

Empirical Analysis of Airport Capacity Enhancement Impacts: A Case Study of DFW Airport

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ABSTRACT

This paper assesses the impact of a major expansion in airfield capacity at Dallas-Fort Worth (DFW) airport. In October 1996, a new runway was commissioned, and the airspace was entirely reconfigured. Our study of the benefits of the expansion is retrospective and based on empirical data and hence provides a useful check on predictive and model-based studies. Also, it pays considerable attention to adaptations made by airlines. Central questions in our research are whether operational impacts and airline adaptations can be observed in the DFW case, and how to define metrics that may capture them.

We developed several new metrics and used them, in conjunction with existing metrics, to measure the impacts and adaptations. We found that average effective travel time from the scheduled departure time to the actual arrival at DFW and hence the average delay did decrease after the capacity expansion, but only under inclement weather conditions. However, no significant reductions in delay against schedule were observed. The daily maximum rate of operations of American Airlines, the dominant carrier at DFW, increased. Also, major airlines operating at DFW collectively scheduled their daily operations with a higher concentration (across the whole day) than the earlier levels in 1996. Average passenger transfer time of American's flights at DFW improved but the improvement did not last long. Overall, it appears that the impacts and adaptations were more modest than expected, perhaps as a result of confounding events. The metrics and methodology are applicable to any such study about any other airport.

KEY WORDS: Airports, Airport Capacity, Airport Capacity Enhancement, Flight

Delay, Airline Scheduling, Dallas-Forth Worth Airport

1. INTRODUCTION

This paper assesses the impact of a major expansion in airfield capacity at Dallas-Fort Worth (DFW) airport. On October 1, 1996, a new runway, 35R/17L, was commissioned. Nine days later, the airspace was entirely reconfigured and new procedures introduced. These changes allowed triple and quadruple independent arrival streams under IFR and VFR conditions, respectively. Arrival capacities increased from 102 to 146 under VFR, and from 66 to 108 under IFR [1].

The need for and benefits of increased airport capacity have been the subject of extensive study, both at the broad policy level and in the context of specific proposals to improve the National Airspace System. Two features distinguish the work presented here from much of what has been done previously. First, our study is retrospective, and based directly on empirical observation. Understandably, the preponderance of capacity/delay studies endeavor to predict how proposed changes will affect system performance. Such predictions are essential to inform investment decisions, which are usually irreversible and often involve huge expenditures. Predictive studies must, however, rely on simulation and modeling tools, whose results are subject to a wide variety of errors. Retrospective studies like the one presented here cannot directly inform decisions, but can observe what actually happened in the aftermath of a NAS investment. They therefore provide a useful check on predictive, model-based, studies.

Second, our analysis pays considerable attention to adaptations made by airlines, as well as operational impacts. Predictive analyses of NAS improvements generally ignore the impacts of the improvements on the demand for NAS services. Yet economic logic

suggests that when airport congestion is alleviated, users will adjust their airport use in order to take advantage of the improved conditions. Such changes may lead to additional benefits from capacity expansion, but may also diminish the delay reduction benefits on which conventional studies focus. Central questions in our research are whether airline adaptations can be observed in the DFW case, and how to define metrics that may capture them.

The remainder of this paper is organized as follows. In Section 2, background on the DFW expansion, and on contemporaneous events that may also be reflected in our data, is presented. Section 3 considers the impact of the expansion on observed arrival throughput rates. Section 4 examines delay impacts, and Section 5 investigates airline adaptations. Conclusions are offered in Section 6.

2. BACKGROUND

The 1996 changes at DFW were initially conceived in the late 1980s, through two interrelated planning efforts. The DFW Airport Development Plan (ADP)[2], completed in 1991, succeeded the 1967 Master Plan under which the airport was originally built. The ADP forecast 1.2 million aircraft operations in the year 2010. Without new runways, average aircraft delays exceeding 20 minutes per operation were anticipated. Two new runways the one on the east side of the airport that opened in 1996 as well as one on the west side scheduled to open in 2004 were proposed, along with other airfield improvements. The plan also called for a complete reconfiguration of the terminal area, which has since been replaced with a more incremental approach.

The changes in the air traffic control system were developed in the DFW Metroplex Air Traffic System (DMATS) Plan [2], the product of an FAA task force established in 1987. The DMATS Plan focused on improving the ATC system throughout the Dallas terminal area, which more than 100 airports and airfields in addition to DFW. Major elements of the plan included expansion of the TRACON airspace, new arrival and departure routes for both DFW and other airports, and new ATC facilities at DFW. The latter included two new towers, each dedicated to one side of the airport, which provided the additional control positions and equipment required to operate the new runways.

Local communities resisted the expansion plans. The proposed runways were to be located much closer to developed areas than the previous ones. Anticipating noise impacts, the cities of Grapevine, Irving, and Euless, each of which contain portions of DFW airport within its boundaries, enacted ordinances that any changes at DFW require land use permits [4]. The legality of these ordinances was litigated in a sequence of suits and countersuits and eventually upheld by the state courts. Airport supporters then brought the matter to the Texas state legislature, which enacted a bill exempting DFW from municipal ordinances. Grapevine then took the matter to the federal courts, which refused to intervene, allowing construction of the runway to begin in late 1993 [5]. The airport has spent over \$100 million to mitigate noise impacts from runway 35R/17L, buying out nearly 1000 properties and providing noise insulation for a like number of others [5].

American Airlines is the primary tenant at DFW, accounting for roughly 70 per cent of its operations in 1997. In assessing the impacts of the 1996 capacity expansion, it is important to bear in mind other factors that were influencing American during this period. Difficult contract negotiations between American and its pilots union, the Allied Pilots Association, were proceeding during the latter part of 1996 and early 1997. Disagreements centered on pay scales and whether American Eagle would be permitted to operate regional jets. During this period, American pilots engaged in sick-outs and other actions that forced the airline first to cancel flights and later to curtail its schedule [6]. Responding to what it perceived as excessive labor costs for pilots, management proclaimed that there was little incentive for domestic growth. [6] Negative publicity surrounding the conflict, particularly when a strike appeared imminent in early 1997, may have also reduced traffic and capacity for the airline [7]. Agreement on a new contract was reached, after intervention of a Presidential Emergency Board, in March.

Also in this time frame, American undