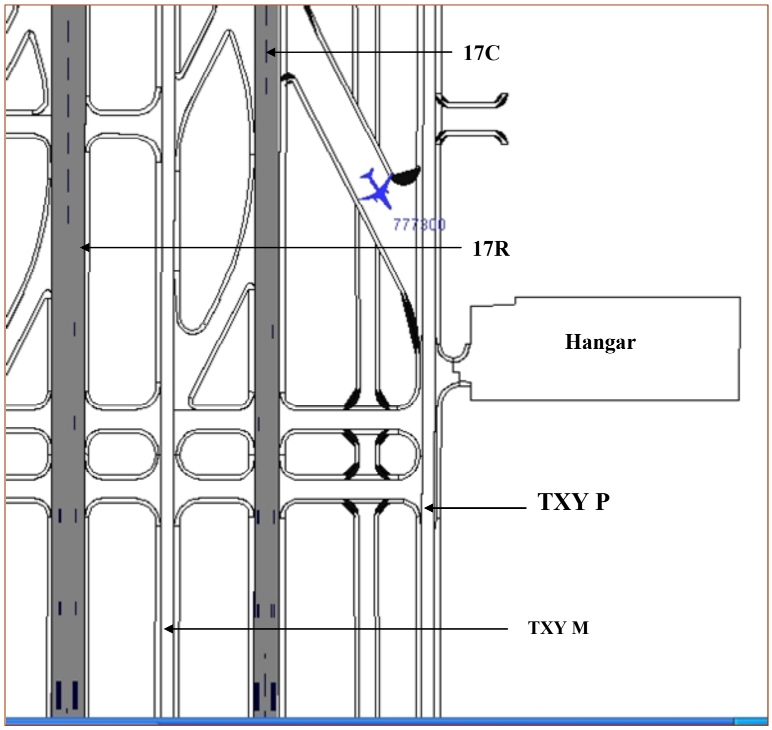

Figure 78 DFW east side Taxiway P

This portion of the taxiway requires the development of detailed procedures and guidelines for arriving pilots to watch for aircraft exiting from the hangar on the east side. If the cargo aircraft is heavy (Group V) arriving on 17C, it has to take the high speed exit to taxiway P, then head north to east cargo apron, or if the aircraft is large, it has to take the high speed exit to taxiway M to travel south on the SE PTs . The heavy aircraft will make a left turn from the high speed exit, and go north on Taxiway P to the cargo apron on the NE end freight area. The large aircraft will use the PT to taxi on Taxiway P to head north to the cargo apron on the NE quadrant of DFW. Therefore, it is suggested that all cargo aircraft should be directed to land on 17L and after exiting from the runway they will travel north on taxiway Q to reach the east freight and FedEx aprons, thus avoiding conflict on taxiway P with the arriving heavy aircraft destined to terminal buildings on the west side of runway 17C.

9.3.6 South Flow arrivals

During South Flow operations, the NE quadrant PT and the NW quadrant PT do not carry any aircraft taxiing to the terminals. The only aircraft taxiing in the NE quadrant of the PT are turboprops heading to runway 13L for takeoff as shown in Figure 79, where an MD82 is overflying a SF340 on the PT taxiing to runway 13L. During South Flow configuration, there were 408 aircraft arriving on runway 17C and 74 aircraft assigned to departure runway 13L for departure. There are no aircraft on the NW quadrant PT traveling to any terminals or cargo aprons. This is true for the SW quadrant PT and SE quadrant PT during the North Flow operations.

Therefore, the arrival aircraft flying over the PT do not encounter any aircraft rather than the departure situation where the departing aircraft has to overfly all types of aircraft traveling on the PT towards terminals.

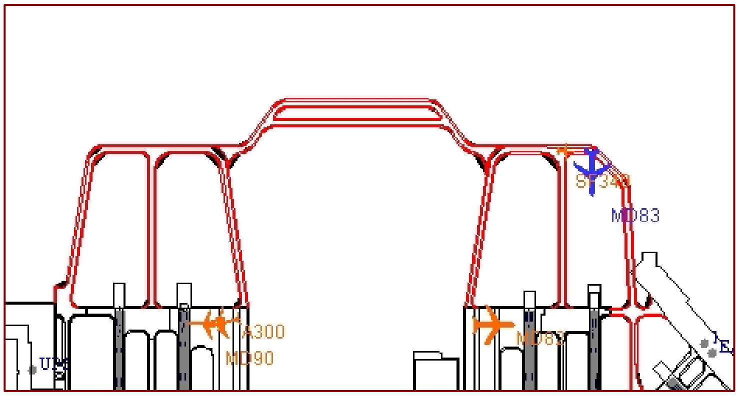

Figure 79 South Flow arrivals over North PT

9.3.7 North Flow arrivals

North Flow arrivals are shown in Figure 80 where one MD 82 is overflying the SW quadrant PT, and another MD 82 is overflying the SE quadrant PT. There were 457 aircraft arriving on runway 36L and 72 aircraft assigned to runway 31L for departure..

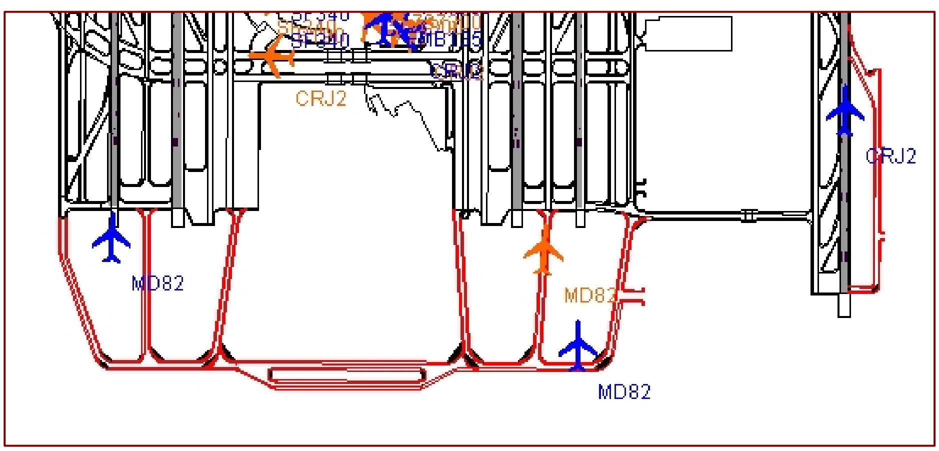

Figure 80 North Flow arrivals over South PT

The FAA had simulated the operation of the arrival flights over the PT with video of several aircrafts taxiing on the PT and an aircraft overflying them. Four views of the video film clips can be found in Appendix E. This research found that the arriving flights do not encounter as many aircraft as perceived by the FAA and shown in the video clips in Appendix E.

9.4 Discussion of AOSC decision on PTs

A copy of the FAA/AOSC decision on PT design and construction is available in Appendix D. The AOSC team restricted the height of aircraft on the PT to be at 65 ft at a distance of 2,650 ft. (40:1 slope) for all weather departure of Group V aircraft during South Flow on Runway 17R. Any aircraft with a tail height greater than 65 ft is not allowed to use the PT without specific instruction from the ATC. In the VS simulation all types of aircraft were allowed to use the PT in all four quadrants. An analysis of the flight tracks over 17R/35L and 18L/36R showed that the departing aircraft reaches high altitude by the time they cross the PT centerline at a distance of 2,650 ft on the North and South side of DFW as shown in Figure 60 (Section 7.13).

9.5 Runway elevation and barrier design

The FAA has decided to erect a visual barrier at 1,100 ft. from the end of the runway for 13 ft high, for a distance of 350 ft on either side of runway 17R to shield the aircraft on the SE quadrant PT from the departure aircraft pilot's view during South Flow. Any aircraft within the Runway Protection Zone (RPZ) is considered an obstacle to the departure path. The runway elevation for 18L on the north end is 601.7 ft and on the south end it is 575.3 feet a difference of 26.4 feet. On runway 17R, the north end elevation is 566.5 ft and south end is 563.3 feet, a difference of 3.2 feet. The PT centerline elevation along the centerline of 17R is 555 feet, a difference in elevation of 11.5 feet from the end of runway as shown in Figure 59. The height is reversed for North Flow on 35L (26.4 ft) ft and 36R (3.2 ft), respectively. The design of the visual barrier and its ability to shield the aircraft taxiing on the PT at a distance of 16,050 (3.04 miles) from the departure end of runway 17R require further evaluation to determine its usefulness and its ability to shield the aircraft from the departing aircraft pilot's view. The elevation difference is another factor where the aircraft is already taxiing 11.5 ft below the north end of runway 17R elevation.

9.6 PT night time operations

The PT systems should be designed to operate in all weather conditions and during night time in an efficient and effective manner. Proper lighting and signing of high speed exits, taxiway markings of PT directions and the flow controlled areas where aircraft may meet in opposing directions is required. The PT layout and restrictions on the use of taxiways leading to the PT, and choke points should be indicated in the Navigational charts and clearly marked on the pavement. As suggested in the AOSC decision document # 6 (Appendix D), pilots should be briefed and given adequate training in the PT operations and runway safety at DFW.

This chapter reviewed in detail the operation of DFW when the PT is completed for all four quadrants. The operation will be smooth and efficient if operational guidelines and standard taxiway procedures are established to have conflict free movements. Further study is needed to determine the impact of proposed cargo aprons adjacent to the west side Taxiway C and east side Taxiway P for efficient and safe movement of air traffic on these taxi ways.

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

This research project concentrated on the merits of building a PT which will ultimately reduce or eliminate the runway crossing delay by an arrival aircraft at DFW. Historical flight data was input into VS to replicate the real time operations at DFW. This facilitated validation of the results using the FAA collected real time data. At that time , there was no PT at DFW. A baseline date July 22, 2004 was selected for VS simulation. The future traffic operations data in 2010 was estimated to increase at 3.5% per year from 2004 to reach a mean of 2,808 operations per day. This research analyzed the Flight track data obtained from EAD with a view to evaluate and critically estimate the height of an arriving and departing aircraft over the PT at DFW. The statistical analysis of the flight data established that the probability of an aircraft flying below the threshold limit set by the FAA of 65 ft for departure or 72 ft for arrival is very close to zero and is shown in the Table 88

Table 88 Probability of flying below the threshold specified by the FAA

.

	DEPARTURE ON RUNWAY			
	17R	**18L**	**35L**	**36R**
P(X<65)	**1.8E-05**	**2.2E-05**	**2.2E-05**	**1.5E-06**
	ARRIVAL ON RUNWAY			
	17C	**18R**	**35C**	**36L**
P(X<72)	**1.1E-06**	**4.0E-06**	**1.5E-05**	**1.4E-07**

Therefore, the PT can be used safely for both arrival and departure operations at DFW.

In addition, a detailed study of the runway and taxiway geometry was undertaken to reduce runway incursion possibilities, improvements to runway safety, increase in departure rates, reduce or eliminate runway crossing delays, elimination of LAHSO and improve overall operational performance at DFW. The results from this research concluded that there was a real need to develop detailed procedures and standard taxiway operation guidelines for safe movement of aircraft over the PT at DFW. The research showed that the airport was operating around 50% of its theoretical capacity set by the FAA/ATC facility for DFW in 2010, thus indicating future traffic could safely be handled at DFW, requiring an efficient use of exiting runways, taxiways, and PTs. The need for the construction of the eighth runway was evaluated and concluded that money saved by not building the eighth runway can be wisely spent on the PT for incident free operation. At present, the gates in the five terminals were not utilized to the full extent and there was room to handle additional flights without building another terminal in the foreseeable future.

The scope of this research did not consider estimating the fuel savings or cost savings to airlines and passengers as a result of reducing the runway crossing delay or the increased taxiing time over the PT that may result in additional fuel consumption and/or delay to passengers. This will be a topic for future research.

The cost of building the PT on all four quadrants should be approximately $268 million in 2006 constant dollars. Additional cost may have to be incurred for field surveys, soil investigation, preliminary design for review and approval, the design and construction of four bridges to connect the PT on the north and south side of the airport over the International Parkway. The FAA has approved the construction of the SE quadrant PT at $67 million in 2006. Therefore, assuming another $32 million for the design, engineering and preparation of contract documents for the PT on all four quadrants, the total project should cost nearly $300 million in 2006 constant dollars. The PT on the three remaining quadrants should be designed taking into account the expected movement and safety of operations due to aircraft arriving to and departing from the proposed additional cargo facilities' aprons on the east and west airfield at DFW.

10.1 Runway incursions

Runway incursions, one of the fundamental concerns in airports has been discussed in detail by the FAA, ICAO, EURO Control, NTSB and other organizations, such as the Airline Pilots Association. The purpose of this discussion is to identify the causes and eliminate it fully in airport operations. Runway incursions or mistaken use of system facilities, occur due to miscommunication, inability to recognize vital airport markings at an, attention deficit due to work overload, the lack of rest and sleep for operating personnel, a lack of situational awareness by operating personnel, and in some instances poor weather conditions. With the introduction of the PT at DFW, the operation is expected to become orderly to a certain extent, but the movement of aircraft on taxiways requires adequate warning of other aircraft in the vicinity and potential conflicts in the direction of movement. Conflicts arise because the cargo facilities are located very close to the Taxiway C on the west and Taxiway P on the east, which are the primary routes for aircraft taxiing to terminals and taxiing in and out of cargo aprons and maintenance hangars once the PT operation begins. Taxiways C and P are prime examples where aircraft may be moving in opposing direction as discussed in the Taxiway C and P analysis in Chapter 9. One aircraft from the cargo apron is heading to the departure queue, while the other aircraft that just landed is taking the same taxiway to reach the terminal building. This creates a situation where the ATC must inform all pilots involved in this scenario to watch for other aircraft taxiing in the opposite directions. The PT has to be clearly marked on the ground, well lit during the night and during all weather conditions and the pilots need to be given advance notice listing all the relevant procedures for the PT's in the navigational charts. Above all, every incoming aircraft pilot needs to be cautioned and reminded about the PT operations at DFW that require the aircraft to follow certain pre-designated paths to reach the terminal gates and cargo aprons. Switching between PT and non-PT operations after the start of PT operations at DFW may confuse pilots and reintroduce the possibility of runway incursions that were significantly reduced by building the PT.

10.2 Runway safety

Runway safety and interference free operations are the prime motivation in designing and building the PT at DFW. To a large extent, the VS animation of PT operations indicates that there is an improvement in departure rates and a total reduction of runway crossing delays by arriving aircraft. This in turn should reduce the communication between the controllers and the pilot in the cockpit on arriving flights. The controllers will be able to spend more time on directing departure traffic and concentrate more on the safe movement of aircraft within the airfield at DFW.

However, the increased traffic in the near future from cargo aircraft will significantly alter the movement of aircraft on TXY C and P, which will require adequate coordination between the ATC and taxiing aircraft to avoid heading in the opposing directions. The PT is used by turboprop aircraft for departure on runway 13L or 31L, which places an additional burden on controllers for coherent and effective communication with pilots who will often be new to DFW.

10.3 Taxi In and Taxi Out time

The simulation of DFW with and without the PT showed that the taxi in time increases when the aircraft taxi on the PT to reach the terminal gates and cargo aprons. Aircraft arriving on runways 17C/35C and 17L/35R, 18R/36L have to taxi over the PT to go to terminals A, B, C, D, and E as shown in Appendix G. The comparison of operations without PT and with PT yielded a mean difference of 7.09 minutes per arriving aircraft for the South Flow and a mean difference of 6.71 minutes per arriving aircraft for the North Flow, based on the four scenarios selected and shown in Tables 41 and 44. The increase in Taxi In time and the resulting safe operations far outweighs the delay to both aircraft and passengers due to the introduction of PT. On the other hand, Taxi Out time gets reduced with the introduction of PT's at DFW, which is apparent from the Taxi Out time analysis in Tables 60 and 64,(Section 8.2 and 8.3) which shows that only 5.4% and 5.6% of departing flights incur runway crossing delay for the South Flow and North Flow configuration, respectively.

10.4 Runway use

The runway use by aircraft originating from the east and west side cargo aprons requires special consideration. In the PT simulation, the aircraft leaving the east side cargo ramps is directed to the 17C departure queue from the east side. The freighter aircraft is permitted to take off when there is a gap in the arrival stream on runway 17C during the South Flow operations; this will eliminate taxiing on the PT to access the 17R departure runway. The turboprop aircraft intending to take off from runway 13L will be able to travel without waiting on the PT for cargo aircraft taxiing in the opposite direction, to use 17R or 17C for departure from the west side departure queue.

In the PT simulation, during South Flow, the aircraft originating from UPS and the west air freight aprons are allowed to taxi to the runway 18R departure queue from the west side and they are allowed to take off when there is a gap in the arrival stream. Similarly, this will eliminate unnecessary travel on the PT to go to the east side departure queue of runway 18L.

During North flow, the aircraft from the east airfreight apron is allowed to take off from runway 35C, by accessing the runway from the departure queue on the east side of runway 35C, by traveling south on Taxiway P. During the North Flow operations, the aircraft from UPS and west cargo aprons taxi to the west side departure queue of runway 36L The freighter aircraft is allowed to take off when there is a gap in the arrival stream on runway 36L. This study recommends that DFW and FAA/ATC make this a permanent feature of runway assignment by establishing departure procedures for freight aircraft from the east and west cargo aprons to take off from arrival runways 17C/35C and 18R/36L when PT operations begins in the future.

10.5 PT's future in the existing airports

The PT at DFW will be a great addition to improve operations and will also eliminate the need for construction of another runway. The terminal buildings have several gates for use by new airlines that may plan service at DFW. The operations will be much smoother, without interruption from arriving aircraft and departure can be scheduled without consideration for arrival aircraft. Overall airport efficiency is bound to increase once the PT is in operation, as observed in the VS simulation, thus reducing delay for traveling public at DFW. This research considers the data from flight track obtained from EAD. Further research can be done to determine the accuracy of the aircraft height as reported by the FAA/ARTS system and ASR-9 radar data to EAD. Using the flight track data, the inter-arrival time and separation distance between successive aircraft on the four arrival runways 13R, 18R, 17C and 17L during South Flow and runways 31R, 35R, 35C and 36L during North Flow can be computed to establish the speed, wake vortex impact on aircraft on the arrival stream and estimate the safe separation distance at DFW. The information thus computed will enable the ATC to sequence the arrival rate of aircraft mix, thus increasing the capacity of arrival runways.

At present, four major airports in the US, ORD, DTW, STL and LAX are pursuing the possibility of adding a PT system to their existing runway configurations. The FAA/AOSC Decision document #7 has specified that an airport should have a minimum of 150,000 departures and 10,000 minutes of delay annually to warrant the construction of a PT or EAT [FAA/AOSC Decision Document #7 of 9-21-06]. It is estimated that about 30 OEP airports presently qualify for this criteria for developing design guidelines and standards for constructing PTs to improve safety and capacity enhancement. The author also recommends that a critical evaluation of planned addition to existing terminal buildings, cargo facilities and general aviation in the 30 OEP `airports while implementing the PT system. An analysis of the arrival and departure aircraft over PT also to be completed before final designs are undertaken for PT. The impact of cargo carriers on airfield operations should not be taken lightly as more and more cargo carriers are introducing heavy aircraft to ferry freight which may drastically affect movement of aircraft on taxiways.

10.6 Use of Visual SIMMOD

This is the first time VS has been used for research and analysis of a complex airport like DFW with seven runways and more than two thousand eight hundred and eight operations per day forecast in 2010. Therefore, it can be used to evaluate the operations at large airports with multiple runways like DFW.

VS can also be used for a variety of other applications:

- Expanding an airport with one or more runways,
- Evaluating a new terminal gate complex,
- Testing runway or taxiway closures at existing airports,
- Adding or changing air space routes and structures and

- Implementing new taxiway flow patterns.

There are many research areas that can use VS for a reliable simulation of airport/airspace operations with supporting 2D and 3D modeling capabilities.

In this research, the flight track data analysis considers an aircraft flying over another aircraft taxiing on the PT with all engines in operation. The FAA/AOSC has considered the one engine operation criteria for departure on runway 17R at DFW. This is an area that needs further investigation and evaluation of the safety of operation flying over aircraft taxiing on the PT.

The possibility of extensive research in the design of PTs and the supporting operating standards, specifications, and taxi routes opens up a whole new area of airport operations that has never been explored in detail before.

10.7 Future research areas

This research found that the aircraft can safely overfly an aircraft on the PT when arriving at DFW. The FAA and NASA can evaluate the arrival case in a flight simulator at the NASA facility in Moffett field to validate the results from this research.

One engine operation due to failure in a multiengine aircraft, during departure is not considered in this research due to lack of information at DFW. This is an area that the FAA can study in real time in the flight simulator at the NASA facilities in Moffett field.

Flight track data can also be used to estimate the runway capacity for South and North Flow at DFW as the data contains aircraft type, time of entry at the gates placed at different distance in space, and the touch down time on the arrival runway. These data can be used to estimate the inter-arrival time, spacing between successive aircraft, and speed. This study will facilitate ATC to properly sequence aircraft and increase the arrival capacity of runways 13R, 18L/36R, 17C/35C, 17L/35R, and 31R.

This is the first attempt to simulate the operation of the PT using real time historical data in VS with all types of aircraft and it is perceived to become the pioneer in PT research of the future.

Existing Multilateration System can be used to track arrival and departure aircraft on the PT. Once the Wide Area Multilateration (WAM) System is installed at DFW, it can be used to track the aircraft height on the approach and departure path and compare them with flight track data at EAD, for effective prediction of aircraft height over PT.

10.7.1 Airport Layout Plan (ALP) in the cockpit

The RWSL installation evaluation study at DFW uses a video display showing the airfield layout on the east side and west side in the control towers. The controllers in the East and West Tower at DFW are able to view the movement of aircraft on the airfield in the form a "white" dot. The aircraft type tag and the airline tag is visible on the screen. This information is collected from the Multilateration system, ASR-9 radar, and the surface monitoring system at the airfield. The information that is gathered is collated and presented on the video display in real time. The author proposes the installation of a 10 inch or 12 inch heads up display (LCD monitor) in the cockpit of each aircraft that will display the same information that is seen by the air traffic controllers at the towers. The data from the FAA control system will be beamed as a radio signal on a specific channel to be received by the onboard TV display unit. The unit will be programmed to receive the information as soon as the aircraft reaches an altitude of 200 feet above the airport on the arrival path. The pilot and the co-pilot will be able to watch the movement of all aircraft on the airfield. They will be able to view their own aircraft as a “Blue or Red” dot moving towards the arrival runway. They will also be able to view the movement of aircraft on the PT systems and taxiways. In addition, the taxiway names and runway markings will be clearly visible on the screen. The data will be beamed from the tower in an encrypted format to prevent access by unauthorized persons and to ensure of the data security. At the video display, the encrypted signal will be received and shown on the video screen. The screen will have touch control to facilitate zoom in and zoom out to permit viewing selected areas on the airfield. This will ensure safe operation on the airfields as each aircraft operator will be able to view his location with reference to all other aircraft on the airfield and will prevent runway incursions. The cost of installing the display monitor will be economical and the systems are already available. The FAA needs to develop a method to transmit the data in real time in the form of a TV signal on a specific channel. The Multilateration system is now installed at many international destinations such as Charles DeGaulle Airport near Paris, and at Frankfurt International as well as other airports. The use of such a real time visual display coupled with the airport layout will facilitate the aircraft operators to locate themselves in the airfield in reference to all other aircrafts at the airport.

10.8 Contribution to aviation research

The complex operations at DFW with 2,808 operations per day is the first large scale simulation successfully completed in VS; this effort leads the way for use of VS in several other large airports like ORD, DTW, STL and LAX. Historical flight data for arrivals and departures from any large airport can easily be input into VS for simulating operations. Aircraft height cannot be estimated with reasonable accuracy, as VS is not originally developed for such an investigation. Therefore, actual historical flight track data from EAD is used to estimate the aircraft height overflying the aircraft taxiing on the PT. VS can be programmed and enhanced to estimate the aircraft height above the airport at any given distance along the centerline of runway for arrivals and departures.

This research's contribution to the advancement of the PT concept is critical because the FAA is considering the PT option to eliminate runway crossings in parallel runway operations and reduce runway incursions at several US airports. The VS Animator projects a true visual image of the movement of aircraft at the airfield on runways and taxiways in an aerial view. This affords the researcher an opportunity to study the overall movement on the airfield. The author uses the VS Animator to identify the choke points and conflict areas in the PT operation at DFW. This animation helps to design the operations to duplicate in VS the standard taxiway procedures stipulated and used by the ATC and DFW operations. This research uses only VFR conditions in all sixteen applications. VS requires additional probability functions and programming capability to simulate VFR and IFR conditions similar to DFW, where weather and wind directions change frequently in a day. This capability is already available in the JSIMMOD simulation program developed by Airport Tools Inc, Las Altos, CA.

This research did a thorough analysis of the movement of the aircraft on the PT and on the taxiway systems for both the South Flow and North Flow configurations. The detailed investigation found that the Taxi In time increases during peak hours when several aircraft taxi on the PT after arrival to reach the terminals creating choke points at the intersections on the four quadrants of the PT depending on the direction of flow. The Ground Controllers have to meticulously control the movement of aircraft and guide them into the taxi queue considering the type of aircraft and its arrival time at DFW, to continue to maintain priority. The Ground Controllers' attention in the future will shift from facilitating runway crossings for arriving aircraft to monitoring the safe movement of arrival aircraft at the intersection of Taxiway E and Taxiway M with the PT.

In VS, the aircraft are classified into four categories, GA, Small, Large and Heavy. The ability to assign the characteristics of each aircraft based on the equipment and size will enable more precise estimation of arrival and take off distances on the runway, the height of aircraft over the threshold, arrival and departure sequencing on the flight path and estimation of Taxi In and Taxi Out times. This research did not include in the simulation the Airbus 380 or the Boeing 787 aircraft, which are likely to enter service in the very near future. VS classifies them as Heavy aircraft, but their real time operating characteristics data will not be available until they are placed in commercial air service.

The PT used in the VS simulation is at distance of 2,650 feet from the end of the runways at DFW in all four quadrants of the airfield. The author recommends that this distance can be verified with further simulation while varying the distances from the end of the runway to establish the safe distance to plan the PT for future implementation, which can be used by the FAA to establish design criteria.

The performance measures and choke point analysis indicate that the PT may not be able to alleviate all operational challenges; however, the analysis still looks promising especially from a safety perspective. Future research must carefully assess the parties impacted by operational changes.

APPENDIX A

FLIGHT DATA SAMPLE FROM VARIOUS SOURCES

FLIGHT DATA SAMPLE FROM VARIOUS SOURCES

Table 89, shows the OAG time table by the carrier name, flight number, origin/destination airport, aircraft type, scheduled arrival and departure time.

Table 89 Official Airline Guide data for 22 July 2004

Flights to/from DFW Airport
July 29, 2004
Taken from OAG MAX - July 2004 Issue - Non-stop, operating flights only

Carrier	Carrier Name	Flight No	Dep Airport	Dep City Name	Dep State	Dep IATA Ctry Name	Arr Airport	Arr City Name	Arr State	Arr IATA Ctry Name	Local Dep Time	Local Arr Time	Specific Acft	Specific Acft Name
AA	American Airlines	5	DFW	Dallas/Fort Worth	TX	USA	HNL	Honolulu	HI	USA	1005	1313	763	Boeing 767-300 Passenger
AA	American Airlines	6	OGG	Kahului	HI	USA	DFW	Dallas/Fort Worth	TX	USA	1649	0500	763	Boeing 767-300 Passenger
AA	American Airlines	7	DFW	Dallas/Fort Worth	TX	USA	OGG	Kahului	HI	USA	1200	1458	763	Boeing 767-300 Passenger
AA	American Airlines	8	HNL	Honolulu	HI	USA	DFW	Dallas/Fort Worth	TX	USA	1650	0515	763	Boeing 767-300 Passenger
AA	American Airlines	37	ZRH	Zurich		Switzer	DFW	Dallas/Fort Worth	TX	USA	1010	1425	763	Boeing 767-300 Passenger
AA	American Airlines	38	DFW	Dallas/Fort Worth	TX	USA	ZRH	Zurich		Switzerla	1500	0755	763	Boeing 767-300 Passenger
AA	American Airlines	38	SFO	San Francisco	CA	USA	DFW	Dallas/Fort Worth	TX	USA	0735	1300	763	Boeing 767-300 Passenger
AA	American Airlines	48	DFW	Dallas/Fort Worth	TX	USA	CDG	Paris		France	1730	1000	763	Boeing 767-300 Passenger
AA	American Airlines	49	CDG	Paris		France	DFW	Dallas/Fort Worth	TX	USA	1050	1435	763	Boeing 767-300 Passenger
AA	American Airlines	50	DFW	Dallas/Fort Worth	TX	USA	LGW	London (GB)		United Ki	1705	0800	777	Boeing 777 Passenger
AA	American Airlines	51	LGW	London (GB)		United I	DFW	Dallas/Fort Worth	TX	USA	1025	1420	777	Boeing 777 Passenger
AA	American Airlines	60	DFW	Dallas/Fort Worth	TX	USA	AUS	Austin	TX	USA	1713	1807	M80	Boeing (Douglas) MD-80
AA	American Airlines	60	NRT	Tokyo		Japan	DFW	Dallas/Fort Worth	TX	USA	1810	1540	777	Boeing 777 Passenger
AA	American Airlines	61	AUS	Austin	TX	USA	DFW	Dallas/Fort Worth	TX	USA	0947	1048	M80	Boeing (Douglas) MD-80
AA	American Airlines	61	DFW	Dallas/Fort Worth	TX	USA	NRT	Tokyo		Japan	1200	1510	777	Boeing 777 Passenger
AA	American Airlines	66	DFW	Dallas/Fort Worth	TX	USA	ORD	Chicago	IL	USA	1400	1618	777	Boeing 777 Passenger
AA	American Airlines	67	ORD	Chicago	IL	USA	DFW	Dallas/Fort Worth	TX	USA	1730	1952	777	Boeing 777 Passenger

Source: OAG, Miami, FL

The data in Table 90 shows the date, time and the flight id of an aircraft. The equipment type column shows the type of aircraft. Operation category is A for arrival. Navigational fix, runway used for landing and the airport id which is DFW. PWR, for type of engine, showing it is a jet aircraft, type PAX is passenger and the Beacon ID in the last column. The flight track data has two different formats. Table 59 shows the information on flight number that is common in the data Table 60. The two data records are sorted by flight number to arrive at the equipment type, runway use and height above runway for all flights.

Table 90 DFW FliteGraph® data from EAD

Date/Time	Flight ID	Equip	Op	NavFix	Runway	APT	PWR	Type	Beacon
7/29/2004 0:01	EGF460	E135	A	JEN	18R	DFW	J	PAX	5265
7/29/2004 0:02	AAL1302	MD82	A	JEN	UNK	DFW	J	PAX	4072
7/29/2004 0:02	AAL1203	MD82	A	BYP	17C	DFW	J	PAX	5167
7/29/2004 0:04	AAL2446	B772	A	UKW	18R	DFW	J	PAX	5264
7/29/2004 0:05	AAL2194	B738	A	BYP	17C	DFW	J	PAX	2541
7/29/2004 0:06	AAL1591	MD82	A	BYP	17C	DFW	J	PAX	7233
7/29/2004 0:07	AAL2274	MD82	A	UKW	18R	DFW	J	PAX	5345
7/29/2004 0:08	DAL1242	B733	A	BYP	17C	DFW	J	PAX	5132
7/29/2004 0:10	AAL2260	B752	A	JEN	18R	DFW	J	PAX	2531
7/29/2004 0:12	TRS118	B712	A	BYP	17C	DFW	J	PAX	2470
7/29/2004 0:12	AAL816	B752	A	JEN	18R	DFW	J	PAX	2332
7/29/2004 0:14	CAA179	CRJ7	A	UKW	17C	DFW	J	PAX	5222
7/29/2004 0:15	DAL1062	B738	A	JEN	UNK	DFW	J	PAX	2727
7/29/2004 0:17	UAL521	B733	A	JEN	UNK	DFW	J	PAX	2555
7/29/2004 0:17	DAL1161	MD90	A	BYP	17C	DFW	J	PAX	5242
7/29/2004 0:17	AAL1212	B752	A	UKW	18R	DFW	J	PAX	5114
7/29/2004 0:20	CAA506	CRJ7	A	BYP	17C	DFW	J	PAX	2642
7/29/2004 0:20	AAL1302	MD82	A	JEN	18R	DFW	J	PAX	4072
7/29/2004 0:21	AAL1156	B738	A	JEN	UNK	DFW	J	PAX	2544
7/29/2004 0:23	EGF874	CRJ7	A	UKW	18R	DFW	J	PAX	5111
7/29/2004 0:23	TRZ7911	B72Q	A	JEN	UNK	DFW	J	OTH	2420
7/29/2004 0:24	DAL533	MD88	A	CQY	17C	DFW	J	PAX	2414

The Table 91 shows the flight track data on date and time of arrival on Runway 17C. The column, 'Name' shows the horizontal distance from the end of runway. Next column shows the flight ID. The Pen X is internal data designator used by FliteGraph® program. Pen Y shows the height above airport GL and the last column altitude of the aircraft above MSL. The airport average elevation used by the FliteGraph® program in the computation is 600 ft above MSL

Table 91 DFW FliteGraph® runway 17C arrival data at a distance of 2650 ft

Flight Time	Gate Time	Name	Flight ID	Pen X	Pen Y	Alt
7/29/2004 0:02	0:01:37	2650	AAL1203	950	227	827
7/29/2004 0:05	0:04:05	2650	AAL2194	941	247	847
7/29/2004 0:06	0:06:04	2650	AAL1591	951	275	875
7/29/2004 0:08	0:08:00	2650	DAL1242	933	244	844
7/29/2004 0:12	0:11:22	2650	TRS118	937	242	842
7/29/2004 0:14	0:13:45	2650	CAA179	991	240	840
7/29/2004 0:17	0:16:55	2650	DAL1161	1001	251	851
7/29/2004 0:20	0:19:40	2650	CAA506	924	252	852
7/29/2004 0:24	0:23:22	2650	DAL533	893	254	854
7/29/2004 0:27	0:26:26	2650	DAL1062	891	228	828
7/29/2004 0:29	0:28:49	2650	CAA253	936	279	879
7/29/2004 0:32	0:31:30	2650	COA415	930	251	851
7/29/2004 0:34	0:33:58	2650	AAL1153	936	242	842
7/29/2004 0:38	0:37:48	2650	AAL2452	962	254	854
7/29/2004 0:42	0:42:07	2650	UPS309	913	222	822
7/29/2004 0:44	0:43:57	2650	CAA724	908	276	876
7/29/2004 0:46	0:45:43	2650	DAL1077	954	258	858
7/29/2004 0:48	0:47:16	2650	DAL743	928	265	865
7/29/2004 0:50	0:49:39	2650	AAL2473	945	219	819
7/29/2004 0:52	0:51:11	2650	EGF712	906	227	827
7/29/2004 0:53	0:52:34	2650	COA1519	951	275	875
7/29/2004 0:55	0:54:39	2650	EGF478	935	210	810
7/29/2004 0:57	0:56:21	2650	DAL397	915	269	869
7/29/2004 0:58	0:57:48	2650	UPS775	871	216	816
7/29/2004 1:23	1:22:21	2650	AWE544	910	269	869
7/29/2004 1:27	1:26:20	2650	UPS607	879	249	849
7/29/2004 1:29	1:28:25	2650	CAA342	909	286	886
7/29/2004 1:30	1:29:52	2650	AAL699	934	242	842
7/29/2004 1:35	1:34:48	2650	AMT205	966	247	847
7/29/2004 1:37	1:36:25	2650	DAL1297	940	238	838
7/29/2004 1:39	1:38:39	2650	UPS2784	911	269	869
7/29/2004 1:42	1:41:15	2650	CAA200	898	285	885
7/29/2004 1:48	1:47:10	2650	CAA199	918	266	866
7/29/2004 1:51	1:50:06	2650	AAL324	894	245	845
7/29/2004 1:52	1:52:01	2650	DAL1499	930	263	863
7/29/2004 2:00	1:59:06	2650	DAL1235	955	251	851
7/29/2004 2:05	2:04:38	2650	AAL877	964	237	837
7/29/2004 2:45	2:45:04	2650	NWA405	895	288	888
7/29/2004 4:08	4:07:11	2650	FDX1735	951	227	827

The Table 92 shows the schedule information from DFW database giving the date, actual arrival or departure time and the airlines two letter designator. The flight number, origin and destination and gate used by the airline are shown in the last three columns. The common denominator in all these data is the flight number which is used to compile the input data file for VS simulation.

Table 92 Flight Schedule data from the Scheduling Department DFW

DATE	TIME	A/D	AIRLINE	AIRLINE	FLIGHT #	O/D	Airport ID	GATE
7/22/2004	11:22:00	A	AA	AA	1040	Gua	DFW	A36
7/22/2004	10:52:00	D	AA	AA	1042	New	DFW	A9
7/22/2004	16:41:00	A	AA	AA	1043	Ral	DFW	C33
7/22/2004	14:56:00	A	AA	AA	1051	Ral	DFW	A9
7/22/2004	15:41:00	D	AA	AA	1051	Col	DFW	A9
7/22/2004	18:47:00	D	AA	AA	1052	MA	DFW	A13
7/22/2004	18:06:00	D	AA	AA	1057	Ren	DFW	C32
7/22/2004	19:44:00	D	AA	AA	1058	Was	DFW	C17
7/22/2004	6:42:00	D	AA	AA	1062	Jac	DFW	A9
7/22/2004	17:59:00	A	AA	AA	1064	Mex	DFW	A37
7/22/2004	9:41:00	A	AA	AA	1066	Mex	DFW	A36
7/22/2004	10:43:00	D	AA	AA	1066	Orl	DFW	A36
7/22/2004	10:45:00	A	AA	AA	1067	Orl	DFW	C10
7/22/2004	11:41:00	D	AA	AA	1067	Col	DFW	C31
7/22/2004	8:44:00	A	AA	AA	1069	Phi	DFW	C33
7/22/2004	11:21:00	D	AA	AA	1070	Bos	DFW	A13
7/22/2004	7:04:00	D	AA	AA	1071	Aus	DFW	C3
7/22/2004	14:06:00	D	AA	AA	1073	Pho	DFW	A20
7/22/2004	17:41:00	D	AA	AA	1074	Orl	DFW	A9
7/22/2004	14:51:00	A	AA	AA	1077	Det	DFW	C14
7/22/2004	18:38:00	A	AA	AA	1079	Bos	DFW	C14
7/22/2004	15:05:00	A	AA	AA	1083	Pit	DFW	A10
7/22/2004	10:16:00	A	AA	AA	1085	For	DFW	C30
7/22/2004	9:10:00	D	AA	AA	1086	New	DFW	C32
7/22/2004	18:45:00	A	AA	AA	1087	Phi	DFW	A11

The Table 93 and Table 94 show the input data spread sheet for VS simulation. FLT_ID specifies the data is for arrival or Emplane. . Event_time gives the arrival or departure time, ALN_ID gives the airline ID, FLT_NUMBER gives the flight number. ACM_ID shows the type of equipment, A_D FLAG shows the event an arrival or departure, ROUTE_ID gives the runway assignment for arrival and departure, TXP_ID_USED is for the taxi path to and from terminal. APT_ORG_ID for origin airport, APT_DEST_ID the destination airport ID, and GATE_ID_USED for the gate assigned for the flight.

Table 93 Visual SIMMOD Input data for Arrival flights July 22, 2004

FLT_ID	EVENT_TIME	A_D_FLAG	ALN_ID	FLT_NUMBER	ACM_ID	RTE_ID	TXP_ID_U	GTE_ID_USED	APT_ORIG_ID	APT_DEST_ID
ARRIVAL_0079	7.52	A	EGF	796	EMB145	ARR_13R		B3	GRR	DFW
ARRIVAL_0080	7.58	A	CAA	345	CRJ2	ARR_18R		E22	CRP	DFW
ARRIVAL_0081	7.61	A	AAL	1128	MD82	ARR_13R		C30	ONT	DFW
ARRIVAL_0082	7.73	A	AAL	300	MD82	ARR_17C		C6	SDF	DFW
ARRIVAL_0083	7.83	A	EGF	654	EMB135	ARR_17C		A2B	FSM	DFW
ARRIVAL_0084	7.85	A	AAL	320	MD83	ARR_13R		C15	PDX	DFW
ARRIVAL_0085	7.87	A	AAL	867	MD83	ARR_17C		A12	DAY	DFW
ARRIVAL_0086	7.88	A	AAL	2915	MD82	ARR_17L		C15	STL	DFW
ARRIVAL_0087	7.89	A	EGF	574	EMB135	ARR_18R		B12B	HOU	DFW
ARRIVAL_0088	7.93	A	EGF	504	EMB145	ARR_18R		A2N	BNA	DFW
ARRIVAL_0089	7.94	A	EGF	750	EMB145	ARR_17L		B5	JAX	DFW
ARRIVAL_0090	7.95	A	EGF	720	EMB145	ARR_13R		B10B	CVG	DFW
ARRIVAL_0091	7.97	A	AAL	1559	MD82	ARR_18R		C21	AUS	DFW
ARRIVAL_0092	8.00	A	EGF	568	EMB135	ARR_18L		A2H	GSO	DFW
ARRIVAL_0093	8.02	A	EGF	746	CRJ7	ARR_17C		B9B	LIT	DFW
ARRIVAL_0094	8.05	A	CAA	240	CRJ2	ARR_17C		E32	MEM	DFW
ARRIVAL_0095	8.07	A	EGF	520	EMB145	ARR_13R		B9B	LBB	DFW
ARRIVAL_0096	8.09	A	AAL	2408	MD82	ARR_18R		A14	LAX	DFW
ARRIVAL_0097	8.11	A	AAL	1719	MD82	ARR_13R		C25	OMA	DFW
ARRIVAL_0098	8.11	A	AAL	2409	MD82	ARR_18R		C22	TMP	DFW
ARRIVAL_0099	8.16	A	AAL	653	MD82	ARR_13R		C39	JFK	DFW
ARRIVAL_0100	8.19	A	EGF	482	EMB145	ARR_18R		A2A	MAF	DFW
ARRIVAL_0101	8.20	A	AAL	1851	MD82	ARR_17C		C30	BHM	DFW
ARRIVAL_0102	8.20	A	CAA	565	CRJ2	ARR_18R		E25	MGM	DFW
ARRIVAL_0103	8.22	A	AAL	1783	MD82	ARR_13R		C20	DTW	DFW
ARRIVAL_0104	8.22	A	CAA	273	CRJ2	ARR_18R		E23	AEX	DFW
ARRIVAL_0105	8.27	A	CHQ	6384	EMB135	ARR_13R		E32	IND	DFW

Table 94 Visual SIMMOD Input data for Departure flights July 22, 2004

FLT_ID	EVENT_TIME	A_D_FLAG	ALN_ID	FLT_NUMBER	ACM_ID	RTE_ID	TXP_ID_USED	GTE_ID_USED	APT_ORIG_ID	APT_DEST_ID
EMPLANE_1078	20.77	D	AAL	1964	MD82	DEP_17R_LRG	TXP_17R_LRG	C25	DFW	HOU
EMPLANE_1077	9.43	D	AAL	1876	MD83	DEP_17R_LRG	TXP_17R_LRG	A9	DFW	RIC
EMPLANE_1076	19.23	D	AAL	1479	MD83	DEP_17R_LRG	TXP_17R_LRG	C31	DFW	SAT
EMPLANE_1075	11.00	D	AAL	272	MD83	DEP_18L_LRG	TXP_18L_LRG	A14	DFW	LAX
EMPLANE_1074	7.10	D	AAL	1839	MD82	DEP_18L_LRG	TXP_18L_LRG	A33	DFW	SAT
EMPLANE_1073	9.88	D	AAL	1713	MD82	DEP_18L_LRG	TXP_18L_LRG	C33	DFW	GDL
EMPLANE_1072	14.88	D	AAL	1712	MD82	DEP_18L_LRG	TXP_18L_LRG	A14	DFW	CLT
EMPLANE_1071	22.50	D	AAL	1703	MD83	DEP_18L_LRG	TXP_18L_LRG	A38	DFW	SAT
EMPLANE_1070	14.92	D	AAL	1698	MD83	DEP_18L_LRG	TXP_18L_LRG	C10	DFW	RDU
EMPLANE_1069	20.70	D	AAL	1673	MD83	DEP_18L_LRG	TXP_18L_LRG	A38	DFW	FAT
EMPLANE_1068	13.48	D	AAL	1653	737800	DEP_18L_LRG	TXP_18L_LRG	C22	DFW	MEX
EMPLANE_1067	13.65	D	AAL	1630	MD82	DEP_17R_LRG	TXP_17R_LRG	A11	DFW	BNA
EMPLANE_1066	6.73	D	AAL	1543	MD82	DEP_17R_LRG	TXP_17R_LRG	A19	DFW	IAD
EMPLANE_1065	8.78	D	AAL	1536	MD82	DEP_17R_LRG	TXP_17R_LRG	C11	DFW	PIT
EMPLANE_1064	7.68	D	AAL	1439	MD82	DEP_17R_LRG	TXP_17R_LRG	C29	DFW	SAN
EMPLANE_1063	7.67	D	AAL	1413	757200	DEP_18L_HVY	TXP_18L_HVY	C19	DFW	LAS
EMPLANE_1062	9.75	D	AAL	1347	MD82	DEP_17R_LRG	TXP_17R_LRG	A21	DFW	SJC
EMPLANE_1061	11.77	D	AAL	1245	MD83	DEP_17R_LRG	TXP_17R_LRG	A17	DFW	DEN
EMPLANE_1060	17.25	D	AAL	1210	MD83	DEP_17R_LRG	TXP_17R_LRG	C31	DFW	ATL
EMPLANE_1059	13.65	D	AAL	1180	MD83	DEP_17C	TXP_17C	C17	DFW	RIC
EMPLANE_1058	9.32	D	AAL	1115	MD82	DEP_18L_LRG	TXP_18L_LRG	C22	DFW	DEN
EMPLANE_1057	8.43	D	AAL	1101	MD82	DEP_17R_LRG	TXP_17R_LRG	C6	DFW	SFO
EMPLANE_1056	14.05	D	AAL	1073	MD82	DEP_17R_LRG	TXP_17R_LRG	C35	DFW	PHX
EMPLANE_1055	14.82	D	AAL	1014	MD82	DEP_18L_LRG	TXP_18L_LRG	A38	DFW	SAT
EMPLANE_1054	19.75	D	AAL	963	767300	DEP_18L_HVY	TXP_18L_HVY	C31	DFW	GRU

APPENDIX B

VISUAL SIMMOD

VISUAL SIMMOD

In Visual SIMMOD the DFW AutoCad drawings in DXF format are converted to QGF format and located on the World map as shown in Figure 81, using the latitude and longitude of DFW. The elevation of the airport (607 ft.) is entered in the Airport data field to give the vertical coordinate of the aircraft in space. The arrival and departure time is entered in full 24 hr format, i.e. 7:00:00 for 7 a.m. in the morning and 19:00:00 for evening 7 p.m.

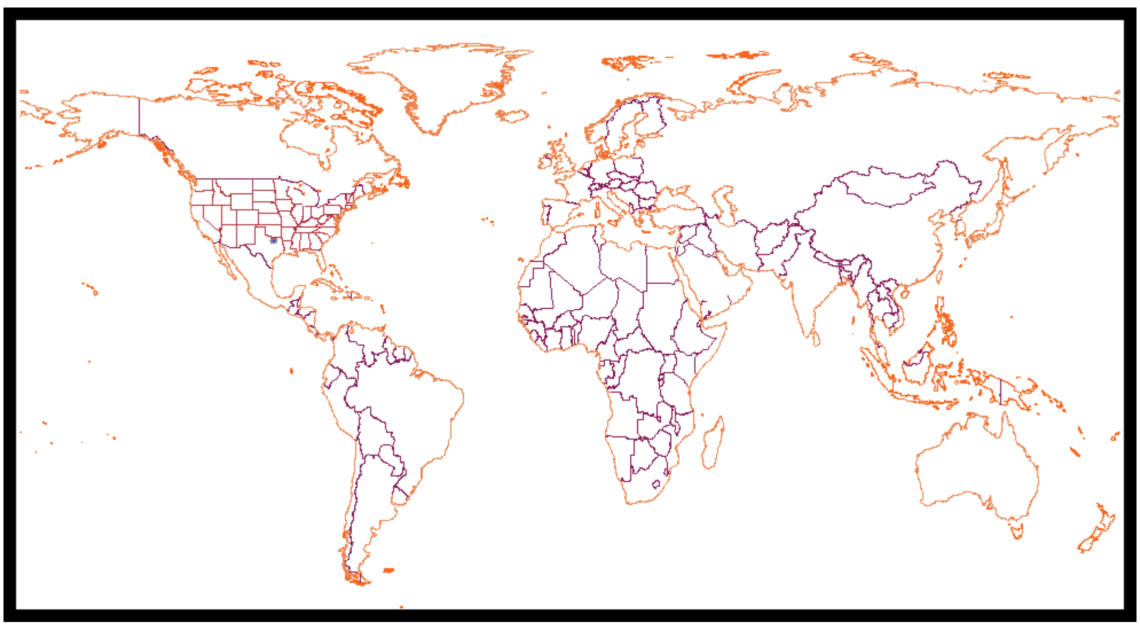

Figure 81 World map layout in Visual SIMMOD

Information on Visual SIMMOD program and the SIMMOD user's library documentation files can be found at the following web site:

http://www.airporttools.com/simmod/docs/flat/index.html

Figure 82 shows the Visual SIMMOD data entry screen capture. The information is input in a sequential fashion in the Workbench editor. The data on runway, taxiway, airlines, aircraft types, flight schedules, classification of aircrafts etc. are input from data compiled from various sources.

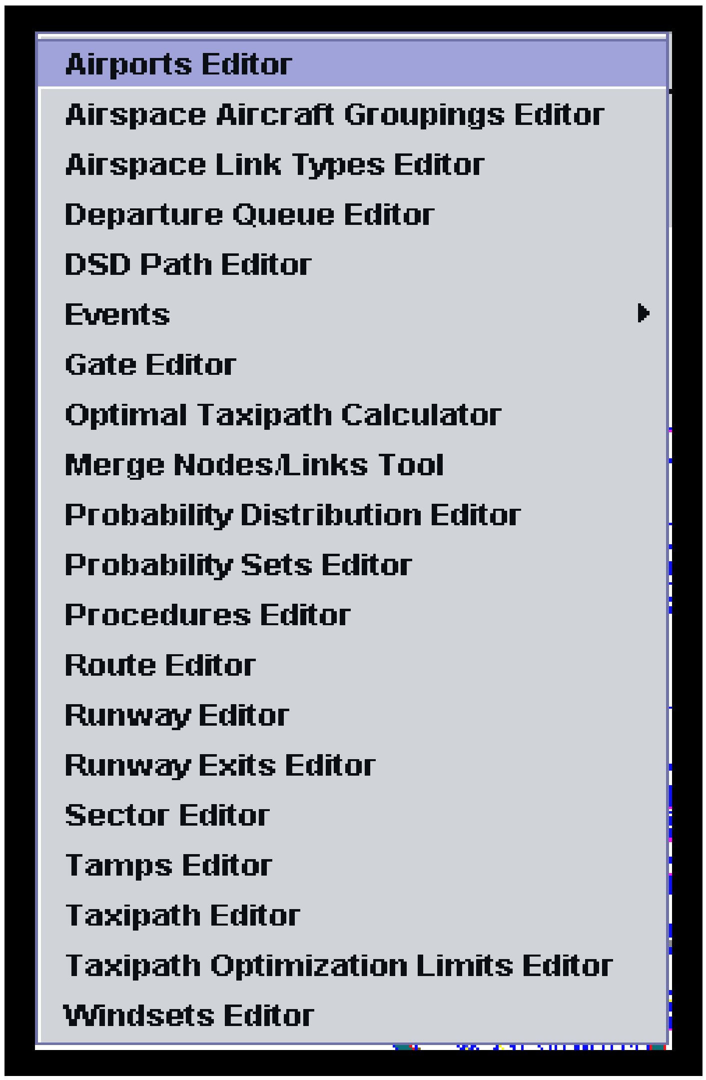

Figure 82 Data input screen

Figure 83 is the airport editor where information about DFW is entered.

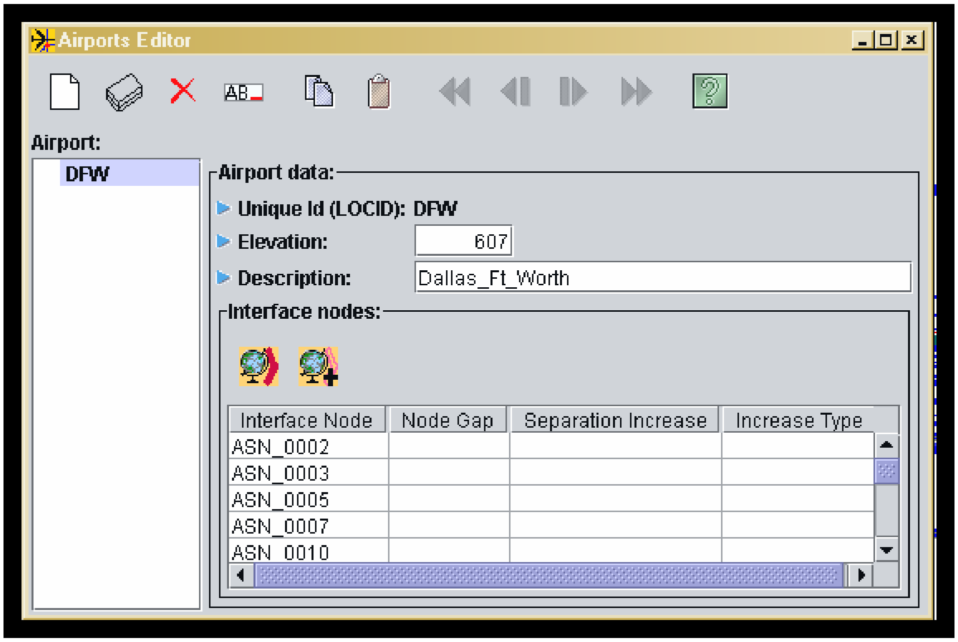

Figure 83 Airport editor

Figure 84 is the menu window where aircraft/airspace information is entered

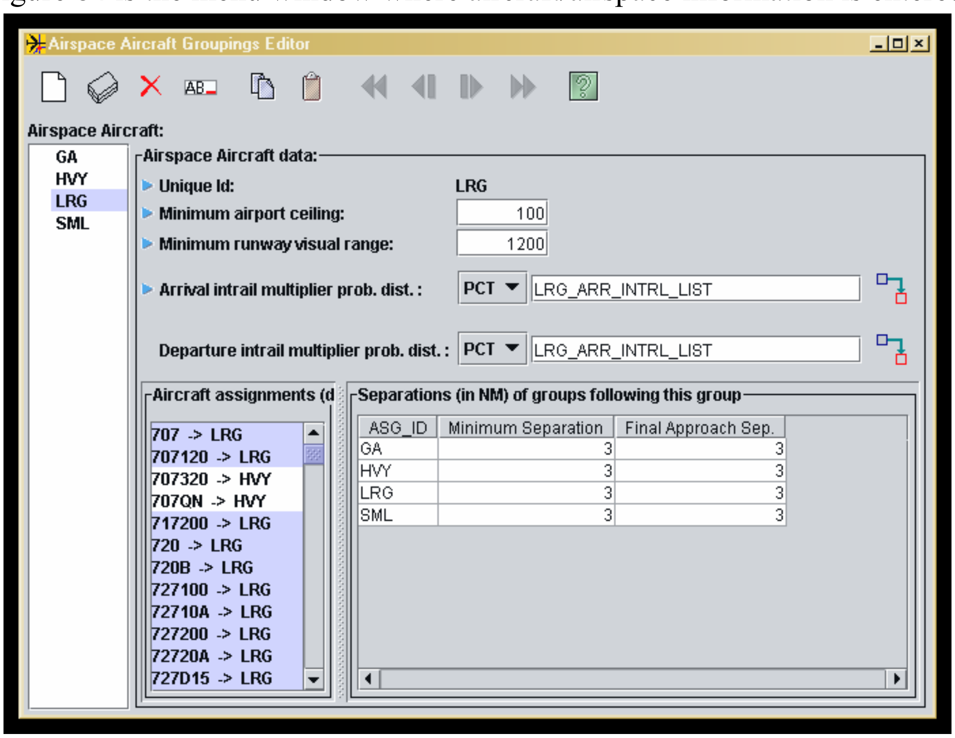

Figure 84 Airspace Aircraft grouping editor

Figure 85 is the screen shot of the departure queue editor. The departure queue that leads to the departure runway during South Flow operation is input in this menu.

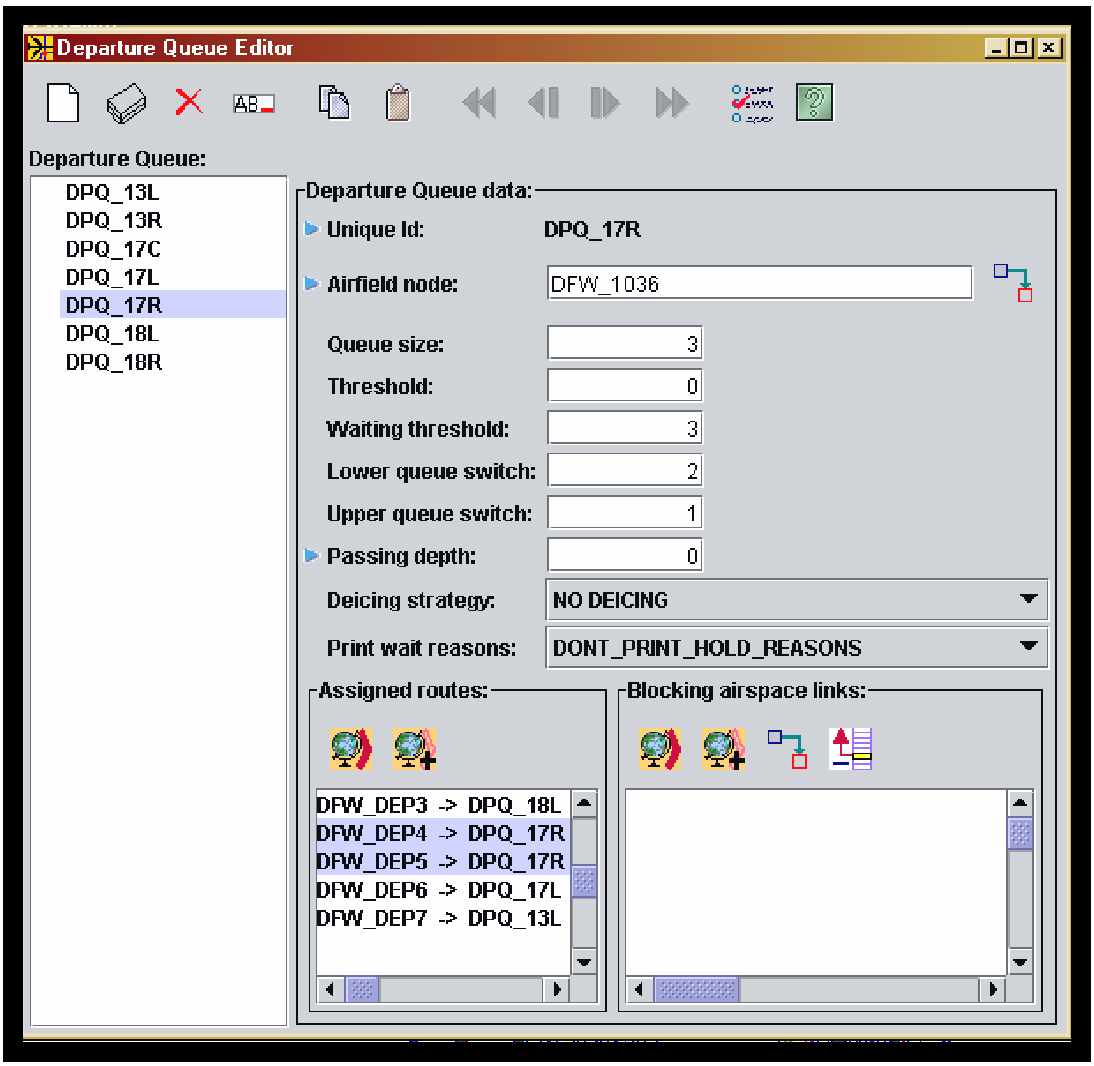

Figure 85 Departure Queue editor

The departure queue and the route specifications are entered here

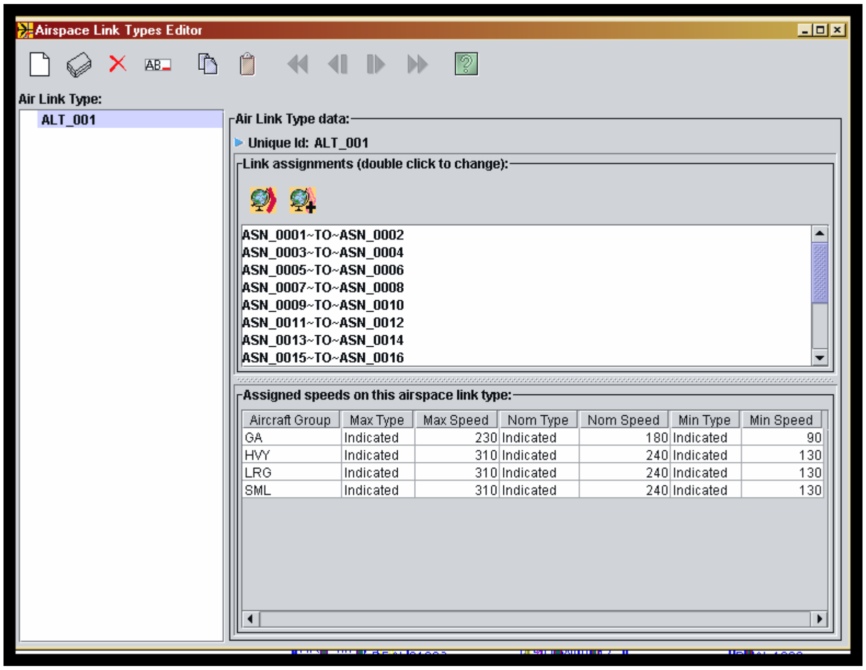

Figure 86 Airspace Links type editor

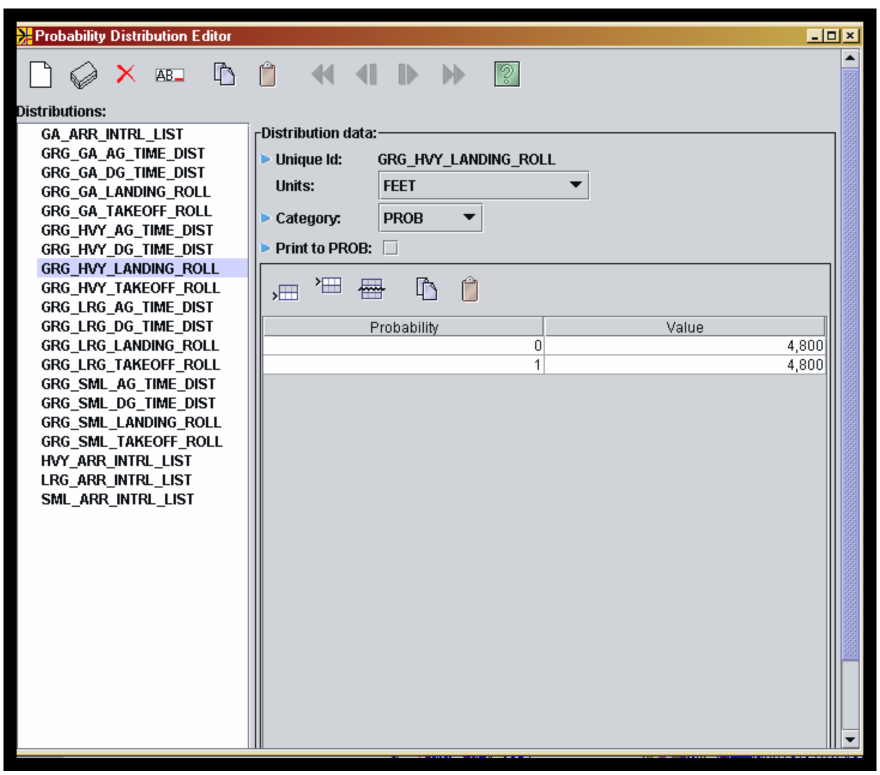

Figure 87 Probability Distribution editor

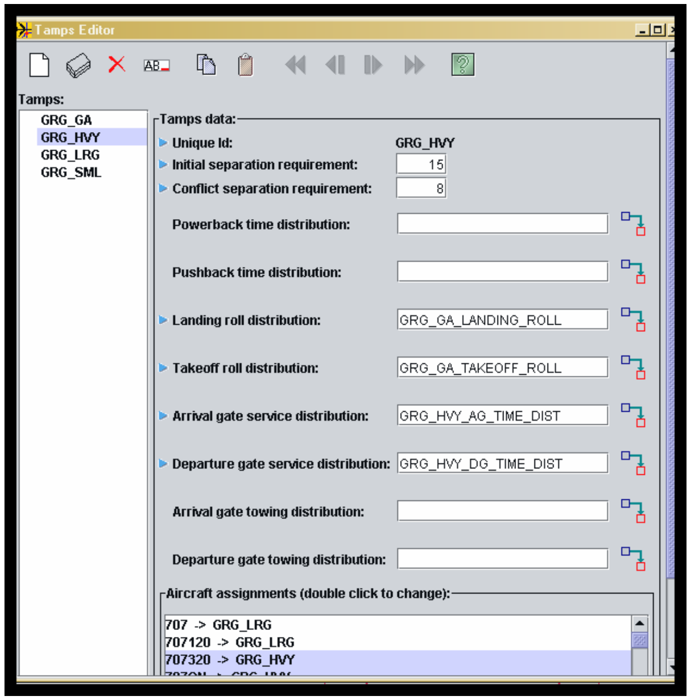

Figure 88 TAMPS editor

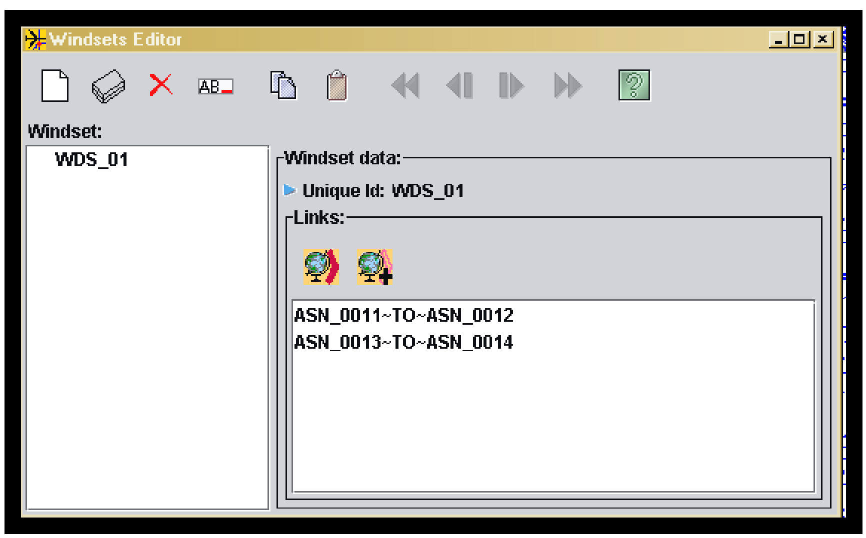

Figure 89 Windset editor

The wind set editor designates the routes for prevailing wind direction and for the opposite direction. In this research the South Flow and North Flow is designated separately in two applications.

Figure 90 shows menu for entering the simulation run time parameters for running the simulation of various applications.

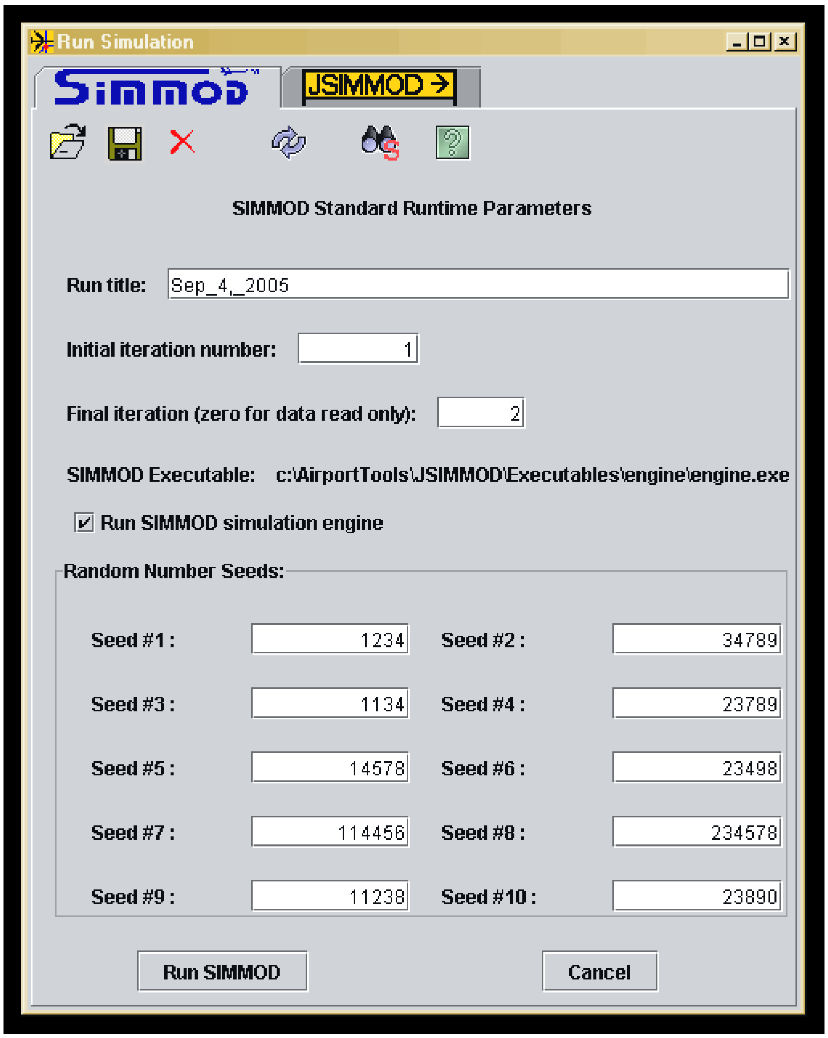

Figure 90 Run Simulation input window

Visual SIMMOD Reporter

The following reports are available in the VS Reporter module

1. Basic metrics

2. Runway usage

3. Departure queue usage

4. Flows

5. Route usage

6. Gate usage

7. Fuel burn

8. Sector reports

9. Airfield link activity

10. Airspace link activity

11. Node activity reports as specified below:

- Airfield Nodes
- Airspace Nodes
- Check Points
- Dstaging Areas
- Deicing Areas
- Departure Queues
- Flow Nodes
- Flow post Nodes
- Gates
- Interface Nodes
- Meter Nodes
- Meter Post Nodes
- Staging Areas
- Taxi Checkpoints
- Towing Nodes
- Utun Nodes

APPENDIX C

FAA AIR TRAFFIC FORECASTS

Table 95 US Mainline Air carriers Scheduled Domestic RPM forecast evaluation [27]

U.S. MAINLINE AIR CARRIERS
SCHEDULED DOMESTIC REVENUE PASSENGER MILES (RPMs)
FORECAST EVALUATION

Year Being Forecast	Actual RPMs (Billions)	Forecast RPMs (Billions) Published -- Years Earlier					
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
1997	434.6	433.2	420.3	426.6	399.9	422.0	507.5
1998	444.7	453.0	451.6	441.0	443.8	414.9	509.2
1999	463.1	455.0	467.6	467.7	455.2	459.5	496.4
2000	490.0	479.0	466.1	482.4	484.1	469.6	492.6
2001	483.8	506.3	493.9	477.9	498.8	501.4	485.0
2002	443.2	425.8	527.0	515.7	505.7	528.8	509.8
2003	453.4	455.6	485.4	548.1	533.2	527.5	499.9
2004	488.4	475.9	473.0	507.7	571.7	556.2	553.3
2005		***496.7***	502.6	489.6	530.6	596.9	567.6
2006			***521.1***	521.7	506.5	553.1	622.1
2007				***541.4***	539.4	523.9	649.6
2008					***558.7***	558.8	650.4
2009						***577.7***	691.8
2010							737.1
2014							***686.8***

Year Being Forecast	Forecast RPMs Percent Error Published--Years Earlier					
	1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
1998	1.9	1.5	(0.8)	(0.2)	(6.7)	14.5
1999	(1.8)	1.0	1.0	(1.7)	(0.8)	7.2
2000	(2.3)	(4.9)	(1.6)	(1.2)	(4.2)	0.5
2001	4.7	2.1	(1.2)	3.1	3.6	0.3
2002	(3.9)	18.9	16.4	14.1	19.3	15.0
2003	0.5	7.1	20.9	17.6	16.3	10.3
2004	(2.6)	(3.2)	3.9	17.0	13.9	13.3

Note on how to read this table: In 2003 the FAA forecast 475.9 billion RPMs would occur in 2004. In fact, 488.4 billion RPMs were recorded, meaning the forecast was 2.6 percent lower than actual.

The 2005 forecast is shown in bold italics.

Table 96 FAA ARTCC Aircraft handled forecast evaluation [27]

FAA ARTCC AIRCRAFT HANDLED FORECAST EVALUATION

Year Being Forecast	Actual Activity (Millions)	Forecast Activity Level (Millions) Published -- Years Earlier					
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
1997	41.4	40.9	42.2	41.5	40.3	40.7	46.0
1998	43.2	42.0	41.8	43.4	42.4	41.1	46.1
1999	44.7	44.2	42.6	42.5	44.4	43.4	46.0
2000	46.0	45.7	45.2	43.2	43.5	45.3	47.1
2001	45.2	47.0	46.8	46.2	44.2	44.4	46.6
2002	43.7	43.2	48.1	48.0	47.3	45.2	45.1
2003	43.7	43.6	45.4	49.3	49.0	48.4	45.0
2004	46.2	45.1	44.8	46.5	50.4	50.1	47.3
2005		***46.9***	46.8	46.0	47.6	51.8	49.3
2006			***48.5***	47.9	47.0	48.6	48.5
2007				***49.7***	48.9	48.0	49.6
2008					***50.7***	49.9	54.2
2009						***51.7***	56.7
2010							58.6
2014							***57.5***

Year Being Forecast	Forecast Activity Percent Error Published--Years Earlier					
	1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
1998	(2.8)	(3.2)	0.5	(1.9)	(4.9)	6.7
1999	(1.1)	(4.7)	(4.9)	(0.7)	(2.9)	2.9
2000	(0.7)	(1.8)	(6.1)	(5.5)	(1.6)	2.3
2001	4.0	3.5	2.1	(2.3)	(1.8)	3.0
2002	(1.2)	10.1	9.8	8.2	3.4	3.1
2003	(0.4)	3.8	12.7	12.0	10.6	2.9
2004	(2.3)	(3.0)	0.6	9.1	8.4	2.3

Note on how to read this table: In 2003 the FAA forecast 45.1 million aircraft would be handled in 2004. In fact, 46.2 million aircraft were recorded, meaning the forecast was 2.3 percent lower than actual.

The 2005 forecast is shown in bold italics.

Table 97 US Long-term Economic Forecasts [27]

U.S. LONG-TERM ECONOMIC FORECASTS

FISCAL YEAR	GROSS DOMESTIC PRODUCT (Billions 2000$)	CONSUMER PRICE INDEX (1982-84=100)	OIL AND GAS PRICE INDEX (CY 2000 = 100)
Historical			
1999	9,361.9	165.5	74.1
2000	9,762.8	170.7	96.0
2001	9,885.1	176.2	101.2
2002	10,018.4	178.9	87.2
2003	10,270.1	183.1	103.3
2004E	10,738.2	187.3	116.8
Forecast			
2005	11,136.6	192.5	141.6
2006	11,528.2	196.7	127.9
2007	11,916.3	201.3	120.2
2008	12,298.2	206.2	118.1
2009	12,685.3	211.1	120.6
2010	13,078.5	216.2	123.1
2011	13,483.9	221.5	125.7
2012	13,896.7	227.0	128.3
2013	14,314.2	232.7	131.0
2014	14,745.0	238.5	133.7
2015	15,188.9	244.5	136.5
2016	15,646.1	250.6	139.4

Source: 2004-2015; Office of Management and Budget, December 2004. Extrapolated to 2016.

Table 98 International GDP forecasts by travel region [27]

INTERNATIONAL GDP FORECASTS BY TRAVEL REGION

CALENDAR YEAR	GROSS DOMESTIC PRODUCT (In Billions of 2000 U.S. Dollars)				
	CANADA	EUROPE/ AFRICA/ MIDDLE EAST	LATIN AMERICA/ MEXICO	JAPAN/PACIFIC BASIN/CHINA/OTHER ASIA/AUSTRALIA/ N. ZEALAND	WORLD
Historical					
1999	688.7	9,966.5	1,766.8	7,920.0	30,284.2
2000	724.8	10,366.7	1,836.5	8,268.6	31,513.0
2001	737.8	10,529.7	1,838.6	8,429.6	31,972.3
2002	763.2	10,694.2	1,818.1	8,618.7	32,527.3
2003	778.7	10,858.4	1,843.8	8,966.0	33,423.8
2004E	801.7	11,188.9	1,940.8	9,435.2	34,830.9
Forecast					
2005	826.5	11,500.1	2,013.4	9,791.4	35,980.5
2006	848.7	11,824.5	2,086.3	10,160.7	37,141.6
2007	877.3	12,165.1	2,167.1	10,532.0	38,357.0
2008	906.4	12,494.5	2,251.4	10,911.1	39,583.6
2009	934.1	12,822.1	2,339.9	11,307.2	40,849.3
2010	962.4	13,161.2	2,432.3	11,712.5	42,163.8
2011	991.1	13,509.3	2,528.2	12,128.3	43,508.6
2012	1,018.8	13,862.6	2,628.9	12,553.6	44,880.4
2013	1,044.9	14,225.2	2,733.9	12,989.7	46,299.9
2014	1,069.9	14,593.4	2,843.8	13,441.2	47,801.5
2015	1,094.6	14,969.8	2,958.5	13,902.8	49,303.7
2016	1,119.2	15,353.1	3,077.8	14,379.1	50,825.2

Source: Global Insight, World Economic Outlook, November 2004.

Table 99 International GDP Forecasts-Selected areas and Countries [27]

INTERNATIONAL GDP FORECASTS--SELECTED AREAS/COUNTRIES

CALENDAR YEAR	GROSS DOMESTIC PRODUCT (In Billions of 2000 U.S. Dollars)				
	NORTH AMERICA (NAFTA)	EUROZONE	UNITED KINGDOM	JAPAN	CHINA
Historical					
1999	10,704.2	5,842.6	1,385.7	4,618.8	1,000.7
2000	11,122.3	6,058.6	1,439.2	4,747.8	1,080.7
2001	11,208.2	6,160.7	1,472.3	4,768.3	1,161.8
2002	11,421.8	6,215.6	1,498.3	4,753.0	1,254.7
2003	11,751.6	6,250.4	1,532.0	4,870.7	1,368.9
2004E	12,253.5	6,368.3	1,580.5	5,070.8	1,493.3
Forecast					
2005	12,651.6	6,482.9	1,621.3	5,170.8	1,603.3
2006	13,033.7	6,623.4	1,659.6	5,277.0	1,720.3
2007	13,449.4	6,770.2	1,706.8	5,378.7	1,843.5
2008	13,874.7	6,908.8	1,752.3	5,475.5	1,972.6
2009	14,321.5	7,045.9	1,796.2	5,568.6	2,110.5
2010	14,793.5	7,187.2	1,843.3	5,661.8	2,253.0
2011	15,275.1	7,330.9	1,891.2	5,757.7	2,401.3
2012	15,763.9	7,476.7	1,939.2	5,854.7	2,555.9
2013	16,275.3	7,627.0	1,988.3	5,951.2	2,719.4
2014	16,842.9	7,778.5	2,037.0	6,045.6	2,895.7
2015	17,389.1	7,935.3	2,085.7	6,137.6	3,081.1
2016	17,927.8	8,092.4	2,135.3	6,228.5	3,279.9

Source: Global Insight, World Economic Outlook, November 2004.

Table 100 U.S. Commercial Air carriers Scheduled passenger capacity, traffic and load factors [27]

U.S. COMMERCIAL AIR CARRIERS 1/

SCHEDULED PASSENGER CAPACITY, TRAFFIC, AND LOAD FACTORS

	DOMESTIC			INTERNATIONAL			SYSTEM		
FISCAL YEAR	ASMs (BIL)	RPMs (BIL)	% LOAD FACTOR	ASMs (BIL)	RPMs (BIL)	% LOAD FACTOR	ASMs (BIL)	RPMs (BIL)	% LOAD FACTOR
Historical*									
1999	694.7	482.4	69.4	230.1	170.1	73.9	924.8	652.4	70.5
2000	726.6	512.8	70.6	239.3	181.8	76.0	965.9	694.6	71.9
2001	732.5	508.1	69.4	246.6	183.3	74.3	979.1	691.4	70.6
2002	681.3	473.0	69.4	212.3	158.2	74.5	893.6	631.3	70.6
2003	684.4	492.8	72.0	207.0	155.9	75.3	891.3	648.6	72.8
2004E	729.9	540.0	74.0	223.7	177.4	79.3	953.6	717.4	75.2
Forecast									
2005	749.5	559.7	74.7	250.3	198.0	79.1	999.7	757.8	75.8
2006	792.2	592.0	74.7	270.3	213.6	79.0	1,062.4	805.5	75.8
2007	826.6	618.2	74.8	287.3	226.8	78.9	1,113.9	845.0	75.9
2008	855.6	639.6	74.8	303.0	238.9	78.9	1,158.6	878.6	75.8
2009	885.8	662.8	74.8	317.8	250.6	78.9	1,203.6	913.4	75.9
2010	918.1	687.9	74.9	332.6	262.2	78.8	1,250.7	950.1	76.0
2011	950.5	712.6	75.0	347.3	273.8	78.8	1,297.8	986.4	76.0
2012	983.9	738.2	75.0	362.6	285.7	78.8	1,346.5	1,023.9	76.0
2013	1,019.1	765.2	75.1	378.0	297.9	78.8	1,397.0	1,063.1	76.1
2014	1,056.8	794.5	75.2	394.0	310.4	78.8	1,450.8	1,104.9	76.2
2015	1,097.5	826.2	75.3	410.4	323.2	78.8	1,507.9	1,149.4	76.2
2016	1,138.9	858.5	75.4	427.2	336.3	78.7	1,566.1	1,194.8	76.3

* Source: Forms 41 and 298-C, U.S. Department of Transportation.
1/ Sum of Mainline Air Carriers and Regionals/Commuters

Table 101 U.S. Commercial Aircarriers-
Total scheduled US International passenger traffic [27]

U.S. COMMERCIAL AIR CARRIERS 1/

TOTAL SCHEDULED U.S. INTERNATIONAL PASSENGER TRAFFIC

	REVENUE PASSENGER ENPLANEMENTS				REVENUE PASSENGER MILES			
FISCAL YEAR	ATLANTIC (Mil)	LATIN AMERICA (Mil)	PACIFIC (Mil)	TOTAL INTERNATIONAL (Mil)	ATLANTIC (Bil)	LATIN AMERICA (Bil)	PACIFIC (Bil)	TOTAL INTERNATIONAL (Bil)
Historical*								
1999	19.1	23.5	12.3	54.9	79.6	34.4	56.1	170.1
2000	20.9	24.3	11.2	56.4	87.1	36.3	58.4	181.8
2001	20.5	24.8	11.4	56.7	86.2	37.6	59.4	183.3
2002	18.0	23.6	9.6	51.2	74.7	34.5	49.0	158.2
2003	17.8	25.8	10.5	54.1	73.2	36.5	46.2	155.9
2004E	19.9	29.1	12.3	61.3	82.1	41.7	53.5	177.4
Forecast								
2005	21.8	33.0	13.2	68.0	90.8	48.0	59.1	198.0
2006	23.2	34.7	14.2	72.2	97.3	52.1	64.2	213.6
2007	24.3	36.5	15.2	76.0	102.3	55.8	68.8	226.8
2008	25.3	38.3	16.1	79.7	106.6	59.2	73.1	238.9
2009	26.2	40.2	17.0	83.4	110.6	62.8	77.2	250.6
2010	27.1	42.2	17.8	87.1	114.6	66.5	81.1	262.2
2011	28.0	44.3	18.6	90.8	118.6	70.3	85.0	273.8
2012	28.9	46.4	19.4	94.6	122.7	74.2	88.8	285.7
2013	29.8	48.6	20.2	98.6	126.9	78.3	92.7	297.9
2014	30.8	50.9	21.0	102.7	131.2	82.5	96.7	310.4
2015	31.7	53.3	21.9	106.9	135.7	86.9	100.6	323.2
2016	32.7	55.8	22.7	111.2	140.2	91.5	104.7	336.3

* Source: Forms 41 and 298-C, U.S. Department of Transportation.
1/ Sum of Mainline Air Carriers and Regionals/Commuters

Table 102 U.S. Mainline Air carriers-Scheduled Passenger Traffic [27]

U. S. MAINLINE AIR CARRIERS

SCHEDULED PASSENGER TRAFFIC

FISCAL YEAR	REVENUE PASSENGER ENPLANEMENTS (Millions)			REVENUE PASSENGER MILES (Billions)		
	DOMESTIC	INTERNATIONAL	SYSTEM	DOMESTIC	INTERNATIONAL	SYSTEM
Historical*						
1999	537.8	52.1	589.9	463.1	169.4	632.5
2000	561.5	53.3	614.8	490.0	181.0	670.9
2001	546.3	53.5	599.9	483.8	182.3	666.1
2002	485.9	48.4	534.3	443.2	157.3	600.5
2003	482.8	50.6	533.4	453.4	154.8	608.2
2004E	502.2	57.3	559.5	488.4	175.9	664.3
Forecast						
2005	505.7	63.0	568.7	496.7	195.9	692.7
2006	524.4	66.9	591.4	521.1	211.4	732.5
2007	541.2	70.6	611.8	541.4	224.5	765.9
2008	555.8	74.0	629.9	558.7	236.5	795.2
2009	571.4	77.4	648.8	577.7	248.0	825.8
2010	588.0	80.9	668.8	598.5	259.5	858.0
2011	604.4	84.3	688.7	618.9	271.0	889.9
2012	621.3	87.8	709.2	639.9	282.7	922.6
2013	639.4	91.5	730.8	662.3	294.7	957.0
2014	658.5	95.2	753.8	686.8	307.1	993.9
2015	679.0	99.1	778.0	713.6	319.7	1,033.3
2016	700.0	103.0	803.0	740.7	332.6	1,073.3

* Source: Form 41, U.S. Department of Transportation.

Table 103 U.S. Mainline Air Carriers passenger Jet Aircraft [27]

U.S. MAINLINE AIR CARRIERS

PASSENGER JET AIRCRAFT

CALENDAR	LARGE NARROWBODY				LARGE WIDEBODY				LARGE	REGIONAL	TOTAL
YEAR	2 ENGINE	3 ENGINE	4 ENGINE	TOTAL	2 ENGINE	3 ENGINE	4 ENGINE	TOTAL	JETS	JETS	JETS
Historical											
1999	3,139	436	10	3,585	361	204	129	694	4,279	18	4,297
2000	3,364	385	0	3,749	424	169	120	713	4,462	26	4,488
2001	3,412	187	0	3,599	451	89	85	625	4,224	20	4,244
2002	3,387	107	0	3,494	472	69	81	622	4,116	3	4,119
2003	3,379	70	0	3,449	464	37	67	568	4,017	6	4,023
2004E	3,399	65	0	3,464	478	34	66	578	4,042	4	4,046
Forecast											
2005	3,480	65	0	3,545	494	35	66	595	4,140	11	4,151
2006	3,628	64	0	3,692	503	30	66	599	4,291	29	4,320
2007	3,780	63	0	3,843	510	20	66	596	4,439	47	4,486
2008	3,900	62	0	3,962	527	12	66	605	4,567	65	4,632
2009	4,028	61	0	4,089	541	10	65	616	4,705	84	4,789
2010	4,167	60	0	4,227	554	8	62	624	4,851	102	4,953
2011	4,320	59	0	4,379	567	8	58	633	5,012	119	5,131
2012	4,458	58	0	4,516	579	8	58	645	5,161	139	5,300
2013	4,596	58	0	4,654	591	8	58	657	5,311	159	5,470
2014	4,734	58	0	4,792	602	8	58	668	5,460	179	5,639
2015	4,876	58	0	4,934	614	8	58	680	5,614	199	5,813
2016	5,029	58	0	5,087	627	8	58	693	5,780	219	5,999

Table 104 Forecast of operations at 35 Operational Evolution Plan (OEP) airports [27] Source FAA

Table S-2.
Airport Operations At The 35 OEP Airports
(In Thousands)

Loc ID	Reg	Airport Name	2003	2003* Percent	2004	2008	2020	Airport Ranking 2003	Airport Ranking 2020
ORD	AGL	CHICAGO O'HARE INTL	923	0.77	989	1,076	1,304	1	2
ATL	ASO	THE WILLIAM B HARTSFIELD ATLANTA INTL	895	0.74	962	1,131	1,414	2	1
DFW	ASW	DALLAS/FORT WORTH INTERNATIONAL	769	0.64	816	807	987	3	5
LAX	AWP	LOS ANGELES INTL	630	0.52	646	746	987	4	4
PHX	AWP	PHOENIX SKY HARBOR INTL	594	0.49	596	677	853	5	8
DEN	ANM	DENVER INTL	508	0.42	567	644	831	6	10
MSP	AGL	MINNEAPOLIS-ST PAUL INTL/WOLD-CHAMBERLAIN/	506	0.42	533	629	874	7	7
LAS	AWP	MC CARRAN INTL	501	0.42	543	622	796	8	11
CVG	ASO	CINCINNATI/NORTHERN KENTUCKY INTERNATIONAL	496	0.41	519	601	781	9	13
DTW	AGL	DETROIT METROPOLITAN WAYNE COUNTY	491	0.41	514	643	832	10	9
IAH	ASW	GEORGE BUSH INTERCONTINENTAL	469	0.39	513	642	928	11	6
PHL	AEA	PHILADELPHIA INTL	448	0.37	455	599	789	12	12
CLT	ASO	CHARLOTTE/DOUGLAS INTL	438	0.36	458	565	673	13	14
MIA	ASO	MIAMI INTL	422	0.35	397	413	505	14	24
STL	ACE	LAMBERT-ST LOUIS INTL	420	0.35	295	318	375	15	28
EWR	AEA	NEWARK LIBERTY INTL	407	0.34	434	493	624	16	16
MEM	ASO	MEMPHIS INTL	402	0.33	382	444	607	17	17
SLC	ANM	SALT LAKE CITY INTL	400	0.33	421	525	663	18	15
BOS	ANE	GENERAL EDWARD LAWRENCE LOGAN INTL	381	0.32	409	470	556	19	20
LGA	AEA	LA GUARDIA	376	0.31	398	403	403	20	27
IAD	AEA	WASHINGTON DULLES INTERNATIONAL	368	0.31	438	735	1,079	21	3
PIT	AEA	PITTSBURGH INTERNATIONAL	366	0.30	355	297	338	22	33
SEA	ANM	SEATTLE-TACOMA INTL	355	0.30	361	405	517	23	21
SFO	AWP	SAN FRANCISCO INTERNATIONAL	335	0.28	352	405	514	24	22
MDW	AGL	CHICAGO MIDWAY INTL	321	0.27	341	334	369	25	30
HNL	AWP	HONOLULU INTL	310	0.26	307	350	412	26	26
MCO	ASO	ORLANDO INTL	296	0.25	316	429	578	27	18
BWI	AEA	BALTIMORE-WASHINGTON INTL	295	0.25	307	378	506	28	23
JFK	AEA	JOHN F KENNEDY INTL	294	0.24	318	422	566	29	19
FLL	ASO	FORT LAUDERDALE/HOLLYWOOD INTL	283	0.24	306	373	486	30	25
PDX	ANM	PORTLAND INTL	272	0.23	275	310	369	31	29
CLE	AGL	CLEVELAND-HOPKINS INTL	255	0.21	253	283	344	32	32
DCA	AEA	RONALD REAGAN WASHINGTON NATIONAL	250	0.21	268	284	292	33	35
TPA	ASO	TAMPA INTL	232	0.19	238	293	364	34	31
SAN	AWP	SAN DIEGO INTL-LINDBERGH FLD	206	0.17	211	241	299	35	34
Totals			14,931	12.38	15,511	18,004	22,834		

*Percent of total US operations.

Table 105 APO Terminal Area Forecast –DFW [34]

APO TERMINAL AREA FORECAST DETAIL REPORT
Forecast Issued February 2006
AIRCRAFT OPERATIONS

	Scheduled Enplanements			Itinerant Operations					Local Operations				
Year	AC	Comm.	Total	AC	AT & Comm.	GA	Mil	Total	GA	Mil	Total	Total OPS	Total Inst.OPS
AIRPORT:DALLAS/FORT WORTH INTERNATIONAL													
2000	25,998,579	2,663,284	28,661,863	609,681	218,322	25,083	269	853,355	22,158	160	22,318	875,673	878,461
2001	24,320,792	2,608,494	26,929,286	585,705	212,433	13,144	284	811,566	23,823	359	24,182	835,748	835,727
2002	21,445,591	2,976,905	24,422,496	493,772	243,194	12,784	219	749,969	12,133	269	12,402	762,371	763,211
2003	20,793,894	3,807,587	24,601,481	458,863	292,683	6,837	153	758,536	10,780	257	11,037	769,573	770,706
2004	22,726,900	4,820,814	27,547,714	493,887	302,087	6,470	183	802,627	13,479	206	13,685	816,312	816,910
2005*	24,154,107	3,774,697	27,928,804	492,457	233,207	8,520	261	734,445	4,986	86	5,072	739,517	744,743
2006*	24,023,711	3,944,558	27,968,269	477,190	234,606	8,520	261	720,577	4,986	86	5,072	725,649	730,897
2007*	24,721,998	4,129,951	28,851,949	489,119	244,224	8,520	261	742,124	4,986	86	5,072	747,196	752,394
2008*	25,327,055	4,303,408	29,630,463	499,878	252,282	8,520	261	760,941	4,986	86	5,072	766,013	771,183
2009*	25,948,176	4,484,150	30,432,326	510,874	260,606	8,520	261	780,261	4,986	86	5,072	785,333	790,488
2010*	26,585,838	4,672,483	31,258,321	522,111	269,204	8,520	261	800,096	4,986	86	5,072	805,168	810,317
2011*	27,172,188	4,836,019	32,008,207	530,985	276,471	8,520	261	816,237	4,986	86	5,072	821,309	826,468
2012*	27,772,341	5,005,279	32,777,620	540,011	283,934	8,520	261	832,726	4,986	86	5,072	837,798	842,965
2013*	28,386,651	5,180,463	33,567,114	549,190	291,599	8,520	261	849,570	4,986	86	5,072	854,642	859,819
2014*	29,015,485	5,361,778	34,377,263	558,525	299,471	8,520	261	866,777	4,986	86	5,072	871,849	877,034
2015*	29,659,217	5,549,439	35,208,656	568,017	307,555	8,520	261	884,353	4,986	86	5,072	889,425	894,615
2016*	30,318,234	5,743,668	36,061,902	577,671	315,857	8,520	261	902,309	4,986	86	5,072	907,381	912,576
2017*	30,992,933	5,944,695	36,937,628	587,489	324,384	8,520	261	920,654	4,986	86	5,072	925,726	930,925
2018*	31,683,722	6,152,758	37,836,480	597,474	333,141	8,520	261	939,396	4,986	86	5,072	944,468	949,672
2019*	32,391,023	6,368,104	38,759,127	607,629	342,134	8,520	261	958,544	4,986	86	5,072	963,616	968,824
2020*	33,115,267	6,590,987	39,706,254	617,957	351,370	8,520	261	978,108	4,986	86	5,072	983,180	988,393
2021*	33,856,900	6,821,671	40,678,571	628,459	360,856	8,520	261	998,096	4,986	86	5,072	1,003,168	1,008,386
2022*	34,616,382	7,060,428	41,676,810	639,141	370,597	8,520	261	1,018,519	4,986	86	5,072	1,023,591	1,028,815
2023*	35,394,181	7,307,542	42,701,723	650,005	380,602	8,520	261	1,039,388	4,986	86	5,072	1,044,460	1,049,692
2024*	36,190,784	7,563,305	43,754,089	661,053	390,877	8,520	261	1,060,711	4,986	86	5,072	1,065,783	1,071,025
2025*	37,006,690	7,828,020	44,834,710	672,289	401,430	8,520	261	1,082,500	4,986	86	5,072	1,087,572	1,092,822

COMMENT : COMMERCIAL OPERATIONS ADJUSTED TO CONFORM TO OAG DATA FOR 2003 AND 2004.

APPENDIX D

AIRPORT OBSTRUCTIONS STANDARDS COMMITTEE (AOSC)
DECISION DOCUMENT #06

Airport Obstructions Standards Committee (AOSC)
Decision Document #06

Approved: June 8, 2005

Dallas / Fort Worth (DFW) End-Around Taxiway System

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1) Introduction

a) The Dallas / Fort Worth International Airport (DFW) has proposed the construction and operation of end-around taxiways (EAT) for their north/south runways. As designed, these EATs would provide unrestricted taxi to and from the terminal by both arriving and departing aircraft, eliminating the majority of DFW's 1,700 daily runway crossings and also serving to reduce departure delays.

b) The results of a joint FAA and NASA study performed in February 2003 indicated that the proposed end-around taxiways would reduce controller-pilot communications by approximately 25%. In addition, an FAA Technical Center report has projected the full DFW EAT system (all four quadrants) would provide a 30% efficiency gain at a cost of approximately $260M and defer the need for a $1.3B runway project that was projected in the 2001 Airport Capacity Benchmark Report to improve the airport capacity benchmark by 3% in good weather and by 17% in adverse weather.

c) Aside from a July 2004 AOSC decision document approving a proposal for EAT operations beyond the end of a single runway at Atlanta, there are currently no other regulatory criteria or standards that specifically govern EAT design and/or operation. The FAA has reviewed the proposed DFW EAT operational concept and conducted several test simulations to address the viability of these proposed EAT operations. It is expected that the results of these simulations and previous studies will contribute to the development of a national EAT standard.

d) Although DFW's proposal includes both arrivals and departures over the EAT, the departure-only case still achieves a favorable benefit-cost ratio for the project. Given the added complexities of the "arrival over end-around" case, the Agency initially focused on the "departure over end-around" case.

2) Rationale for Decision

a) In August 2004, a proof-of-concept demonstration in level D flight simulators was performed to gather human factors and operational information. In addition, the Flight Standards Service (AFS-420) performed a Terminal Instrument Procedures (TERPS) analysis of the DFW proposal.

b) From a human factors perspective, the initial AFS report (November 2004) indicated no appreciable increase in physical workload that would lead to a compromise in current levels of safety. There were indications, however, in both the objective and subjective data that it was not easy for pilots to determine whether an aircraft was incurring the runway or safely operating on the EAT. These indicators pointed to the need for specific visual and operational mitigators as well as pilot training that address EAT operations.

c) In December 2004, the AOSC agreed to pursue efforts to develop a physical visual barrier that would visually mask the aircraft in such a manner that the departing pilot could discriminate between a runway incursion and aircraft operating on the EAT. Subsequent PC-based simulations were used to help develop a more comprehensive level-D simulation to evaluate the effectiveness of various visual barrier options. This level-D simulation was conducted in April 2005. Simulation results, which included associated pilot feedback, indicated that a visual barrier that would mask up to the top of the engines of an aircraft on the EAT is sufficient to provide a masking effect that will optimize aircraft discernability. The William J. Hughes Technical Center has begun work to develop appropriate design specifications for this visual barrier.

d) The US Standard for Terminal Instrument Approach Procedures (TERPS) requires protection of the 40:1 Obstacle Clearance Surface (OCS) from penetrations by the tails of taxiing aircraft. Analysis of the DFW proposal indicated that aircraft with tail heights up to 65 feet (Group V) can operate in all weather conditions on the EAT without penetrating the 40:1 departure surface. Aircraft with taller tail heights should be controlled so that no over flights of those aircraft occur. Aircraft operators, however, will need to take into account the maximum tail height of aircraft on the end-around taxiway for One-Engine-Inoperative (OEI) surface (62.5:1) considerations.

e) In July 2004, analysis based on 22 years of incident / accident data showed an acceptable risk level (0.6 x 10-7) associated with allowing taxiing aircraft in the Runway Protection Zone (RPZ) of runways with length of 9,000 feet or more, as long as the taxiing operations remain outside the 1000-foot x 500-foot Runway Safety Area (RSA). No taxiways in the DFW EAT design are located within the departure RPZ or RSA.

3) <u>AOSC Decision</u>

Since all evaluations to-date have specifically targeted EAT operations in the Southeast quadrant of DFW, the AOSC approves the proposed unrestricted departures over the end around taxiway for that quadrant at DFW (as depicted on the approved Airport Layout Plan and submitted by DFW as a 15% design), including a visual barrier with an effective height of 13-feet as determined by the analysis completed to date. The outer taxiway will be located 2,650 feet beyond the runway threshold. Taxiway design and usage will be in accordance with standard taxiway requirements and/or limitations, and usage is approved in all weather conditions. The design limits EAT operations to Group V aircraft (65-foot tail height).

4) <u>Action Plan</u>

<u>ARP</u>

a) Provide conditional approval to DFW for the completion of the design and construction of the proposed EAT (SE quadrant) under the following guidelines:

i) A visual barrier must be constructed at least 1,100 feet from the departure end of the runway (DER) for both runways in the quadrant.

ii) The effective height of the visual barriers must be 13 feet as measured from the DER elevation and the barriers must extend 350 feet on both sides of the runway centerline.

iii) The specific visual barrier design must meet the specifications currently being developed at the William J. Hughes Technical Center and must be reviewed and approved prior to construction start.

b) ARP (AAS-100) will provide oversight and funding of the ongoing Technical Center study to determine the visual barrier design requirements and provide a draft visual barrier design standard to the AOSC for approval by September 30, 2007. The standard will include, at a minimum, specifications for physical composition, color scheme, recommended lighting, and recommended implementation requirements.

<u>AVS</u>

a) Provide support to the William J. Hughes Technical Center design study for the visual barrier, primarily providing input regarding operational considerations.

b) Establish EAT pilot training requirements.

<u>ATO</u>

a) Provide support to the William J. Hughes Technical Center design study for the visual barrier.

Airport Obstructions Standards Committee (AOSC) Decision Document #06

Dallas / Fort Worth (DFW) End-Around Taxiway System

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APPENDIX E

FAA PERIMETER TAXIWAY OPERATIONS PHOTOGRAPHS

FAA PERIMETER TAXIWAY OPERATIONS PHOTOGRAPHS-DFW

Figure 91 Aircraft overflying an aircraft on PT

Figure 92 View towards the runway. Arrival aircraft over aircrafts on PT

Figure 93 View of large aircraft overflying a heavy aircraft on PT

Figure 94 View toward the runway. A large aircraft overflying a large aircraft on PT

APPENDIX F

DFW RUNWAY INCURSIONS

DFW RUNWAY INCURSIONS

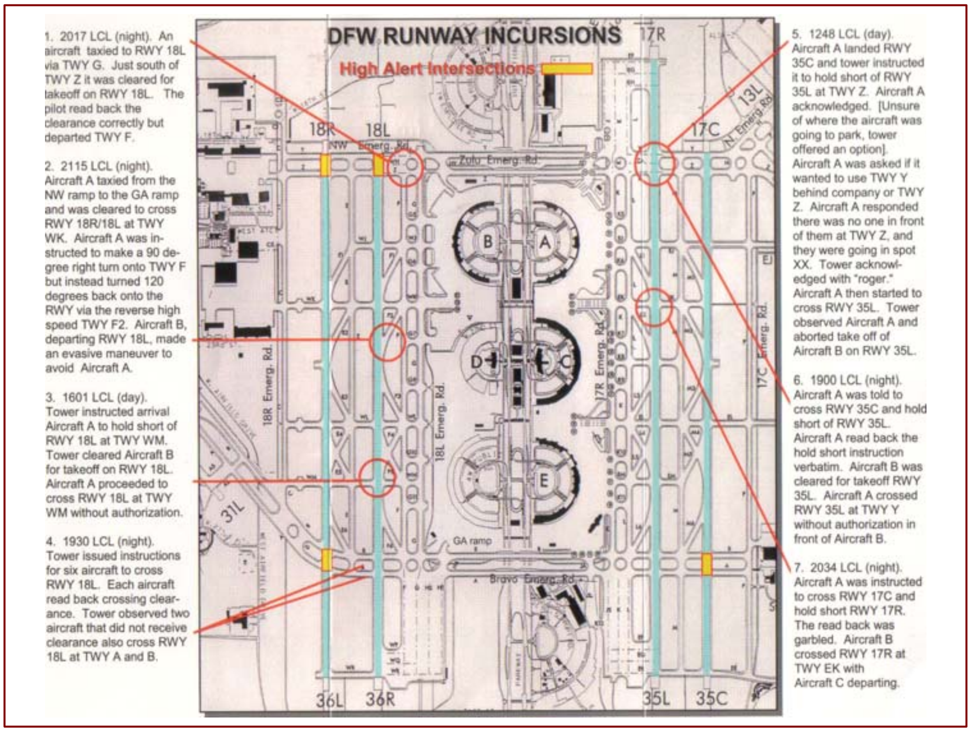


Figure 95 Runway incursions at DFW

For the four-year period, the FAA identified the following common errors that contribute to pilot deviations:

- Pilots read back controllers' instructions correctly but did not comply with the instructions,
- Pilots failed to hold short of the runway as instructed and crossed or taxied into position on the runway, and
- Pilots accepted clearances issued to an aircraft other than their own.

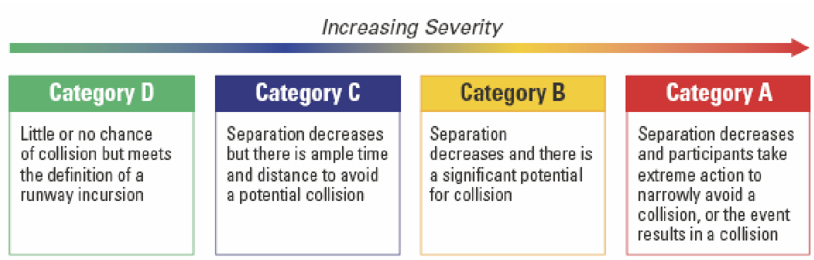


Figure 96 Runway incursions severity categories

APPENDIX G

DFW TAXIWAY LAYOUT FOR SOUTH AND NORTH FLOW

DFW TAXIWAY LAYOUT FOR SOUTH AND NORTH FLOW

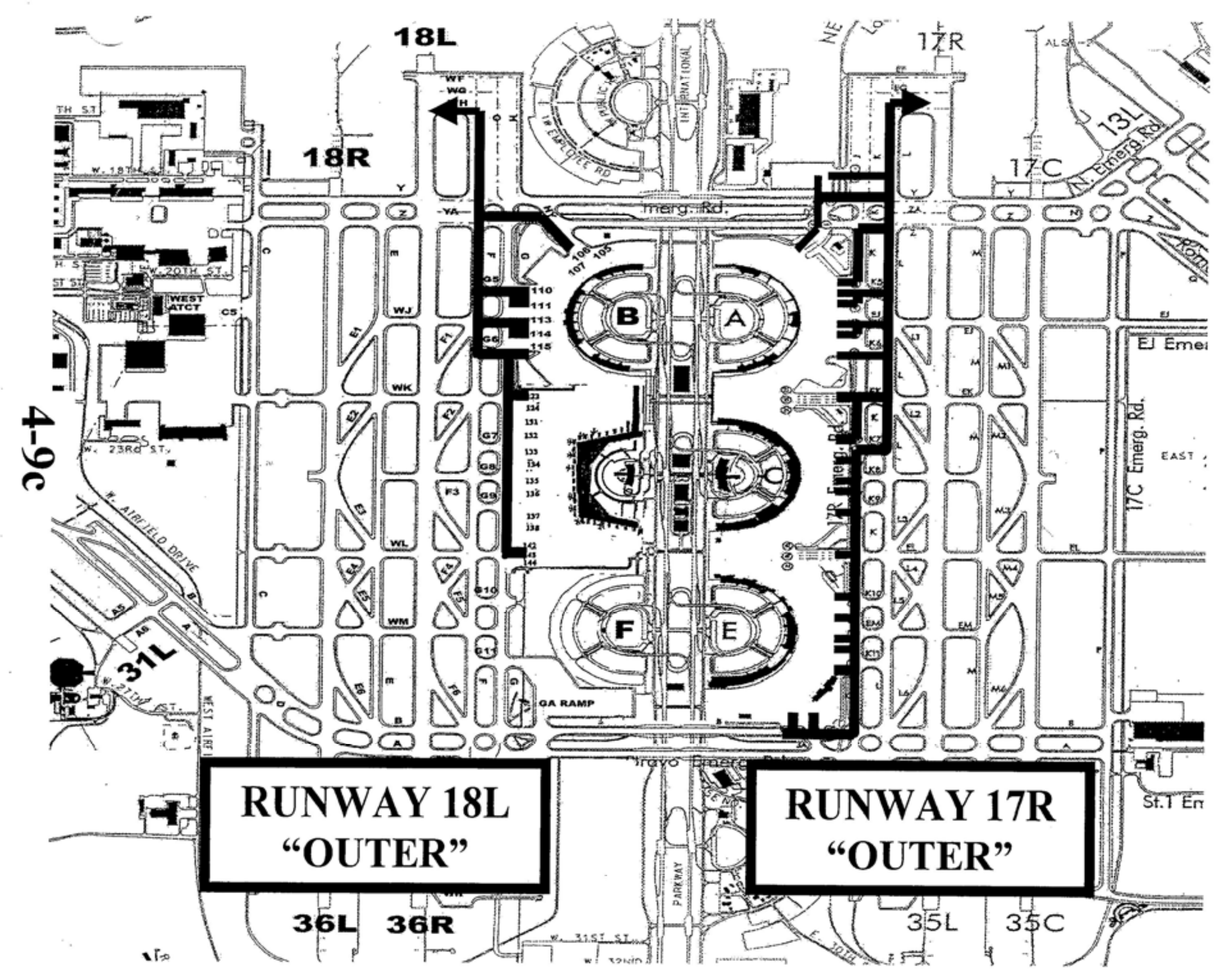


Figure 97 Taxiway Systems for Runway 18L and 17R
"Outer" South Flow

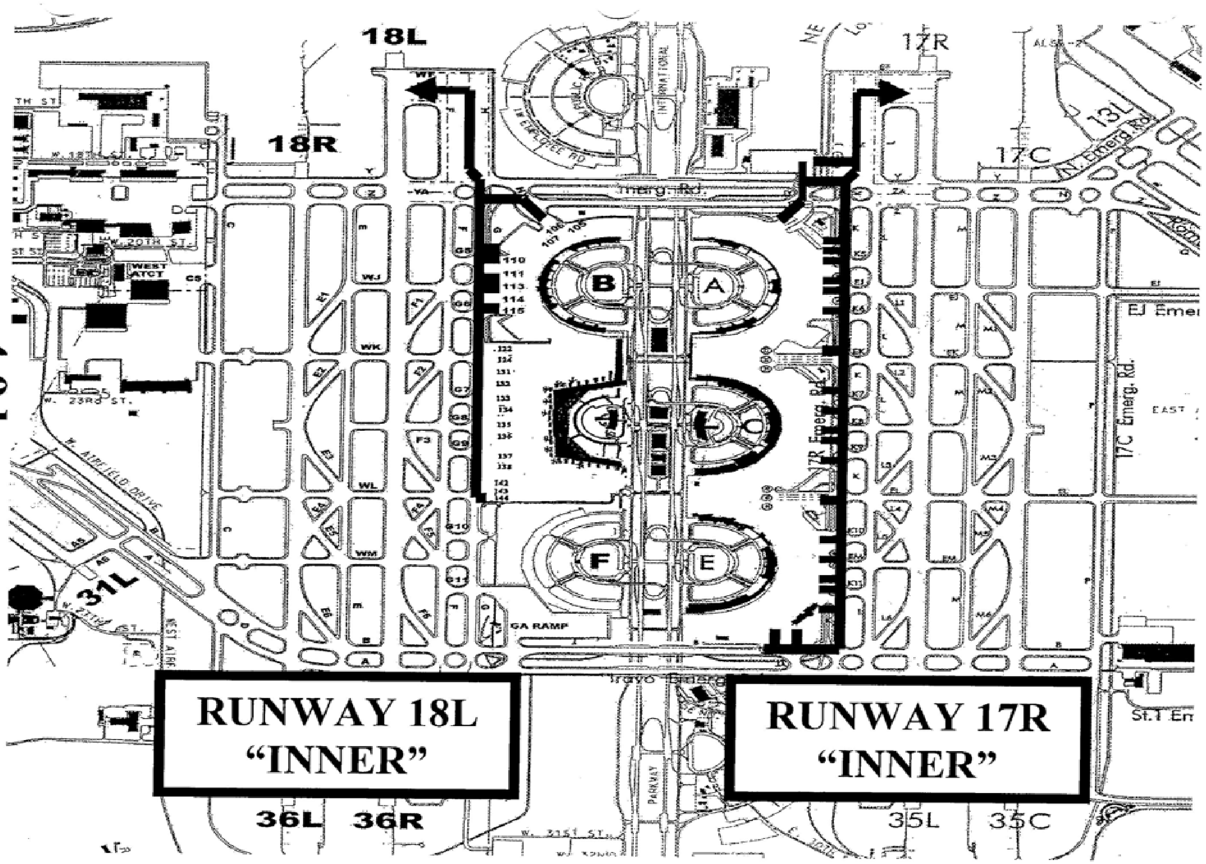
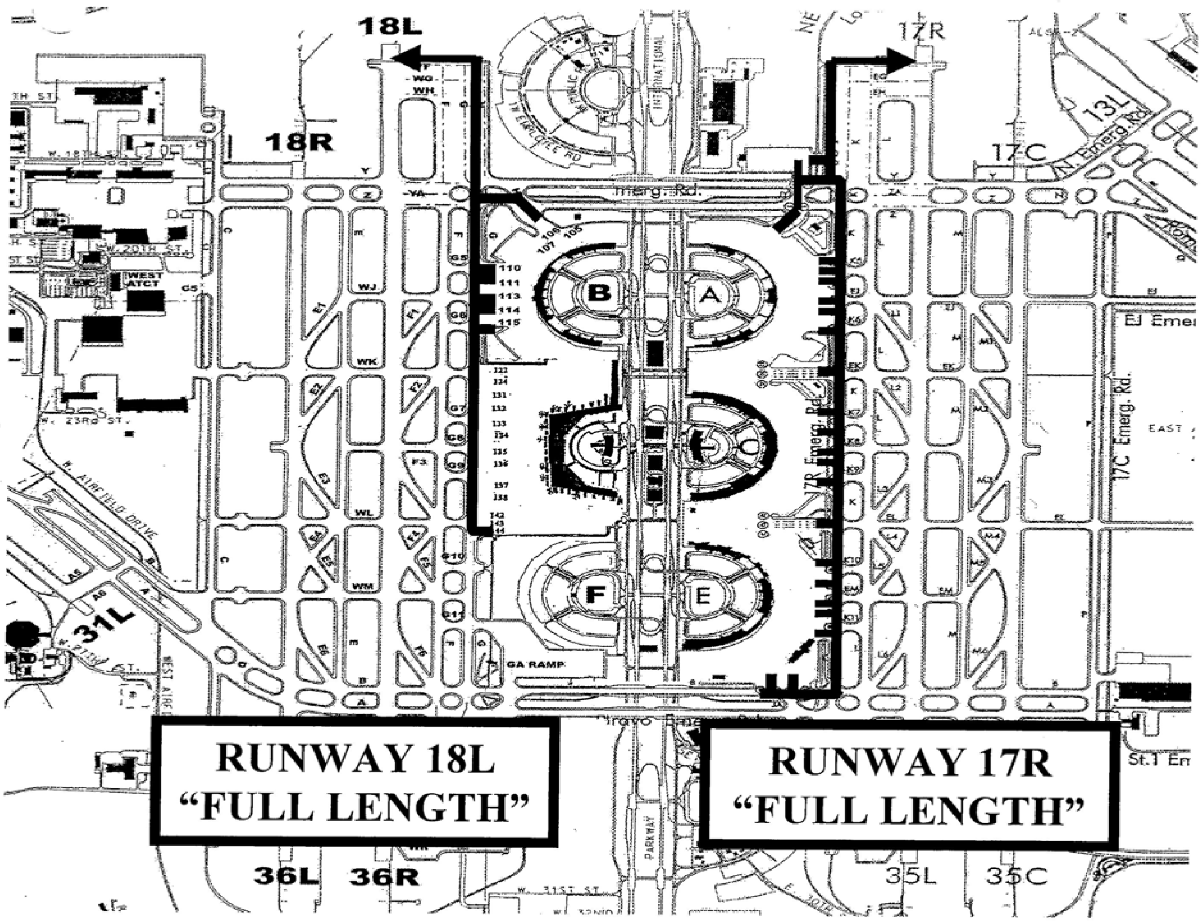


Figure 98 Taxiway Systems for Runway 18L and 17R "Inner" South Flow



4-9e

Figure 99 Taxiway Systems for Runway 18L and 17R
"Full Length" South Flow

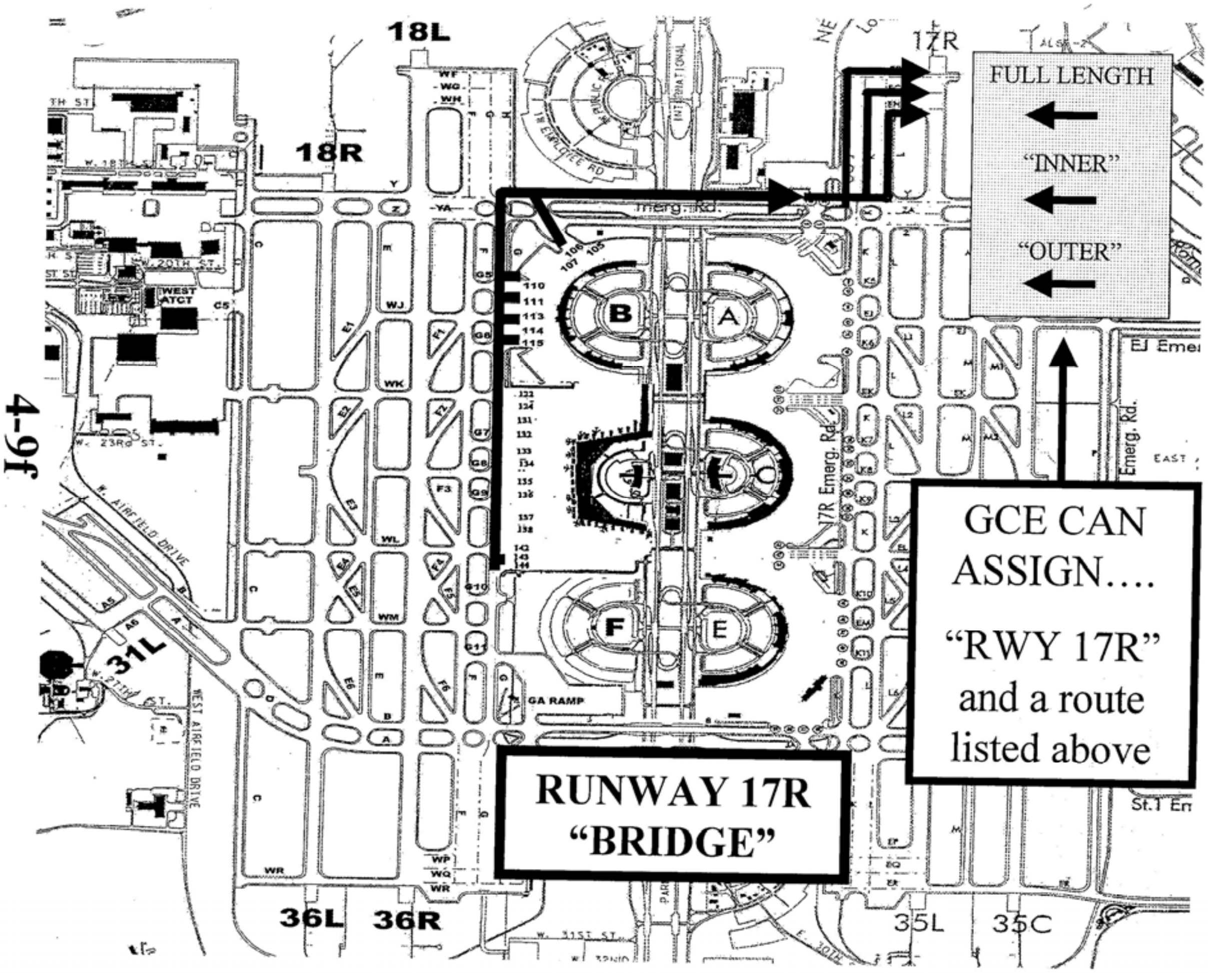


Figure 100 Taxiway Systems for Runway 18L and 17R
"Bridger" South Flow

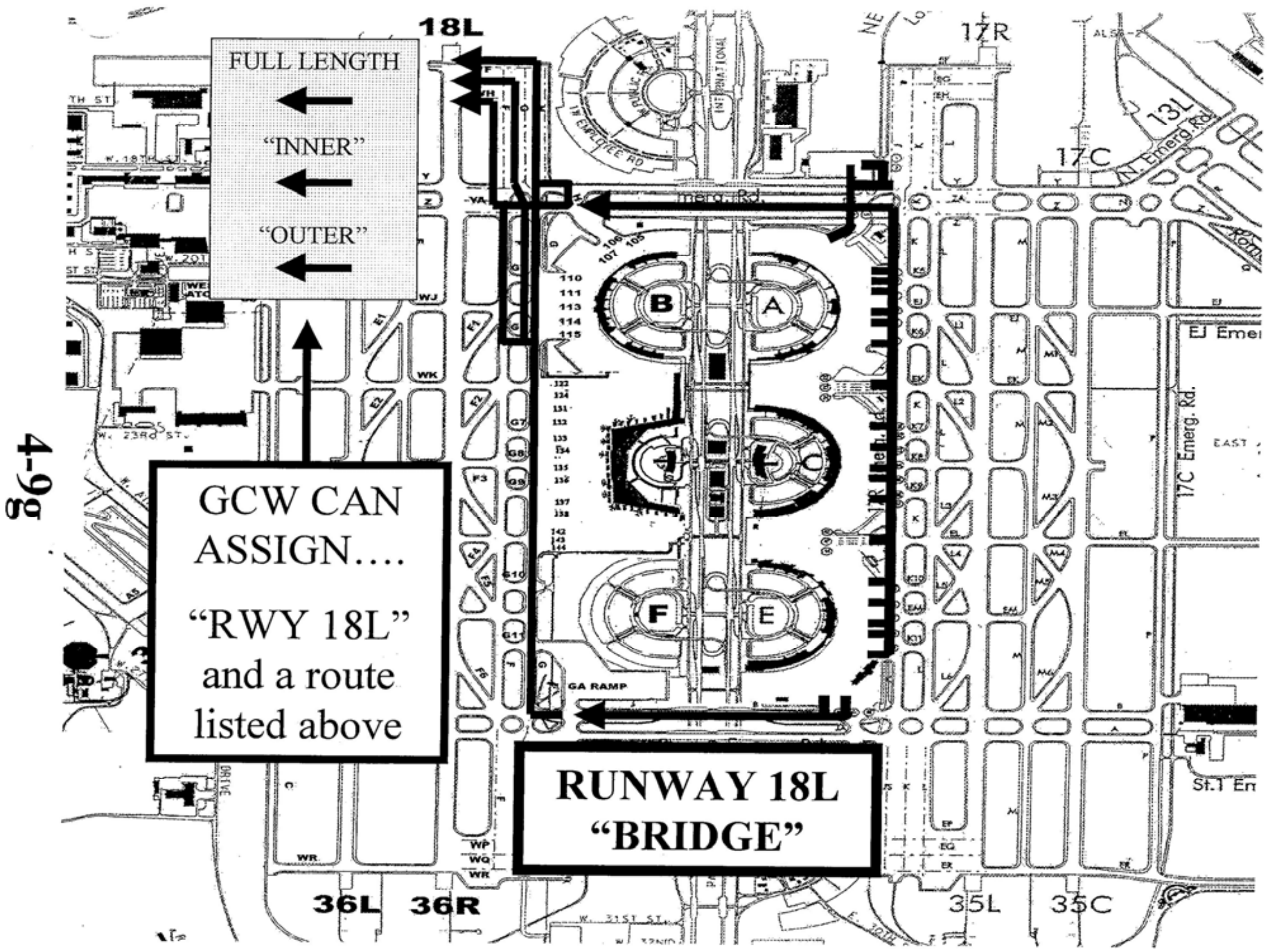


Figure 101 Taxiway Systems for Runway 18L and 17R
"Bridge" South Flow

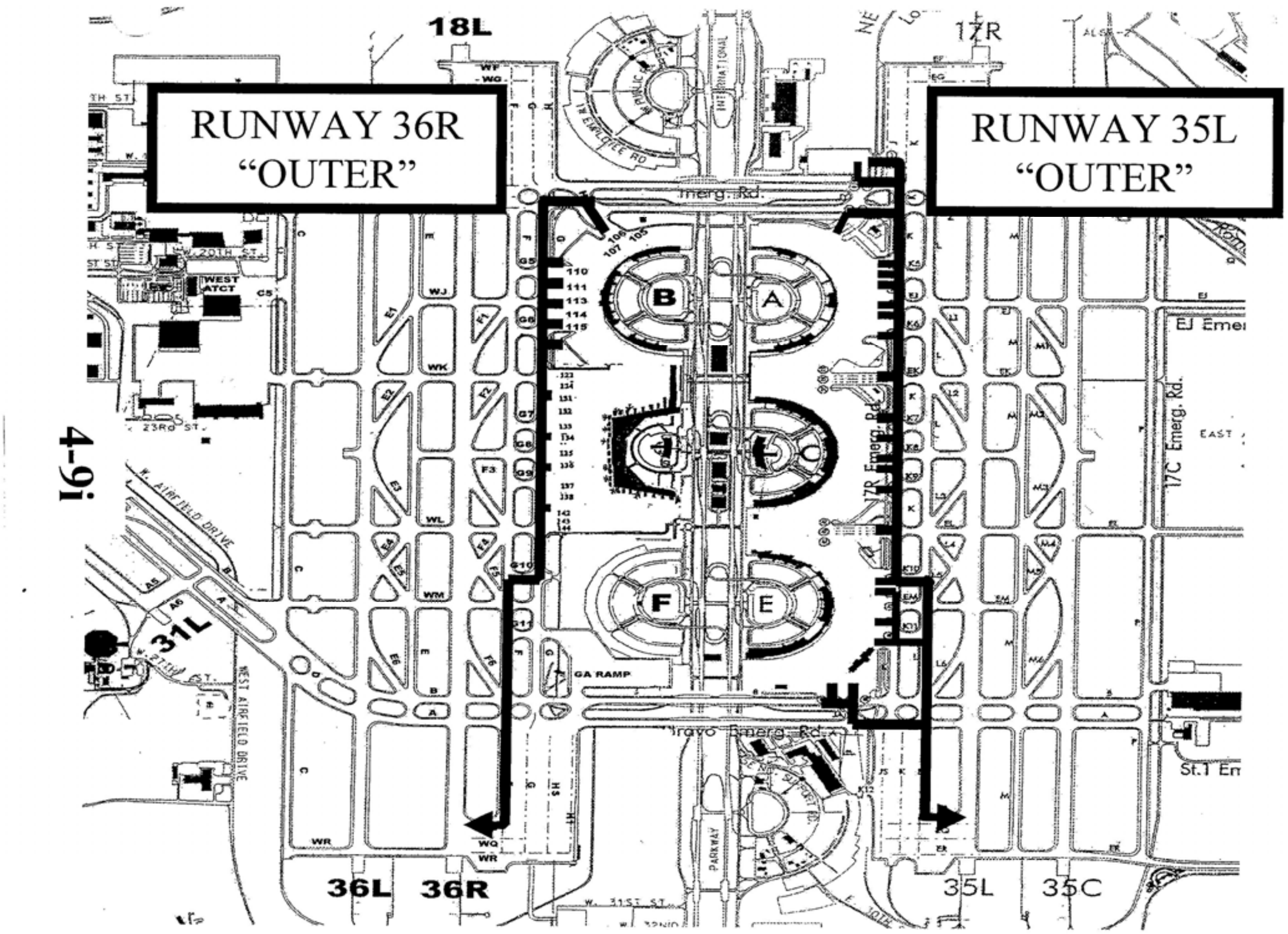


Figure 102 Taxiway Systems for Runway 36R and 35L
"Outer" North Flow

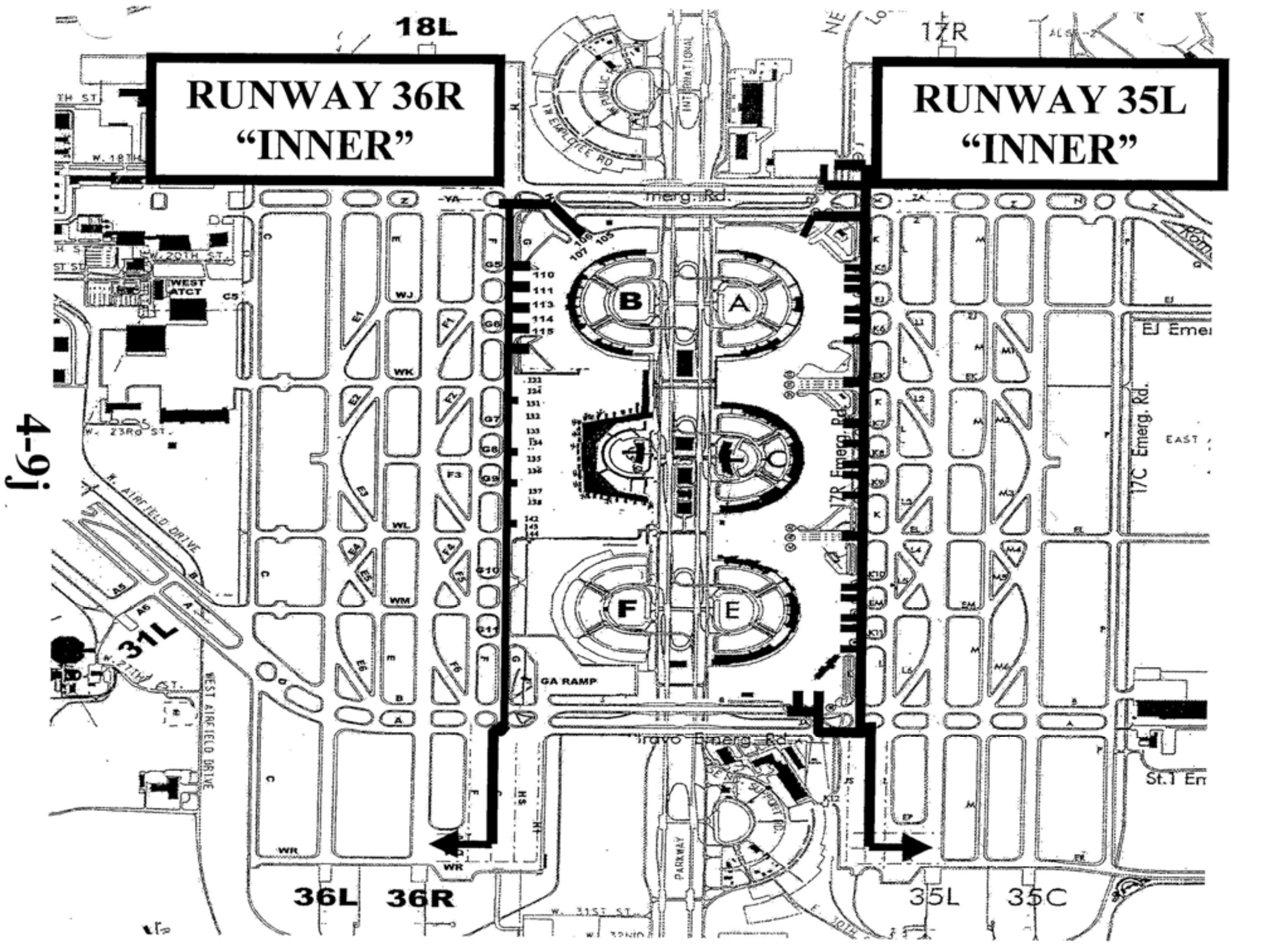


Figure 103 Taxiway Systems for Runway 36R and 35L
"Inner" North Flow

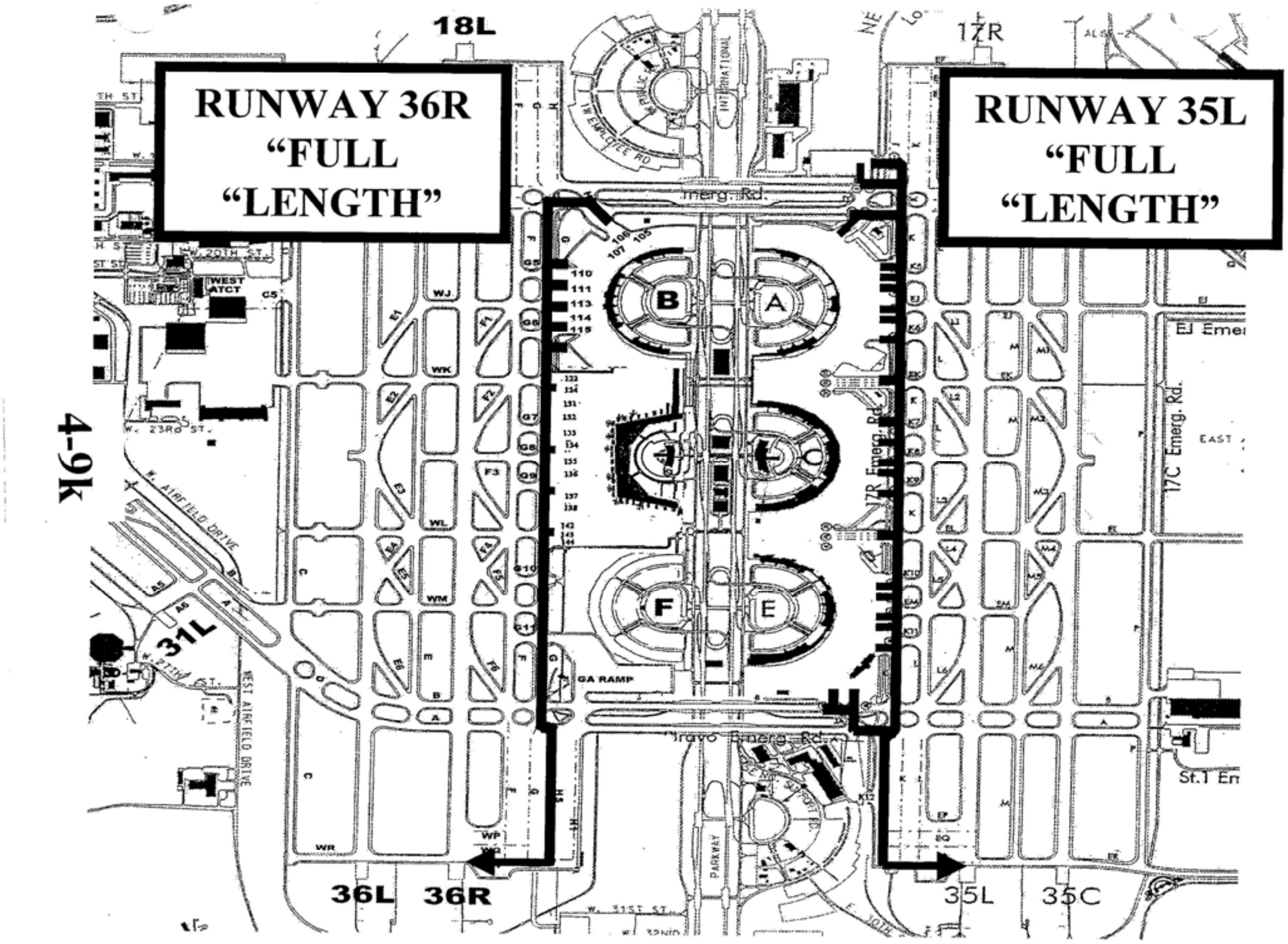


Figure 104 Taxiway Systems for Runway 36R and 35L
"Full length" North Flow

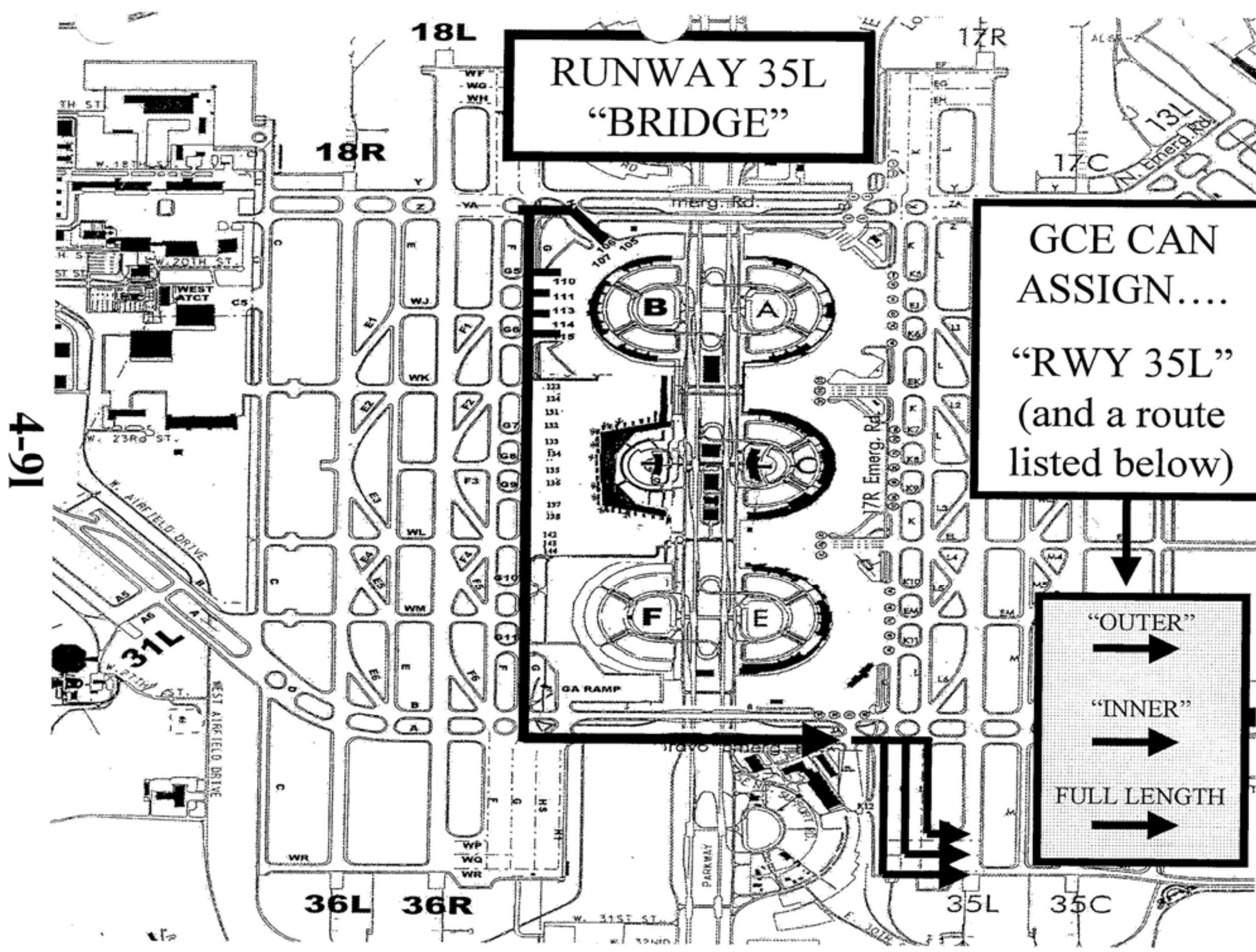


Figure 105 Taxiway Systems for Runway 35L
"Bridge" North Flow

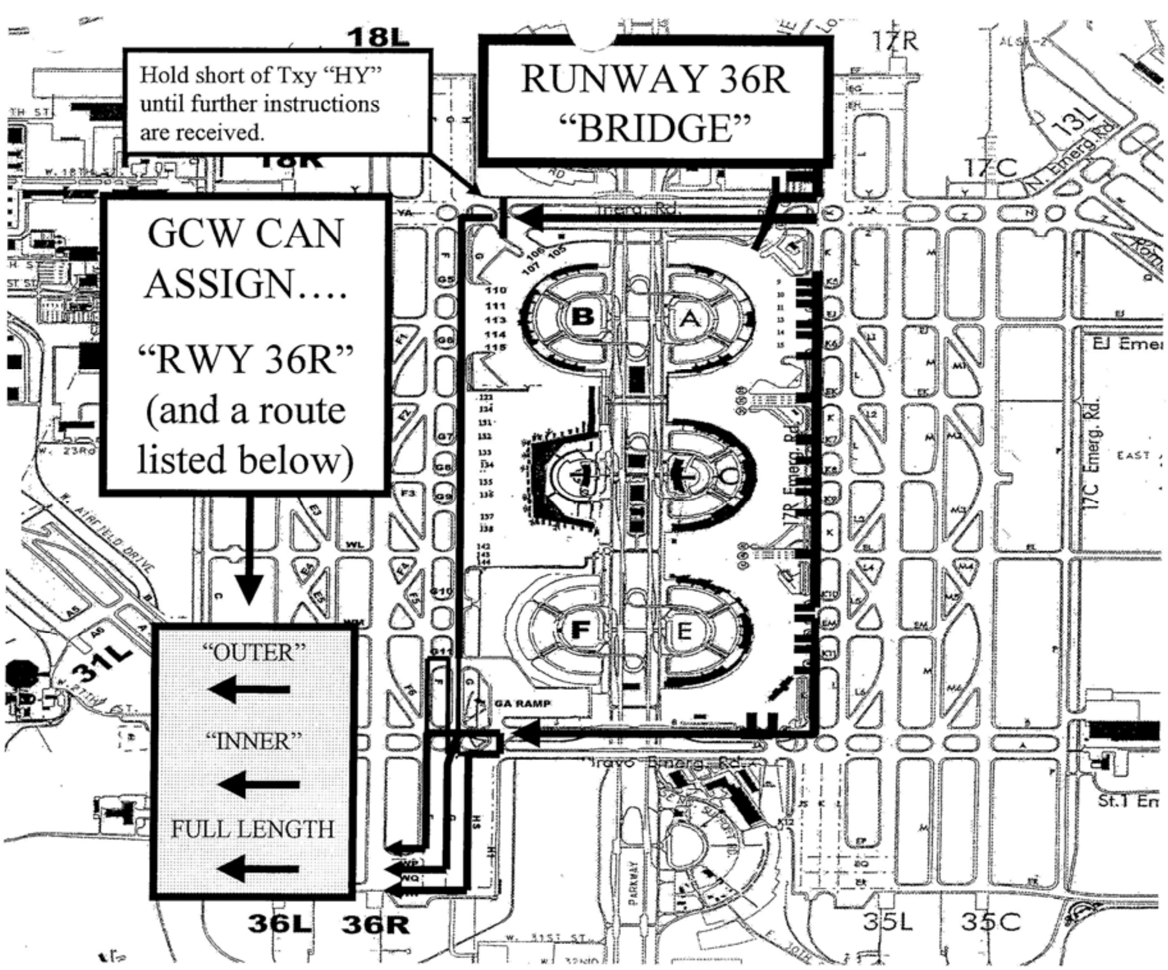


Figure 106 Taxiway Systems for Runway 36R
"Bridge" North Flow

APPENDIX H

PROPOSED PERIMETER TAXIWAY LAYOUT AND AIRCRAFT MOVEMENT DIAGRAMS

PROPOSED PERIMETER TAXIWAY LAYOUT AND AIRCRAFT MOVEMENT DIAGRAMS

Figure 107 Runway 17C arrivals exiting on taxiway M

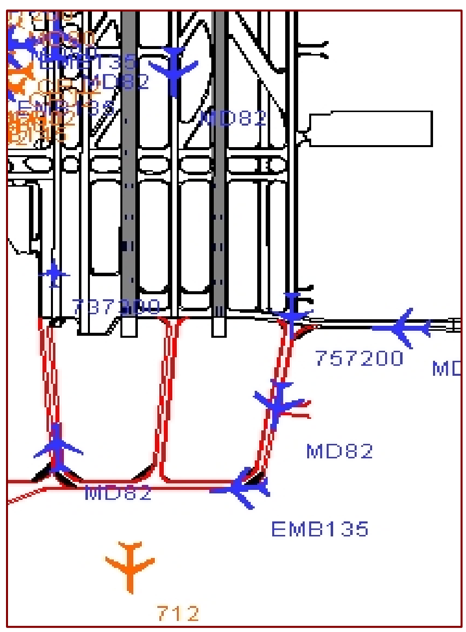


Figure 108 Southeast PT aircraft movement on taxiway M

Figure 109 Runway 17C arrival exit on taxiway P

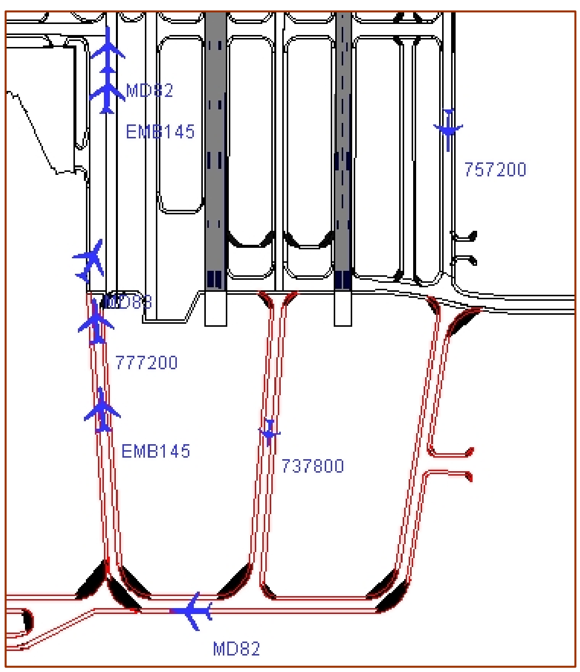


Figure 110 Runway 17C arrival exit on taxiway P

Figure 111 Runway 17L Arrival taxiing on taxiway Q to P

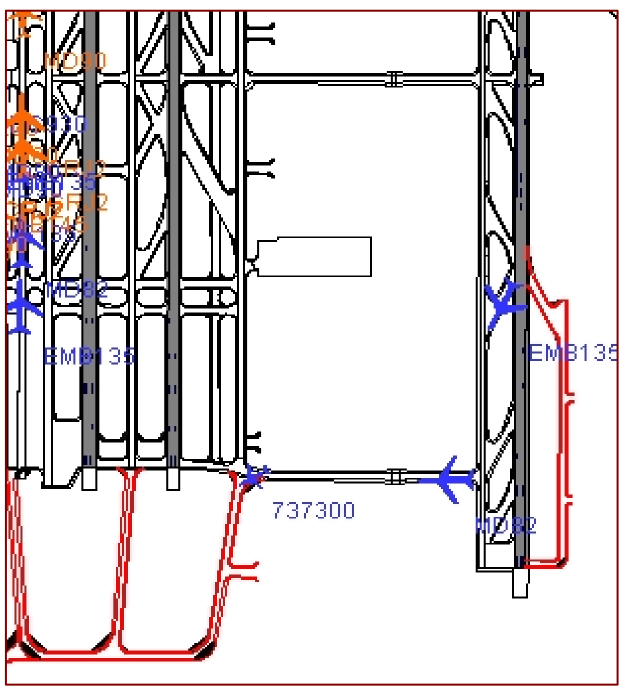


Figure 112 Runway 17L Arrival taxiing on taxiway Q to P

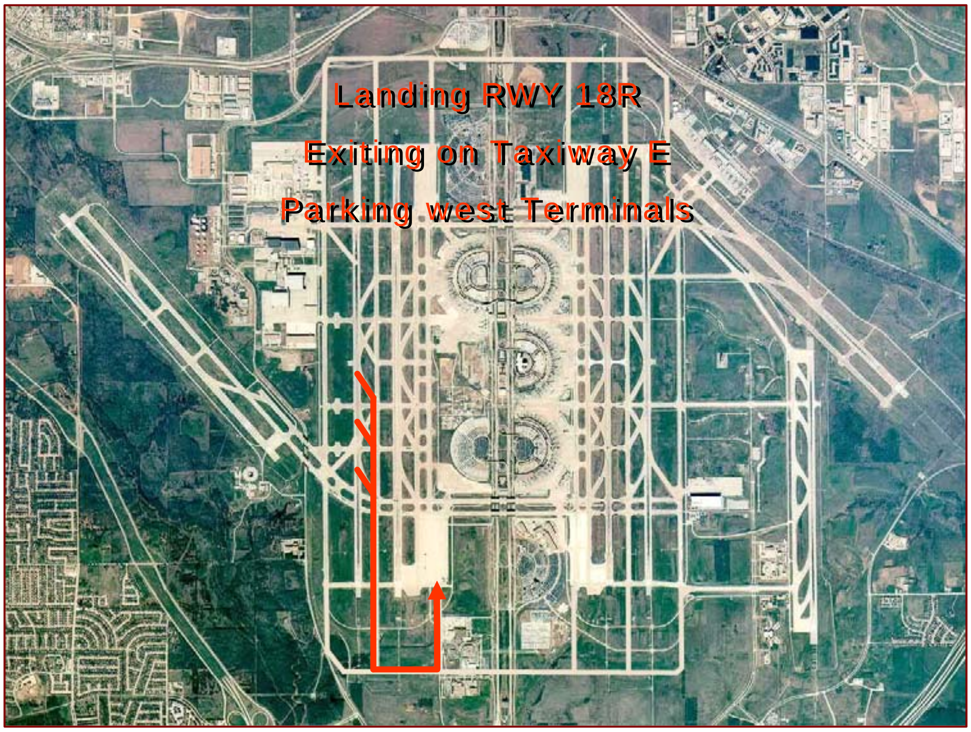


Figure 113 Arrival on 18R aircraft exiting on taxiway E

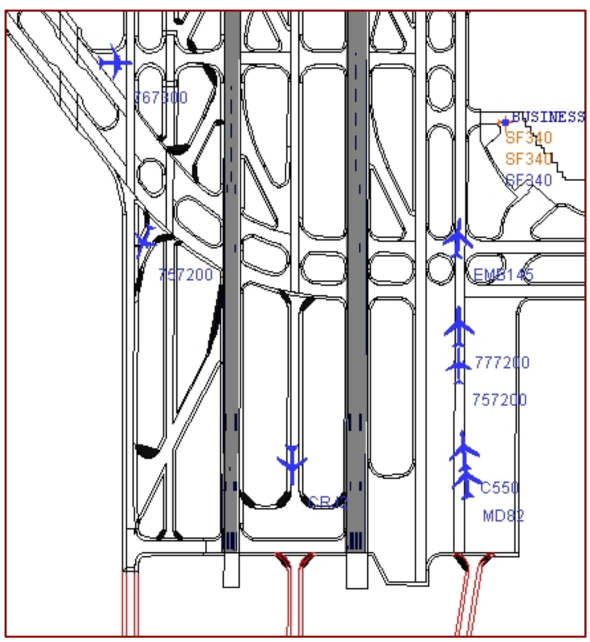


Figure 114 Arrival on 18R aircraft taxiing on taxiway E

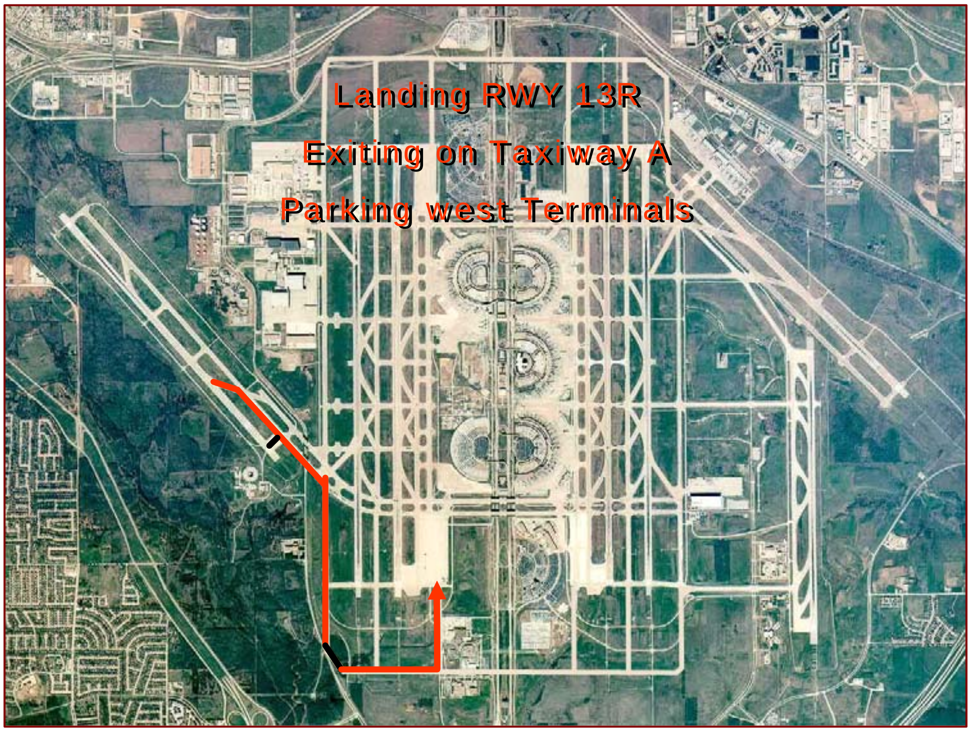


Figure 115 Arrival on 13R aircraft taxiing to west terminals

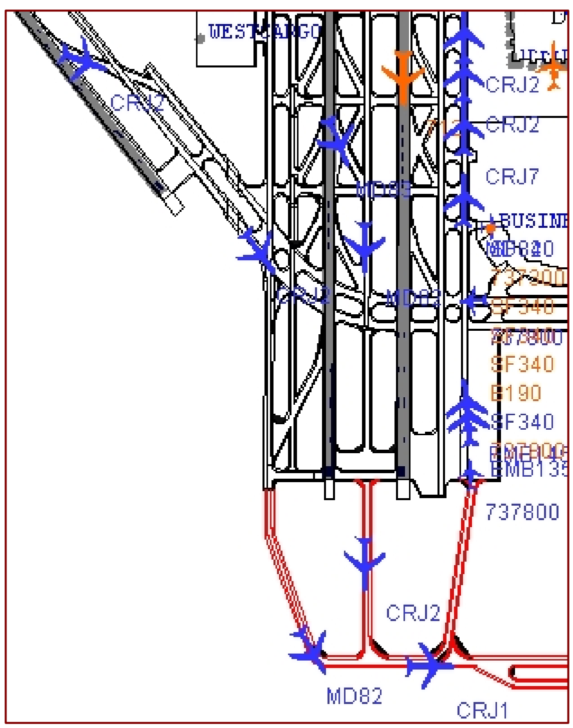


Figure 116 Arrival on runway 13R aircraft taxiing to west terminals

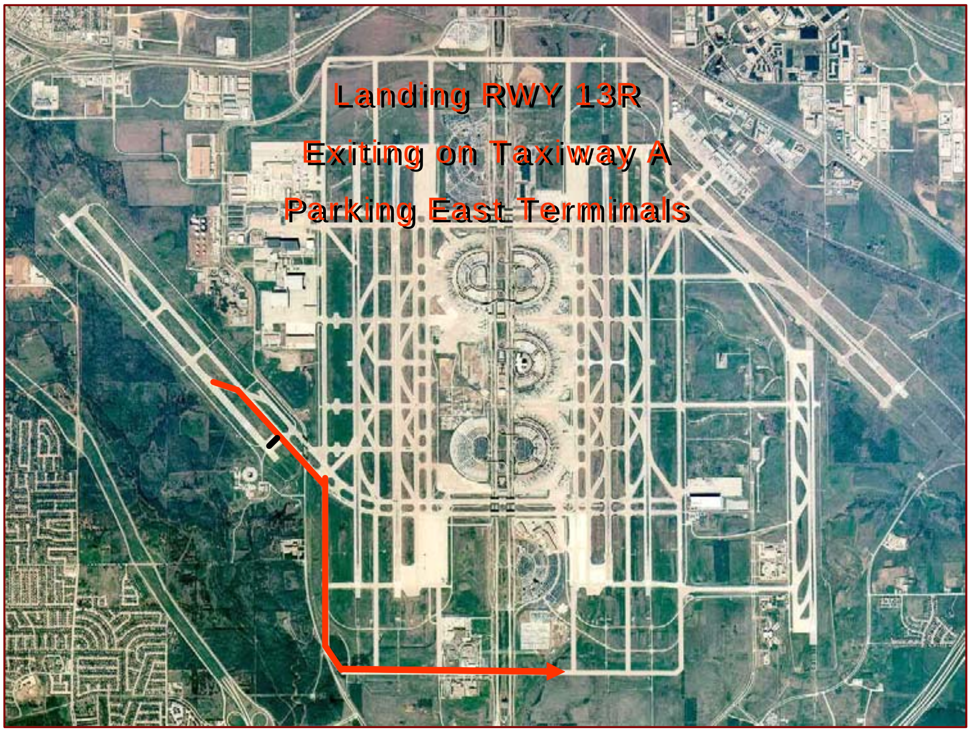


Figure 117 Arrival on 13R aircraft taxiing to taxiway A to east terminals

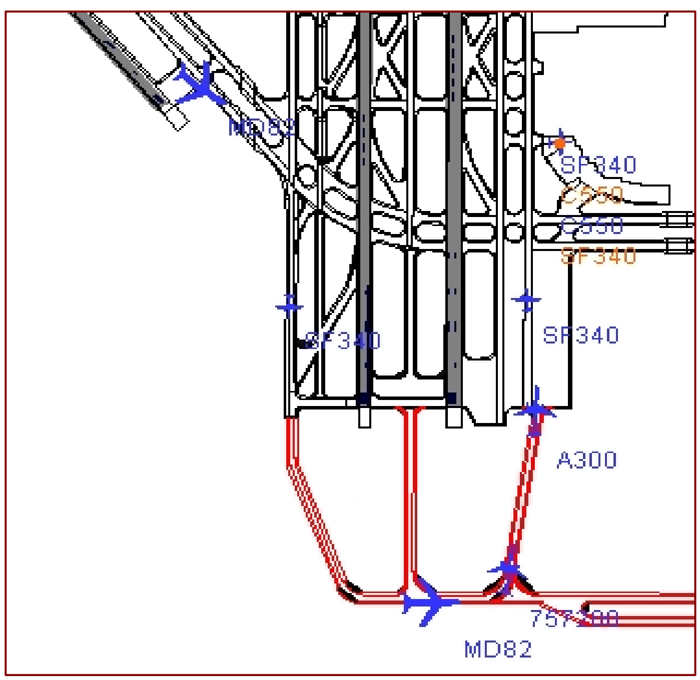


Figure 118 Arrival 13R aircraft taxiing to taxiway A to east terminal

Figure 119 Arrival on 18R taxi on Taxiway D to east terminal

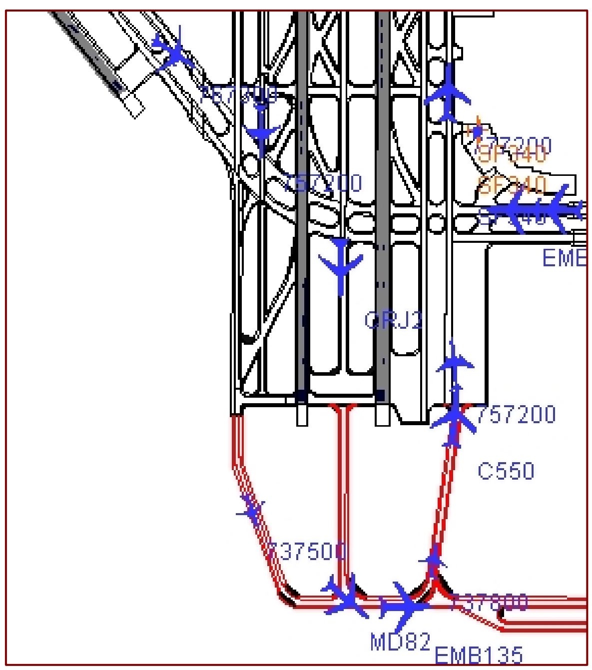


Figure 120 Arrival on 18R taxi on Taxiway D to east terminal

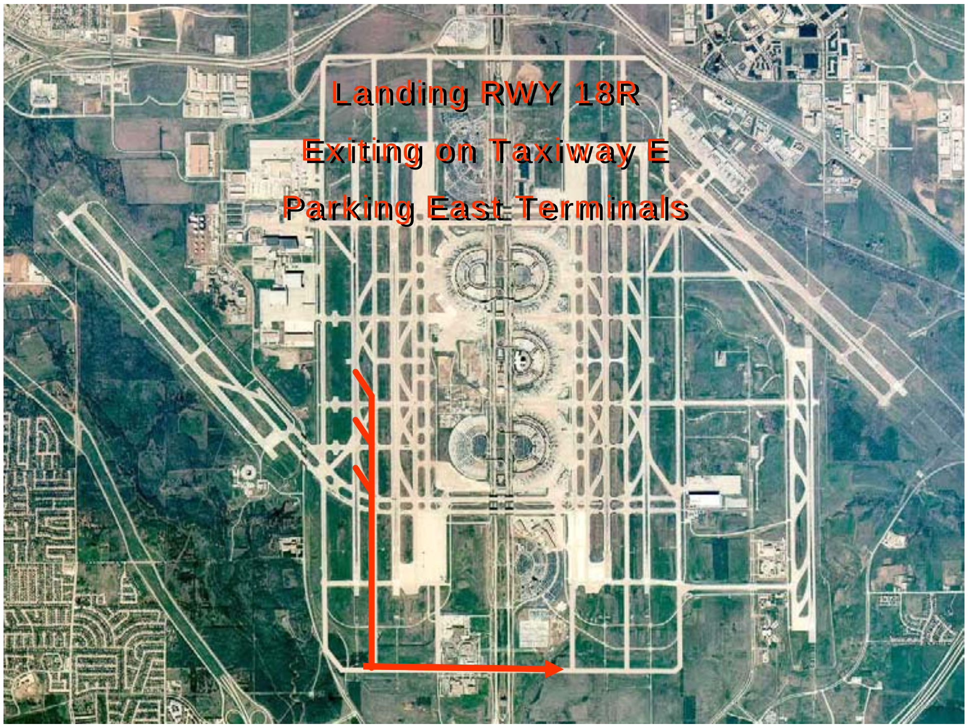


Figure 121 South Flow arrivals on runway 18R taxi on taxiway E to east terminals

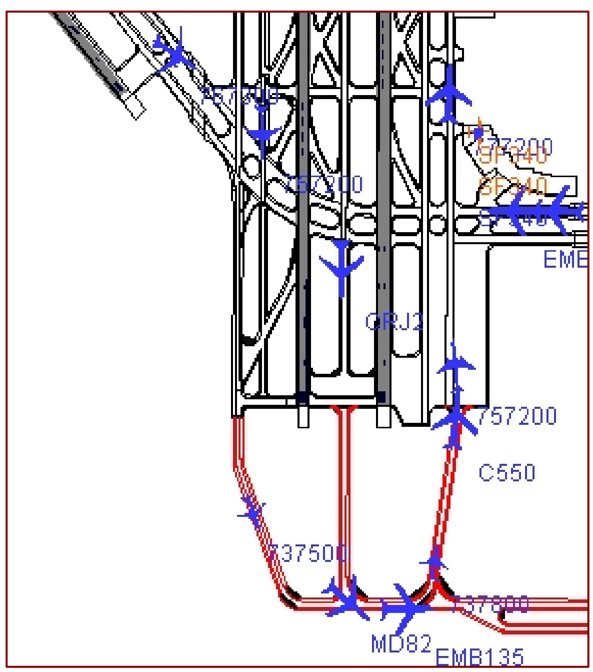


Figure 122 South Flow arrivals on runway 18R taxi on taxiway E to east terminals

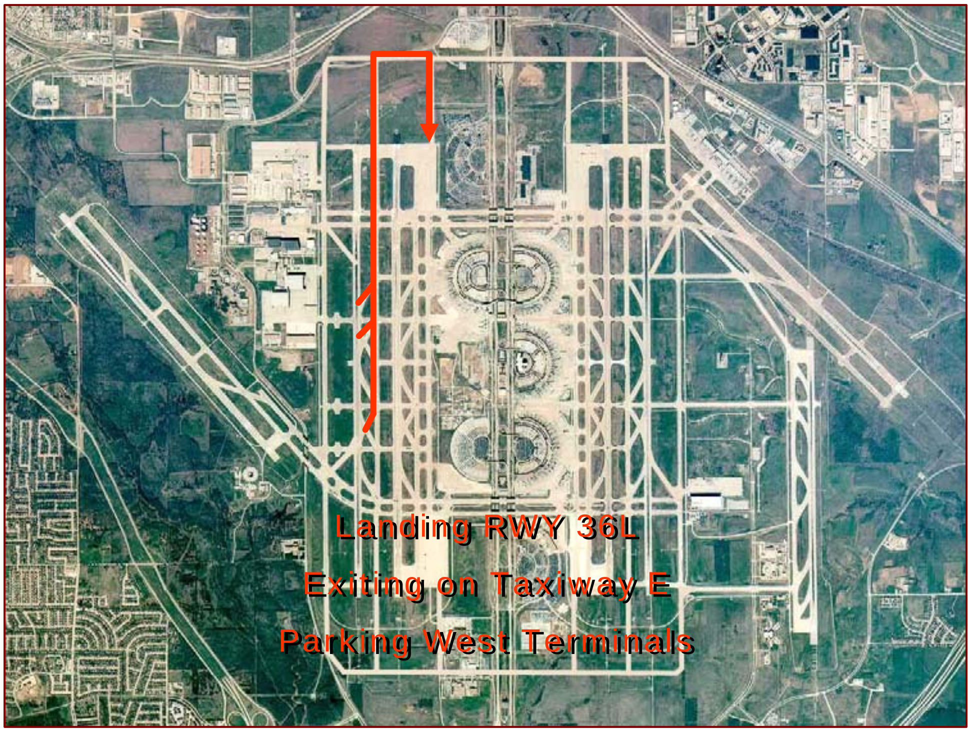


Figure 123 Arrivals on runway 36L

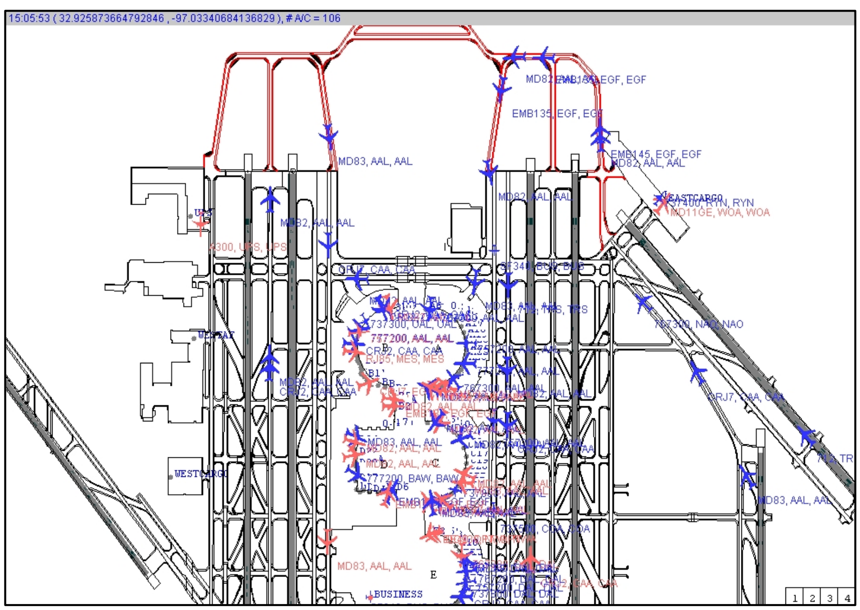


Figure 124 Arrivals on runway 36L

Figure 125 Arrival on 36L exiting on high speed exit to TWY C

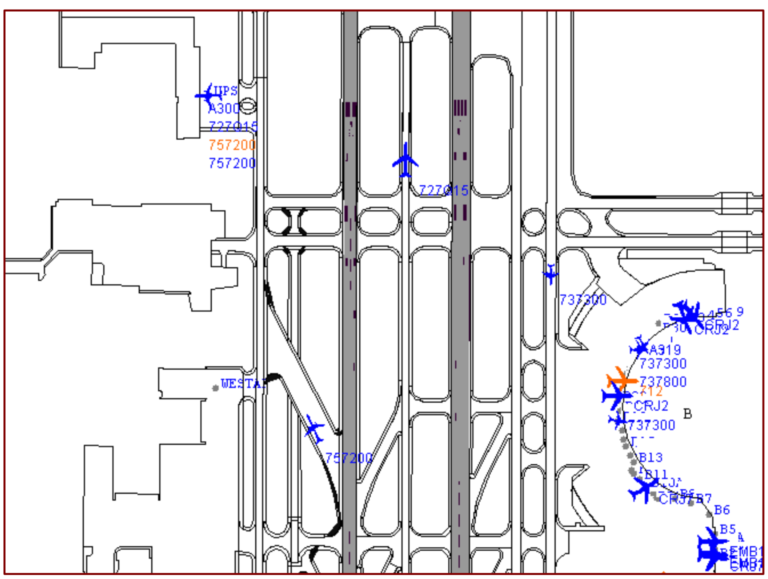


Figure 126 NW PT operations showing high speed exit to TWY C

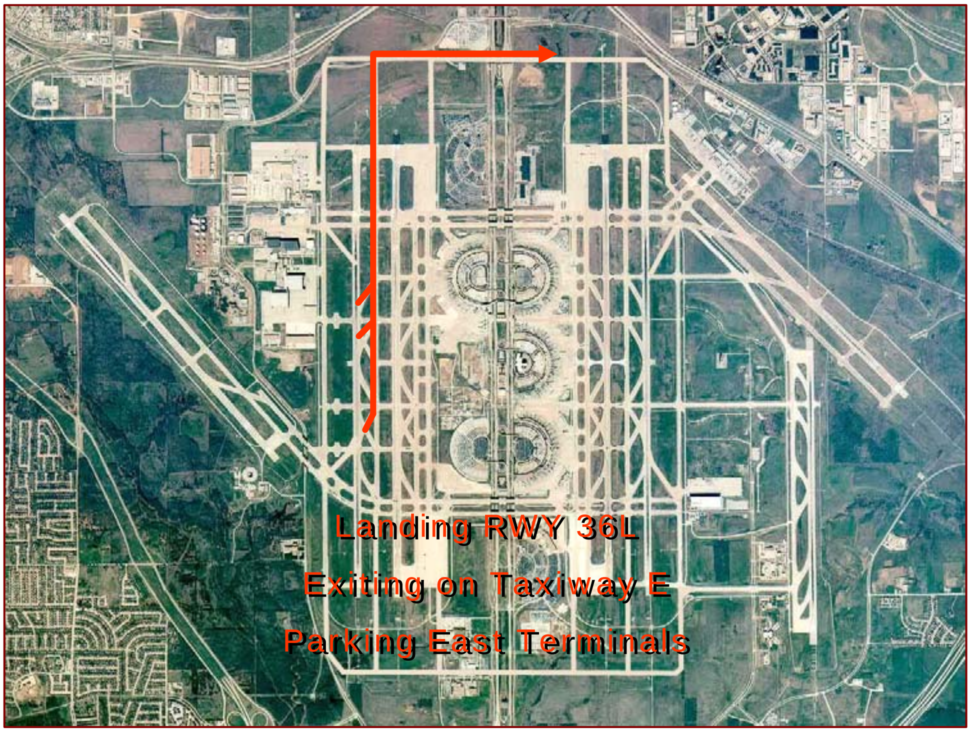


Figure 127 NW quadrant arrivals on runway 36L

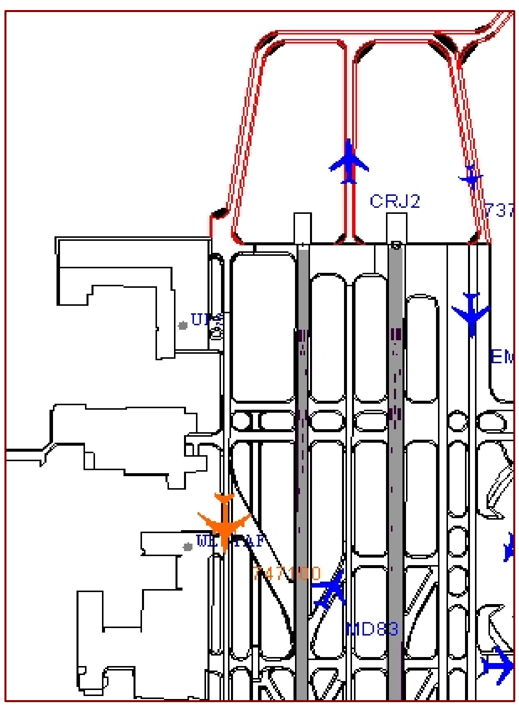


Figure 128 NW quadrant arrivals on runway 36L

Figure 129 Arrival on runway 31R exiting on taxiway R

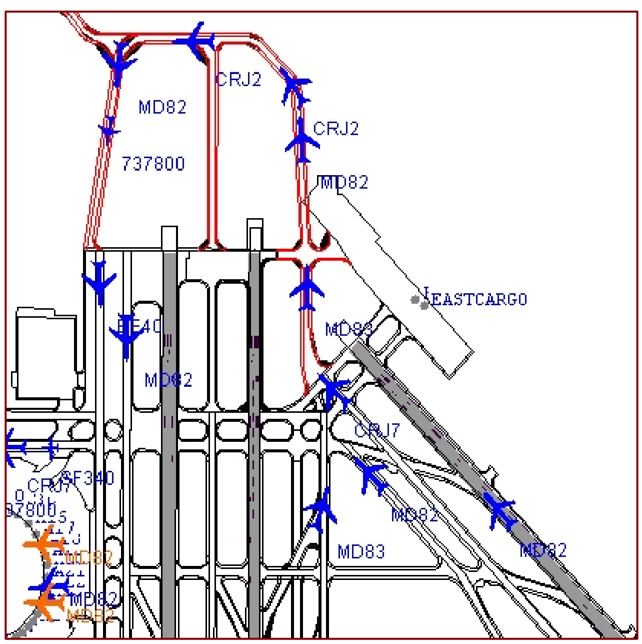


Figure 130 Arrival on runway 31R exiting on taxiway R

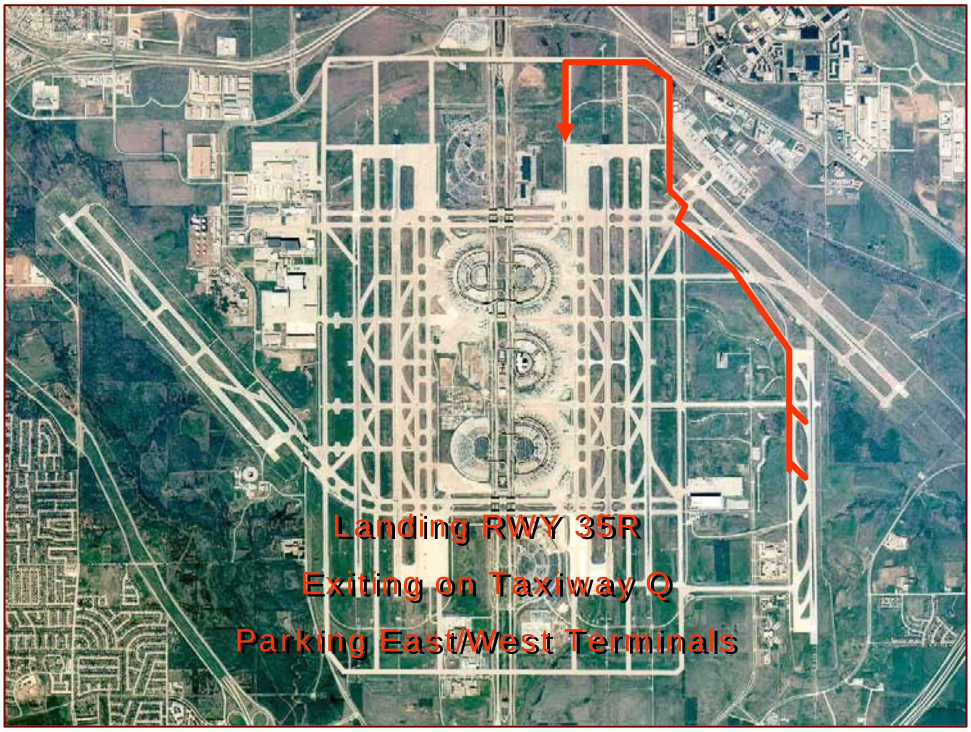


Figure 131 Arrivals on runway 35R taxiing on taxiway Q

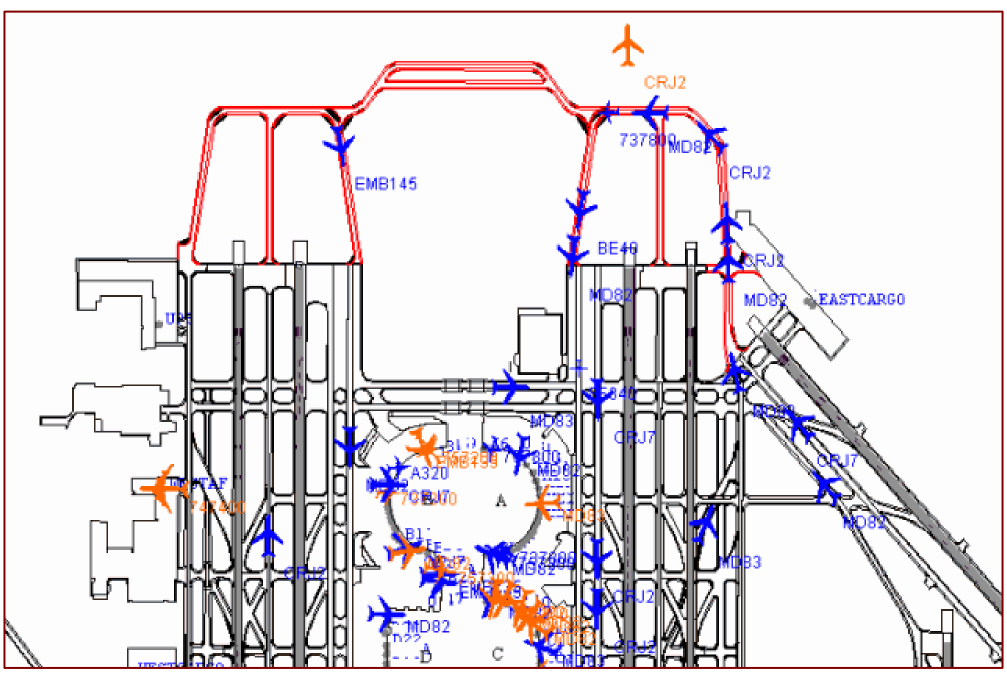


Figure 132 Arrivals on runway 35R taxiing on taxiway Q

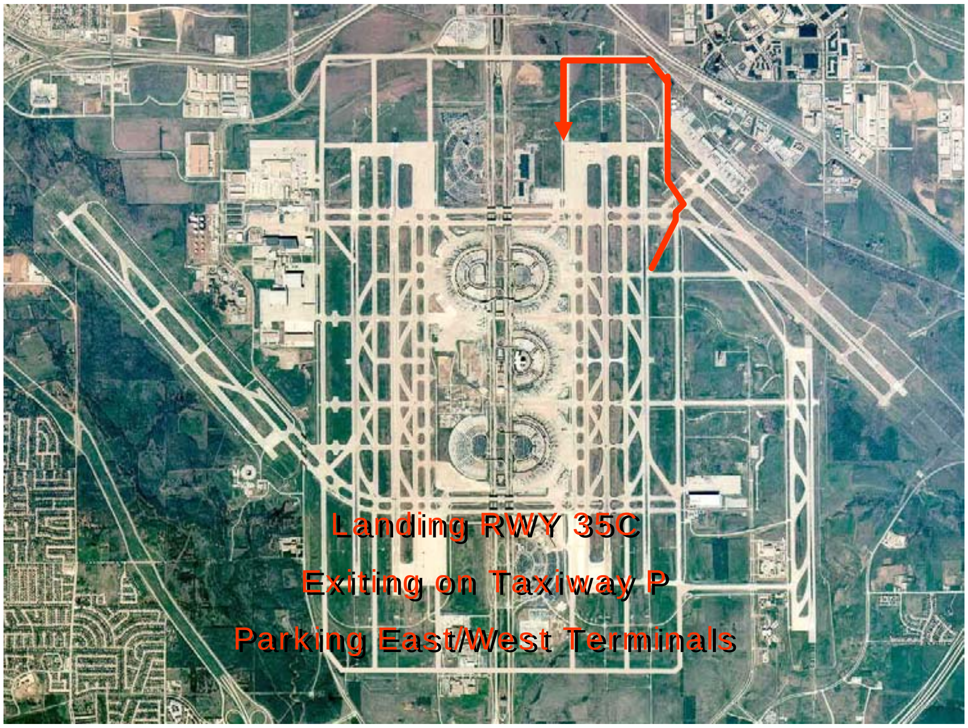


Figure 133 Arrival on runway 35C taxiing on Taxiway P

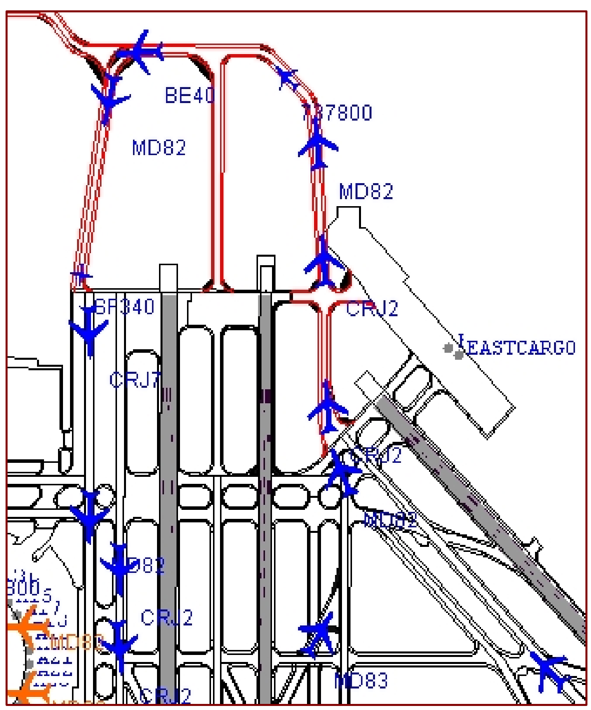


Figure 134 Arrival on runway 35C taxiing on Taxiway P

Figure 135 Arrivals on 35C taxiing on Taxiway M

Note: This option of Taxiway M was not used in the VS simulation of PT operations in 2010.

APPENDIX I

LAYOUT OF DFW TERMINALS

LAYOUT OF DFW TERMINALS
Source: www.dfwairport.com

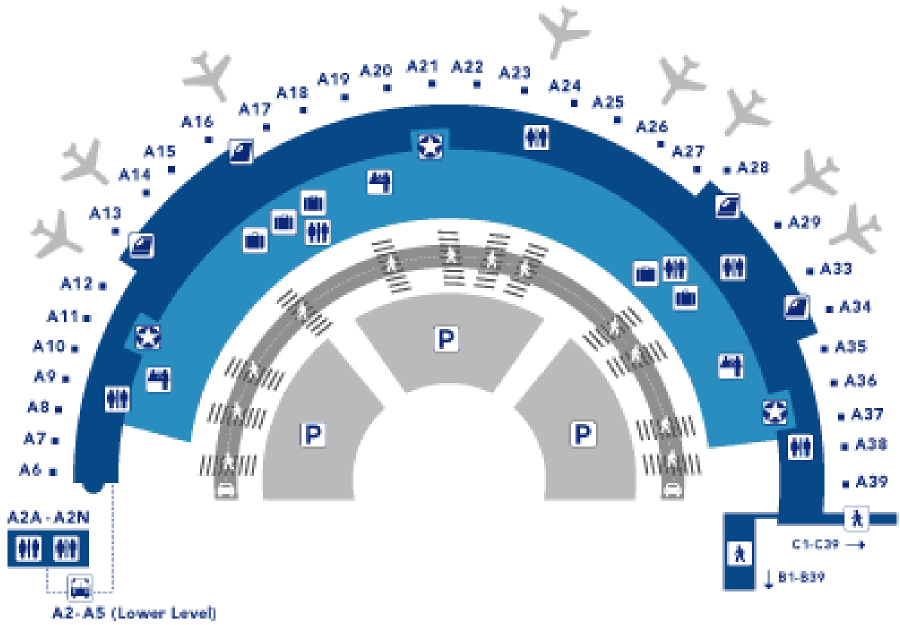


Figure 136 Terminal A gates

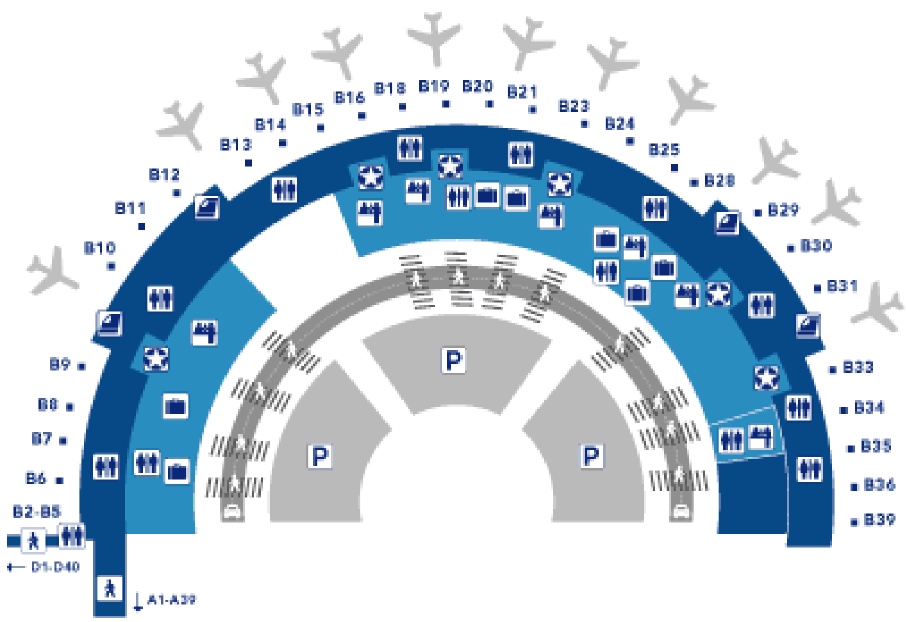


Figure 137 Terminal B gates

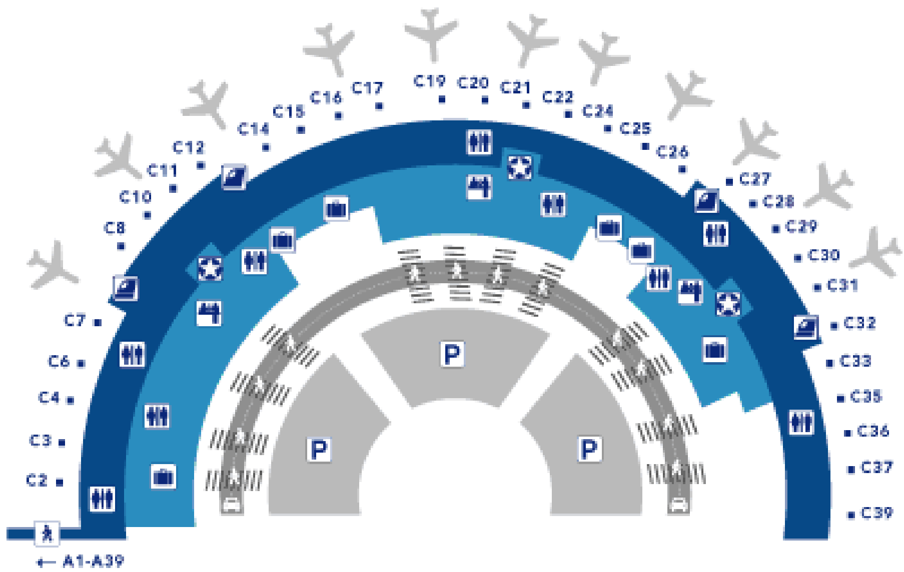


Figure 138 Terminal C gates

Figure 139 Terminal D gates

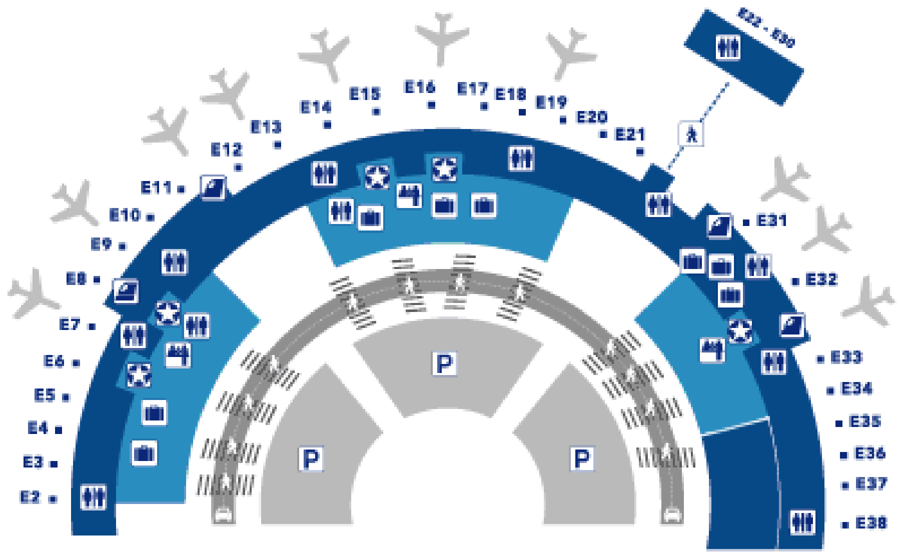


Figure 140 Terminal E gates

Table 106 DFW gate usage report 2010 *without* PT South Flow

DFW AIRPORT TERMINAL GATE USAGE REPORT - SOUTH FLOW 2010 OPERATIONS WITH OUT PT										
F2808_04_N2S										
	Gate	Counts	Gate	Counts	Gate	Counts	Gate	Counts	Gate	Counts
	A6	13	B1	16	C2	18	D11	1	E2	1
	A7	11	B2	13	C3	13	D12	1	E3	8
	A8	13	B3	15	C4	18	D15	2	E4	6
	A9	15	B4A	28	C5	7	D17	4	E5	8
	A10	10	B4B	19	C6	15	D18	7	E6	8
	A11	14	B5	15	C7	14	D20	2	E7	11
	A12	18	B6	13	C8	14	D21A	17	E8	13
	A13	18	B7	17	C9	5	D21B	7	E9	8
	A14	17	B8	32	C10	7	D22	8	E10	7
	A15	15	B9A	21	C11	17	D23	11	E12	13
	A16	17	B9B	24	C12	16	D24	10	E13	5
	A17	15	B10A	21	C13	7	D25	5	E14	7
	A18	17	B10B	25	C14	12	D27	9	E15	9
	A19	14	B11	20	C15	17	D28	6	E16	18
	A20	14	B12A	36	C16	19	D29	10	E17	13
	A21	9	B12B	26	C17	15	D30	10	E18	14
	A22	7	B13	16	C18	13	D31	12	E19	12
	A23	14	B14	7	C19	21	D33X	6	E20	28
	A24	12	B15	10	C20	18	D34	9	E21	25
	A25	11	B16	9	C21	14	D36	5	E22	20
	A26	10	B17	4	C22	17	D37	12	E23	30
	A27	9	B18	19	C23	11	D38	9	E24	45
	A28	10	B19	8	C24	20	D39	12	E25	40
	A29	14	B20	8	C25	18			E26	31
	A32	14	B21	2	C26	16			E27	30
	A33	13	B23	12	C27	15			E28	35
	A34	17	B24	12	C28	16			E29	30
	A35	10	B25	16	C29	17			E30	35
	A36	19	B26	7	C30	16			E31	27
	A37	14	B27	33	C31	13			E32	41
	A38	16	B28	14	C32	12			E33	23
	A39	10	B29	16	C33	16			E34	21
			B30	15	C34	14			E35	27
			B31	6	C35	15			E36	21
			B32	7	C36	14			E37	13
			B33	5	C37	14			E38	9
			B34	13	C38	10				
			B35	1	C39	16				
			B36	13						
			B37	7						
			B38	6						
			B39	3						

Table 107 DFW Terminal usage report 2010 *with* PT South Flow

DFW AIRPORT TERMINAL GATE USAGE REPORT - SOUTH FLOW 2010 OPERATIONS WITH PT										
F2808_10_N2S										
	Gate	Counts	Gate	Counts	Gate	Counts	Gate	Counts	Gate	Counts
	A6	16	B2	18	C2	22	D6	6	E2	5
	A7	10	B3	18	C3	11	D7	7	E3	10
	A8	13	B4A	34	C4	14	D8	7	E4	9
	A9	12	B4B	28	C5	8	D10	9	E5	11
	A10	8	B5	20	C6	15	D12	13	E6	12
	A11	12	B6	17	C7	11	D14	10	E7	9
	A12	11	B7	22	C8	21	D15	8	E8	7
	A13	14	B8	16	C10	9	D16	10	E9	7
	A14	13	B9A	32	C11	12	D17	2	E10	11
	A15	14	B9B	27	C12	12	D18	3	E12	17
	A16	15	B10A	32	C14	13	D20	26	E13	17
	A17	16	B10B	27	C15	15	D21A	13	E14	19
	A18	9	B11	20	C16	12	D21B	11	E15	14
	A19	14	B12A	21	C17	11	D22	6	E16	21
	A20	12	B12B	20	C19	16	D23	8	E17	16
	A21	11	B13	7	C20	18	D24	12	E18	19
	A22	8	B14	5	C21	13	D25	16	E19	18
	A23	11	B15	7	C22	14	D27	14	E20	20
	A24	13	B16	10	C24	13	D28	14	E21	22
	A25	11	B17	3	C25	15	D29	12	E22	22
	A26	9	B18	11	C26	19	D30	11	E23	25
	A27	11	B19	8	C27	12	D31	13	E24	27
	A28	12	B20	26	C28	9	D33	9	E25	29
	A29	11	B21	23	C29	12	D33X	8	E26	28
	A32	7	B23	10	C30	14	D34	14	E27	22
	A33	13	B24	29	C31	10	D36X	7	E28	12
	A34	12	B25	25	C32	9	D37	15	E29	27
	A35	15	B26	6	C33	12	D38	13	E30	32
	A36	14	B28	13	C34	18	D39	8	E31	17
	A37	16	B29	14	C35	11	D40	7	E32	21
	A38	15	B30	12	C36	13			E33	11
	A39	13	B31	19	C37	10			E34	12
			B33	1	C38	12			E35	20
			B34	32	C39	12			E36	15
			B35	26					E37	12
			B36	8					E38	18
			B39	27						

More than 2 aircraft are allowed to park at the following gates B4A, B4B, B9A, B9B, B10A, B10B, B12A and B12B. Terminal D gates are not used to the full extent. Gates D17 and D18 are assigned for Heavy aircraft B747-400.

Table 108 DFW Terminal usage report 2010 *without* PT North Flow

DFW AIRPORT TERMINAL GATE USAGE REPORT -NORTH FLOW 2010 OPERATIONS WITH OUT PT										
F2808_04_S2N										
	Gate	Counts	Gate	Counts	Gate	Counts	Gate	Counts	Gate	Counts
	A6	9	B1	14	C2	17	D6	1	E2	37
	A7	8	B2	17	C3	14	D8	2	E3	7
	A8	13	B3	16	C4	18	D10	2	E4	7
	A9	17	B4A	26	C5	8	D12	1	E5	7
	A10	14	B4B	24	C6	15	D18	3	E6	7
	A11	16	B5	19	C7	17	D20	1	E7	11
	A12	14	B6	16	C8	14	D21A	10	E8	11
	A13	17	B7	15	C9	6	D21B	10	E9	10
	A14	20	B8	20	C10	10	D22	4	E10	7
	A15	13	B9A	31	C11	14	D23	9	E12	14
	A16	16	B9B	32	C12	18	D24	7	E13	9
	A17	15	B10A	22	C13	8	D25	9	E14	7
	A18	16	B10B	23	C14	12	D27	6	E15	10
	A19	19	B11	16	C15	20	D28	10	E16	13
	A20	16	B12A	20	C16	14	D29	5	E17	32
	A21	11	B12B	28	C17	20	D30	10	E18	9
	A22	11	B13	11	C18	9	D31	10	E19	13
	A23	12	B14	6	C19	20	D33X	15	E20	37
	A24	14	B15	6	C20	18	D34	5	E21	27
	A25	12	B16	8	C21	12	D36	7	E22	30
	A26	17	B17	5	C22	18	D37	8	E23	28
	A27	8	B18	10	C23	6	D38	7	E24	43
	A28	10	B19	9	C24	12	D39	7	E25	37
	A29	13	B20	33	C25	20	D40	5	E26	39
	A32	11	B21	2	C26	15			E27	38
	A33	14	B23	14	C27	17			E28	36
	A34	6	B24	38	C28	18			E29	29
	A35	14	B25	42	C29	19			E30	34
	A36	15	B26	1	C30	12			E31	19
	A37	16	B27	8	C31	14			E32	7
	A38	18	B28	20	C32	14			E33	8
	A39	13	B29	23	C33	15			E34	2
			B30	24	C34	17			E35	6
			B31	37	C35	17			E36	6
			B32	33	C36	14			E37	13
			B33	4	C37	13			E38	9
			B34	2	C38	8				
			B35	2	C39	14				
			B36	13						
			B37	1						
			B39	3						

More than 2 aircraft are allowed to park at the following gates B4A, B4B, B9A, B9B, B10A, B10B, B12A and B12B. Terminal D gates are not used to the full extent. Gates D17 and D18 are assigned for Heavy aircraft B747-400

Table 109 DFW Terminal usage report 2010 *with* PT North Flow

DFW AIRPORT TERMINAL GATE USAGE REPORT - NORTH FLOW 2010 OPERATIONS WITH PT										
F2808_10_S2N										
	Gate	Counts	Gate	Counts	Gate	Counts	Gate	Counts	Gate	Counts
	A6	10	B2	31	C2	16	D6	3	E2	38
	A7	9	B3	26	C3	17	D7	13	E3	1
	A8	10	B4A	36	C4	16	D8	11	E4	7
	A9	15	B4B	31	C5	9	D10	13	E5	7
	A10	11	B5	33	C6	14	D12	11	E6	17
	A11	11	B6	17	C7	14	D14	12	E7	18
	A12	13	B7	21	C8	15	D15	2	E8	14
	A13	13	B8	10	C10	11	D16	2	E9	1
	A14	14	B9A	8	C11	12	D17	5	E10	8
	A15	17	B9B	11	C12	14	D18	5	E12	10
	A16	16	B10A	26	C14	15	D21A	13	E13	14
	A17	15	B10B	27	C15	12	D21B	12	E14	11
	A18	10	B11	14	C16	12	D22	7	E15	13
	A19	17	B12A	33	C17	12	D23	6	E16	16
	A20	11	B12B	16	C19	18	D24	11	E17	14
	A21	9	B13	6	C20	19	D25	13	E19	9
	A22	8	B14	3	C21	11	D27	10	E20	25
	A23	15	B15	4	C22	19	D28	10	E21	21
	A24	14	B16	8	C24	14	D29	12	E22	24
	A25	12	B18	16	C25	16	D30	13	E23	27
	A26	8	B19	7	C26	14	D31	12	E24	40
	A27	11	B20	35	C27	15	D33	10	E25	31
	A28	13	B21	34	C28	10	D33X	11	E26	34
	A29	13	B23	11	C29	16	D34	9	E27	28
	A33	16	B24	33	C30	11	D36X	6	E28	22
	A34	14	B25	33	C31	11	D37	8	E29	26
	A35	14	B26	7	C32	10	D38	14	E30	36
	A36	12	B28	19	C33	17	D39	10	E31	19
	A37	13	B29	16	C34	15	D40	7	E32	11
	A38	17	B30	12	C35	15			E33	24
	A39	11	B31	32	C36	11			E35	42
			B33	2	C37	12			E36	20
			B34	33	C38	5			E37	16
			B35	33	C39	10			E38	4
			B36	9						
			B39	7						

More than 2 aircraft are allowed to park at the following gates B4A, B4B, B9A, B9B, B10A, B10B, B12A and B12B. Terminal D gates are not used to the full extent. Gates D17 and D18 are assigned for Heavy aircraft B747-400

APPENDIX J

ACRONYMS & ABBREVIATIONS

ACRONYMS & ABBREVIATIONS

AAR- Airport Acceptance Rate or Airport Arrival Rate

ADR- Airport Departure Rate

AEE- FAA Office of Environment and Energy

AFS- Airport Flight Standards Service

AIP- Airport Improvement Program

AIR TAXI-Regional jets with seats less than 45

ALP- Airport Layout Plan

AOSC-Airport Obstruction Standards Committee

APO-Airport Policy and Planning Office

APP – Airport Planning and Programming

ARTS-Automated Radar Terminal Systems

ASQP-Airline Service Quality Performance

ASPM-Aviation System Performance Metrics

ASV- Annual Service Volume

ATADS – Air Traffic Activity System

ATC- Air Traffic Control

ATM- Air Traffic Management

Cap AAR- Capacity Airport Arrival Rate

CDM- Collaborative Decision Making

DER Departure end of the runway

DFW- Dallas Fort Worth Airport

DME – Distance Measuring Equipment

DOE- Department of Energy

DOT-Department of Transportation

DXF- Drawing Exchange File

EAT- End-Around Taxiway

ETMS- Enhanced Traffic Management System

FAA- Federal Aviation Administration

FliteGraph®- Graphic display of flights, noise, and compliant with a myriad of tools for enhanced analysis

FSDS- Flight Schedule Data System

GDP- Ground Delay Program

ICAO- International Civil Aviation Organization

ILS – Instrument Landing System

LAAS- Local Area Augmentation System

LAHSO- Land and Hold Short Operation

NAS – National Airspace System

NTSB- National Transportation Safety Board

O&M – Operations and Maintenance

OEI –One Engine Inoperative

OEP- Operational Evolution plan

OIS- Operational Information System

OPSNET- Operational Network

PANCAP- Practical Annual Capacity

PT- Perimeter Taxiway

QGF- Quintessential Graphic File

RPZ-Runway Protection Zone

RSA-Runway safety Area

SAER- System Airport Efficiency Rate

TAF- Terminal Area Forecast

TAER- Terminal Arrival Efficiency Rate

TAMIS – Total Airport Management Information System

TERPS- Terminal Instrument Approach Procedures

TIP- Transportation Improvement Program

TRACON-Terminal Radar Approach Control

APPENDIX K

AIRCRAFT MODELS USED IN SIMULATION

AIRCRAFT MODELS USED IN SIMULATION

Beechcraft 1900

Embrear 120

Beechcraft 40

Cessna C280

SAAB SF340

King Air

B737

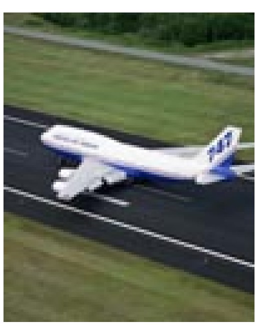
B747

B767

B767

MD-80

A310



B747-400

DC-9-80

DC-9-80

A 300

MD-11

A 321

A 340

APPENDIX L

DFW FLIGHT TRACKS DATA

DFW Flight Tracks data

Flight Time	Gate Time	Name	Flight ID	Pen X	Pen Y	Alt
7/29/2004 0:02	0:01:37	2650	AAL1203	950	227	827
7/29/2004 0:05	0:04:05	2650	AAL2194	941	247	847
7/29/2004 0:06	0:06:04	2650	AAL1591	951	275	875
7/29/2004 0:08	0:08:00	2650	DAL1242	933	244	844
7/29/2004 0:12	0:11:22	2650	TRS118	937	242	842
7/29/2004 0:14	0:13:45	2650	CAA179	991	240	840
7/29/2004 0:17	0:16:55	2650	DAL1161	1001	251	851
7/29/2004 0:20	0:19:40	2650	CAA506	924	252	852
7/29/2004 0:24	0:23:22	2650	DAL533	893	254	854
7/29/2004 0:27	0:26:26	2650	DAL1062	891	228	828
7/29/2004 0:29	0:28:49	2650	CAA253	936	279	879
7/29/2004 0:32	0:31:30	2650	COA415	930	251	851
7/29/2004 0:34	0:33:58	2650	AAL1153	936	242	842
7/29/2004 0:38	0:37:48	2650	AAL2452	962	254	854
7/29/2004 0:42	0:42:07	2650	UPS309	913	222	822
7/29/2004 0:44	0:43:57	2650	CAA724	908	276	876
7/29/2004 0:46	0:45:43	2650	DAL1077	954	258	858
7/29/2004 0:48	0:47:16	2650	DAL743	928	265	865
7/29/2004 0:50	0:49:39	2650	AAL2473	945	219	819
7/29/2004 0:52	0:51:11	2650	EGF712	906	227	827
7/29/2004 0:53	0:52:34	2650	COA1519	951	275	875
7/29/2004 0:55	0:54:39	2650	EGF478	935	210	810
7/29/2004 0:57	0:56:21	2650	DAL397	915	269	869
7/29/2004 0:58	0:57:48	2650	UPS775	871	216	816
7/29/2004 1:23	1:22:21	2650	AWE544	910	269	869
7/29/2004 1:27	1:26:20	2650	UPS607	879	249	849
7/29/2004 1:29	1:28:25	2650	CAA342	909	286	886
7/29/2004 1:30	1:29:52	2650	AAL699	934	242	842
7/29/2004 1:35	1:34:48	2650	AMT205	966	247	847
7/29/2004 1:37	1:36:25	2650	DAL1297	940	238	838
7/29/2004 1:39	1:38:39	2650	UPS2784	911	269	869
7/29/2004 1:42	1:41:15	2650	CAA200	898	285	885
7/29/2004 1:48	1:47:10	2650	CAA199	918	266	866
7/29/2004 1:51	1:50:06	2650	AAL324	894	245	845
7/29/2004 1:52	1:52:01	2650	DAL1499	930	263	863
7/29/2004 2:00	1:59:06	2650	DAL1235	955	251	851
7/29/2004 2:05	2:04:38	2650	AAL877	964	237	837
7/29/2004 2:45	2:45:04	2650	NWA405	895	288	888
7/29/2004 4:08	4:07:11	2650	FDX1735	951	227	827
7/29/2004 4:50	4:49:10	2650	FDX1471	940	253	853
7/29/2004 5:09	5:08:51	2650	AAL8	946	236	836
7/29/2004 6:24	6:23:05	2650	AAL1112	891	246	846
7/29/2004 6:28	6:27:42	2650	CAA452	905	261	861
7/29/2004 6:32	6:31:46	2650	CAA312	862	286	886
7/29/2004 6:36	6:35:14	2650	CHQ6314	935	242	842
7/29/2004 6:46	6:45:13	2650	CAA149	913	272	872
7/29/2004 6:49	6:48:50	2650	ATN820	909	235	835
7/29/2004 6:57	6:56:45	2650	CAA731	903	289	889
7/29/2004 7:00	7:00:03	2650	EGF762	931	243	843
7/29/2004 7:08	7:07:54	2650	AAL1144	887	255	855
7/29/2004 7:44	7:43:09	2650	AAL300	964	237	837
7/29/2004 7:50	7:49:08	2650	EGF654	906	237	837
7/29/2004 7:52	7:51:22	2650	AAL867	929	243	843
7/29/2004 8:01	8:00:17	2650	EGF746	870	268	868
7/29/2004 8:03	8:02:12	2650	CAA240	919	262	862
7/29/2004 8:12	8:11:16	2650	AAL1851	933	266	866
7/29/2004 8:16	8:16:01	2650	CAA205	913	234	834
7/29/2004 8:20	8:19:28	2650	CHQ6304	904	239	839
7/29/2004 8:24	8:23:33	2650	SKW3826	886	229	829

Figure 141 Flight tracks data at 2650 ft for 7-29-04 by flight number

Date/Time	Flight ID	Equip	Op	NavFix	Runway	APT	PWR	Type	Deviation	Beacon
7/29/2004 0:01	EGF460	E135	A	JEN	18R	DFW	J	PAX		5265
7/29/2004 0:02	AAL1302	MD82	A	JEN	UNK	DFW	J	PAX		4072
7/29/2004 0:02	AAL1203	MD82	A	BYP	17C	DFW	J	PAX		5167
7/29/2004 0:04	AAL2446	B772	A	UKW	18R	DFW	J	PAX		5264
7/29/2004 0:05	AAL2194	B738	A	BYP	17C	DFW	J	PAX		2541
7/29/2004 0:06	AAL1591	MD82	A	BYP	17C	DFW	J	PAX		7233
7/29/2004 0:07	AAL2274	MD82	A	UKW	18R	DFW	J	PAX		5345
7/29/2004 0:08	DAL1242	B733	A	BYP	17C	DFW	J	PAX		5132
7/29/2004 0:10	AAL2260	B752	A	JEN	18R	DFW	J	PAX		2531
7/29/2004 0:12	TRS118	B712	A	BYP	17C	DFW	J	PAX		2470
7/29/2004 0:12	AAL816	B752	A	JEN	18R	DFW	J	PAX		2332
7/29/2004 0:14	CAA179	CRJ7	A	UKW	17C	DFW	J	PAX		5222
7/29/2004 0:15	DAL1062	B738	A	JEN	UNK	DFW	J	PAX		2727
7/29/2004 0:17	UAL521	B733	A	JEN	UNK	DFW	J	PAX		2555
7/29/2004 0:17	DAL1161	MD90	A	BYP	17C	DFW	J	PAX		5242
7/29/2004 0:17	AAL1212	B752	A	UKW	18R	DFW	J	PAX		5114
7/29/2004 0:20	CAA506	CRJ7	A	BYP	17C	DFW	J	PAX		2642
7/29/2004 0:20	AAL1302	MD82	A	JEN	18R	DFW	J	PAX		4072
7/29/2004 0:21	AAL1156	B738	A	JEN	UNK	DFW	J	PAX		2544
7/29/2004 0:23	EGF874	CRJ7	A	UKW	18R	DFW	J	PAX		5111
7/29/2004 0:23	TRZ7911	B72Q	A	JEN	UNK	DFW	J	OTH		2420
7/29/2004 0:24	DAL533	MD88	A	CQY	17C	DFW	J	PAX		2414
7/29/2004 0:25	UAL1082	A319	A	UKW	18R	DFW	J	PAX		714
7/29/2004 0:25	EGF844	E145	A	JEN	UNK	DFW	J	PAX		5267
7/29/2004 0:27	DAL1062	B738	A	JEN	17C	DFW	J	PAX		2727
7/29/2004 0:28	CAA327	CRJ2	A	JEN	UNK	DFW	J	PAX		2552
7/29/2004 0:29	CAA497	CRJ2	A	UKW	18R	DFW	J	PAX		5160
7/29/2004 0:29	CAA253	CRJ2	A	BYP	17C	DFW	J	PAX		2466
7/29/2004 0:30	CAA489	CRJ7	A	JEN	UNK	DFW	J	PAX		2517
7/29/2004 0:31	UAL521	B733	A	JEN	18R	DFW	J	PAX		2555
7/29/2004 0:32	COA415	MD82	A	BYP	17C	DFW	J	PAX		7271
7/29/2004 0:33	USA883	B733	A	JEN	UNK	DFW	J	PAX		2503
7/29/2004 0:33	EGF512	E145	A	UKW	18R	DFW	J	PAX		5113
7/29/2004 0:34	AAL1153	MD82	A	BYP	17C	DFW	J	PAX		2547

Figure 142 Flight tracks data for arrival flights -7-29-04

Date/Time	Flight ID	Equip	Op	NavFix	Runway	APT	PWR	Type	Deviation	Beacon
7/29/2004 0:01	AAL1951	MD83	D	TCC	17R	DFW	J	PAX		2356
7/29/2004 0:07	EGF715	E145	D	TCC	18L	DFW	J	PAX		5365
7/29/2004 0:08	AAL194R	B738	D	MLC	17R	DFW	J	PAX		527
7/29/2004 0:10	AAL1285	MD83	D	PNH	17R	DFW	J	PAX		2225
7/29/2004 0:12	AAL1239	MD82	D	ZIM	17R	DFW	J	PAX		5252
7/29/2004 0:16	AAL1575	MD82	D	LBB	17R	DFW	J	PAX		2347
7/29/2004 0:18	AAL1221	MD83	D	ADM	17R	DFW	J	PAX		2316
7/29/2004 0:32	TRS106	B712	D	MLC	18L	DFW	J	PAX		3634
7/29/2004 0:34	CAA612	CRJ2	D	MLC	17R	DFW	J	PAX		2335
7/29/2004 0:40	AAL1027	B752	D	ABI	17R	DFW	J	PAX		2302
7/29/2004 0:41	DAL166	B763	D	ELD	UNK	DFW	J	PAX		535
7/29/2004 0:44	AAL409	MD83	D	ACT	18L	DFW	J	PAX		2367
7/29/2004 0:45	UAL1098	B733	D	TXK	UNK	DFW	J	PAX		533
7/29/2004 0:47	MEP6401	B712	D	MLC	18L	DFW	J	PAX		516
7/29/2004 0:53	FFT127	B733	D	ADM	18L	DFW	J	PAX		2375
7/29/2004 0:55	AAL403	MD82	D	SAT	17R	DFW	J	PAX		2217
7/29/2004 0:57	AAL1401	MD82	D	ACT	17R	DFW	J	PAX		564
7/29/2004 1:18	AAL1865	MD82	D	LBB	17R	DFW	J	PAX		3404
7/29/2004 1:25	AAL1688	B752	D	TCC	17R	DFW	J	PAX		567
7/29/2004 1:46	AAL1464	B738	D	OKM	17R	DFW	J	PAX		577
7/29/2004 1:48	AAL1989	MD82	D	ABI	17R	DFW	J	PAX		2271
7/29/2004 1:50	AAL2882	MD82	D	MLC	17R	DFW	J	PAX		3422
7/29/2004 1:51	AAL1925	MD82	D	PNH	17R	DFW	J	PAX		2201
7/29/2004 1:53	AAL351Q	MD83	D	TCC	17R	DFW	J	PAX		536
7/29/2004 2:00	COA1142	B735	D	TXK	17R	DFW	J	PAX		576
7/29/2004 2:07	AAL2816	MD82	D	ELD	UNK	DFW	J	PAX		551
7/29/2004 2:09	XNA127	A30B	D	LIT	18R	DFW	J	CRG		2275
7/29/2004 2:18	DAL1247	MD90	D	ABI	17R	DFW	J	PAX		6247
7/29/2004 2:20	FDX1201	DC10	D	ELD	17R	DFW	J	CRG		2357
7/29/2004 2:25	EGF531	CRJ7	D	LIT	18R	DFW	J	PAX		560
7/29/2004 2:32	DAL1062	B738	D	ELD	17R	DFW	J	PAX		2220
7/29/2004 2:57	FDX1635	A306	D	ELD	17C	DFW	J	CRG		571
7/29/2004 3:15	GTI9060	B742	D	LIT	18R	DFW	J	OTH		2227
7/29/2004 3:42	UPS924	B763	D	LBB	18R	DFW	J	CRG		2213

Figure 143 Flight tracks data for departure flights -7-29-04

In Figure 143 shows the animated replay of the arrival aircraft, departure aircraft and the over flight aircraft in different colors for ease of identification. In Figure 144 the animated aircraft is highlighted by the height of the aircraft above DFW in different colors.

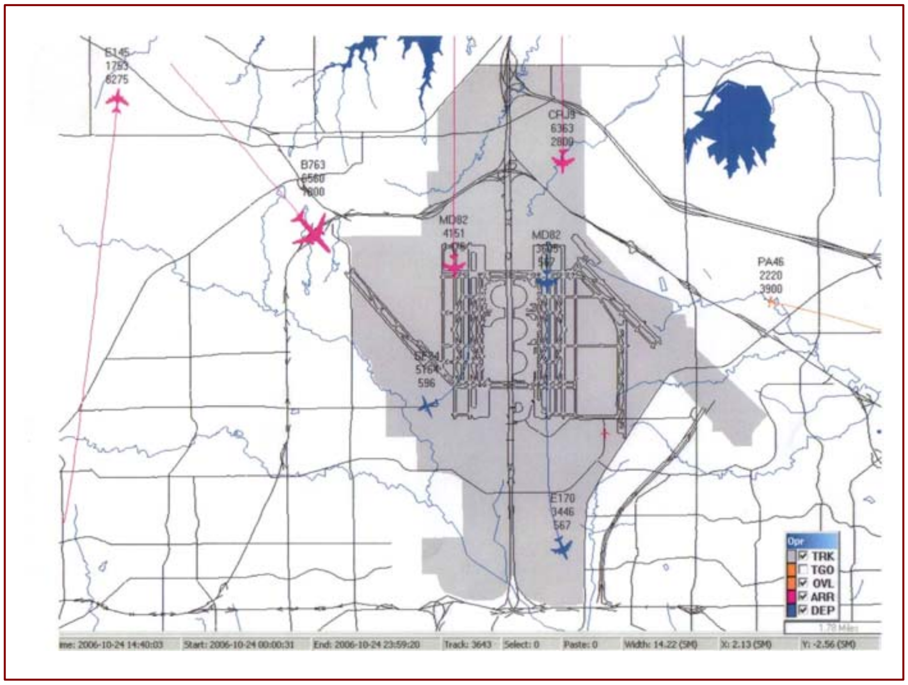


Figure 144 FliteGraph® data showing arriving, departing and over flight aircraft

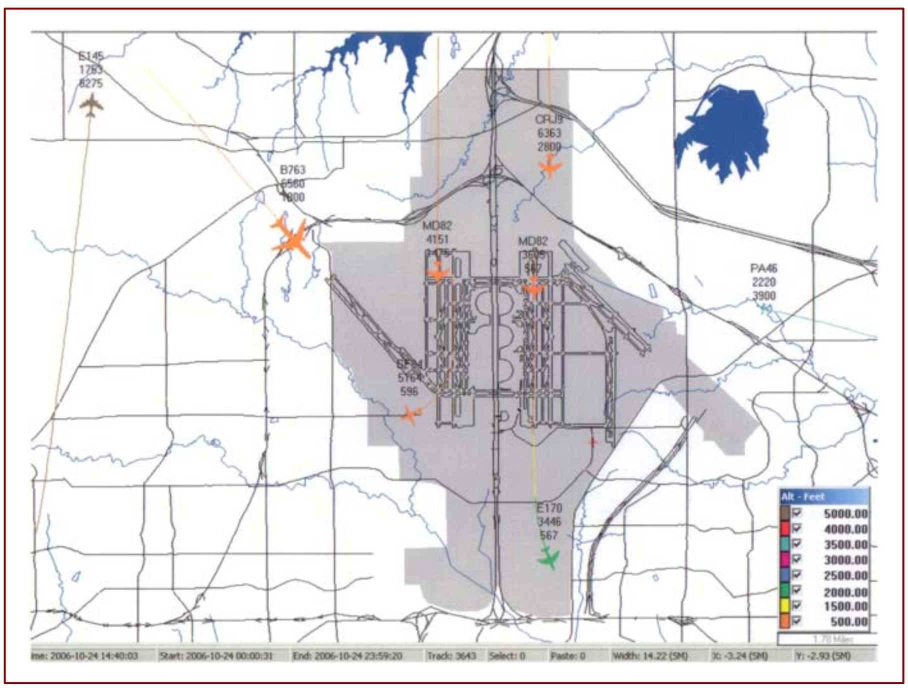


Figure 145 FliteGraph® data showing aircraft at different elevations above DFW

APPENDIX M

CHRONOLOGICAL DEVELOPMENT OF THE PERIMETER TAXIWAY RESEARCH PROJECT

Chronological development of the Perimeter Taxiway research project

17 OCT 03. 1st meeting with Mr. Paul Erway, Manager, Runway safety, FAA Southwest Region office, Fort Worth, TX. **10 a.m. to 11 a.m.**

Discussed the following about evaluation of PT operations at DFW airport:-
Systems engineering approach
-validate numerical model
-not belong to FAA. Independent review
-no bias in decision making
-incident vs accident
Develop a safety system. Analyze MITRE runway safety evaluation of DFW

Unified systems
Runway status lights –RWSL installed along the edge of runway
Timing, actual error, display, red light, stopping distance
Landing and takeoff at DFW
Human factors in operations
Compare the best and the worst case
For PT operations at DFW
Airport improvements 600'-900' offset around the runway
No data yet to prove it is safer to operate with PT
Runway crossing consider 747, 737, 757, 767 etc 3 deg glide slope
Part 121 airlines-commercial airlines
Performance curves
Risk comparison
Risk assessment, safety factors, design changes, flight standards
Industry validation models
Risk modeling, risk evaluation, risk assessment
Balancing all the risks in the system
Accident data consideration NTSB data on accidents and incidents at DFW

Formalized study is needed
Surface safety materials
Technology issues-surface safety
Look at all major airports, evaluate safety in operations, and create a database
Future study planned at STL, LAX, DTW and ATL

11NOV03 2nd meeting with Mr. Paul Erway **1:30 p.m. to 2:30 p.m.**
Education of operators, awareness, culture, technology
PT –all airports can use the benefit
Required real estate, design requirements, operational issues,

Takeoff climb, climb out limiting factors-load
Boeing, airbus check climb rate for take off conditions, obstructions
Comparative risk analysis
Physical, economic considerations cost benefit analysis
Review the document Aviation Human Factors by Dr. Heinrich, UT, Austin, Psychology professor.
Aviation-medical-incidents due to stress
Performance, fatigue, cultural issues, professional, national culture
Human factors, psychologists
Runway safety, human error, elimination, increasing capacity
Reliability of the hub
Regulatory guidelines and standards
European rules definition-EUROControl
Harmonize with other airport operators
Account for airport surface incident
Categories of severity of accidents, avoidance of an accident

Category	Level of severity
A	
B	
C	
D	
E	

For data collection, explore sources, structure and availability
Reclassify, DFW, LAX based on PT operations findings

3DEC03, 3rd meeting with Mr. Paul Erway of FAA **10 a.m. to 11 a.m.**
Review Airport Design Advisory circulars 16.3 from FAA
Design guide –FAA
B747-400SP tail height may be the governing factor? Analyze
Airbus A380 is a special case at DFW
Flight SIM 2002 new package in 2004
Obtain data for operations at DFW for various types of aircraft and operations
Modify the time period if necessary
Accident/incident database
For the top 35 towered airports find out the number of incursions per day on the active runway. Estimate the real number of infractions
Come up with a factor for use in the study
Takeoff/landings actual data available at airports
Obtain from maintenance engine failure on the runway, how often and what was the result
For flight carriers use the theoretical calculations
Push back on the assumption. If the perimeter taxiway is not built what is the real risk?
Give a good recommendation; compare the risk with/without PT

Flight performance model
Assume the real risk-come up with a factor
Establish a methodology
NTSB-CD data available from FAA
FAA “same time” program?
Got information on runway Latitude and Longitude for DFW from DFW navigation plan

19DEC03 Received free copy of Visual SIMMOD software from Mr. Gregory Bradford of Airport Tools inc., Los Altos, CA

12JAN04 Obtained DFW airport ALP drawings from Mr. Vic Nartz of DFW Operations, DFW Airport, TX

15MAY05 4th meeting with Mr. Paul Erway of FAA **10 a. m to 11 a. m**
Existing runway configuration
East arrivals on 17C
Departures on 17R and 18L
West arrival on 18R crossing active runway to reach terminal gates similar to arrivals on 17C
Crosswind component- runway use changes
Existing taxiway configuration
Problem is runway incursions at DFW
Include freight airlines and air cargo
General aviation practically nil
Emergency response fire fighting, security, status
Baseline operation year 2004 data
Active runway crossings number per day
Estimate the delay and number of aircraft waiting to cross the active runway
Runway incursions-what to do about it?
Visual SIMMOD results
PT Configuration
Why and how? Review PT design criteria?
Aircraft speed on taxiways? What is the minimum and maximum permitted by FAA?
VFR types of aircraft
IFR-types of aircraft
For emergency response there is a parallel road to taxiway at DFW
Total elimination of active runway crossing during peak periods with PT
FAA and ATC perspective from controllers
Perspective from Pilots?
Airlines perspective-cost savings?
Fuel savings, reduction in pilot communication with ground controllers
Better use of gate positions

Visual SIMMOD results perform mathematical analysis, assign probability for engine failure?
Statistical analysis, develop construction cost. schedule, recommendations
Advantages, cost effectiveness and savings to airlines
Conclusion acknowledgement, references, glossary of terms

2JUN05 1st Meeting with Mr. Gregory Bradford of Airport Tools Inc, Las Altos, CA **10 a.m. to1 p.m.**
For flight characteristics –noise model-takeoff climb models and distance traveled
Weather conditions could be specified in Visual SIMMOD
Low ceiling, fog, rainy etc
Delay can be computed in minutes and hours
Fuel savings, the analysis will not consider fuel burn and pollution from noise and fuel burn
With and without PT in percent
SIMU odd numbers input data
SIMU even numbers output from SIMMOD
SIMU02 error messages bottom of the file, number of warnings and errors in input data eliminate all errors before running simulation
SIMU04 errors during the simulation-grid lock errors and other error listings, warnings, messages search for gridlock and look for reasons
DSD path Dynamic Single Directional path
SIMU04 traces review the tutorial 500 traces 1- 500
Taxi trace, gate trace and events are traces
Events and control events
Runway delay statistics
Events continuing arrival and continuing departures
Reviewed the DFW airport plans with the proposed PT system

13JUN05 2nd meeting with Mr. Gregory Bradford of Airport Tools Inc, Las Altos, CA, **9 am to 12 noon**.
Discussed reporter tab SIMMOD reporter and list of reports available
Export tool for reports generation and tables
Reporter tab; Node activity in time bucket:
15 minutes, 30 minutes and 1 hr
Gate scenario and gate usage report
Received a revised version of Visual SIMMOD software on a CD from Mr. Gregory Bradford..

22JUN05 5th meeting with Mr. Paul Erway of FAA **9 a.m. to 10 a.m.**
AutoCad drawing for DFW with present and future configurations of runway with PT.
Fuel burn data for takeoffs and landings
Runway orientation and lengths in the future

Consider American airlines in the past, present and future
Met with FAA Chief Design Engineer Mr. Rick Compton with regard to DFW drawings

22FEB06 Showed the DFW project animation to Dr. Stephen Mattingly and Dr. Jim Williams in CE conference room (NH414) from **3:30 p.m. to 4.15 p.m**.

3MAR06 met with Jim Parrish of DFW to obtain data on flights for 2004 for various dates from the DFW computer systems archives

16MAR06 made a presentation of DFW with Visual SIMMOD animator at the NASUG meeting in Atlanta from 12:45 p.m. to 1:30 p.m. 45 minutes presentation went well. Several questions were raised to clarify the approach to PT simulation at DFW

7APR06 Met with John Parrish of DFW and got flight information for 2004**.**
Met with Ms. Sandra Lancaster of the DFW Noise Mitigation and Environmental Affairs Department. Obtained information on the availability of daily flight data from 1998 thru 2006 in a large database in that department.

21APR06 Met with Dr. Ardekani at 10 a.m. and showed the simulation and animation of DFW PT project. Dr. Ardekani suggested that I include the measures of effectiveness (MOE) in the comprehensive exam presentation in a tabular form for 8 scenarios proposed in the DFW project. He also asked me to consider the move of Southwest Airlines from Love Field to DFW and its impact on delays and PT operations in 2010.

18MAY06 Attended the quarterly Runway safety meeting (RSAT) at DFW Emergency Operations Center. Found out that the bridge connecting the East and West side PT have been eliminated in the final design of PT system. Need confirmation of the change from Mr. Victor Nartz as he made the presentation on the status of the PT.

22MAY06 Comprehensive examination at UTA CE Dept before the Graduate Committee. I presented to the committee the research plan outline and details of the data sets to be used in Visual SIMMOD program. I was declared as a doctoral candidate after successfully completing the Comprehensive Examination.

24MAY06. I met with Mr. Dean Paxton of the FAA ATC at the DFW from 10 a.m. to 11:30 a.m. Had a very good discussion and I was able to obtain details on the operations at the airfield on arrivals, departures and runway assignment procedures used at DFW.

20JUL06 Obtained information on runway assignments for various runways and wind direction from Mr. Dean Paxton of the FAA at DFW

21JUL06 Received the 29JUL04 flight data from Ms. Sandy Lancaster of the DFW Noise mitigation and Environmental Affairs Dept. as an e-mail attachment.

24Jul06 Met with Mr. Paul Erway and discussed the data received from Noise mitigation and environmental affairs dept at DFW.
25Jul06 Met with Mr. Harvey Holden and Mr. Vesa Turpeinen, Intern, of the Environmental Affairs Dept at DFW to discuss the possibility of getting more flight data for 2001, 2002, 2003 and 2005 to estimate the height of aircraft on the arrival and departure path over the four parallel runways at DFW.

1AUG06 Received additional data for year 2001, 2002, 2003, and 2005 from Mr. Vesa Turpeinen for the four parallel runways at DFW.

10AUG06 Received the scheduled flight information for July 2004, published in the Official Airline Guide (OAG) from Ms. Flavia Marples, Director of Sales, Latin America and Caribbean Region, Miami, FL., and Ms. Carol Knight of OAG Worldwide Organization in Chicago.

21AUG06 Received the list of Cargo Airlines serving DFW from Mr. Steven Tobey, DFW Operations Department for inclusion in the Visual SIMMOD simulation.

26AUG06 Reviewed the flight information data for July22 and July 29, 2004 with Dr. Mattingly, for consistency, formulation and input to Visual SIMMOD simulation

19SEP06 Met with Mr. Dean Paxton of the FAA, ATC at DFW for a review the procedures used in Visual SIMMOD simulation. Obtained sketches for taxiway and runway use plans for south flow and north flow of operations. Airfield operation was observed from the West Control Tower from 11 .a.m. to 12 noon to ascertain the high speed exit used by arriving aircraft and the height at which the departing aircraft fly during take off.

21SEP06 Met with Mr. Tom Wade of the FAA Planning and Programming Branch to discuss the planning and forecasting methods used by the FAA in their forecast of operations at thirty-five towered (OAP) airports including DFW. Received a copy of the working paper prepared for DFW Airport Board by Leigh Fisher Associates in 1996, wherein they have discussed the proposed PT operations.

6DEC06 Met with Mr. Greg Juro of the FAA, ATC at DFW to discuss the methods used to compute the airport and runway efficiency by the FAA to report at the FAA/APO web site. Information about DFW weather, wind speed, temperature and status of runway and taxiway are also input from the facility at DFW.

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BIOGRAPHICAL INFORMATION

Saty Satyamurti received his Bachelor of Engineering Degree with a specialization in Civil Engineering from the University of Madras in Coimbatore, India in 1957. After graduation, Mr. Satyamurti moved to the Northern Indian state of West Bengal and worked on major steel plant construction projects. In 1967, Mr. Satyamurti, along with his wife and two children moved to Canada to begin a new life. There, he worked as a civil engineer and from 1973 to 1978 he taught Civil Engineering at Humber College in Toronto, Canada. While teaching, Mr. Satyamurti completed his Master's Degree in Transportation Engineering at the University of Toronto.

In 1978, Mr. Satyamurti moved to Houston, Texas and worked for various Engineering consulting firms including, Stone and Webster, Rust Engineering, Flour Daniel, MW Kellogg, and Parsons Corporation. In 2000, Mr. Satyamurti retired from Parsons Corporation and settled in Arlington, Texas. In 2002, he decided to pursue his Ph. D in Civil Engineering, specializing in Transportation Engineering.

Mr. Satyamurti's interests include travel and spending time with his grandchildren. He has been married to his wife, Girija, for 48 years. Mr. Satyamurti's elder son Durgesh, his wife Sujatha, and children Sundeep and Sungita live in Houston, Texas. His other son, Ravi, his wife Thana, and children Roshini and Rajesh live in Grand Prairie, Texas.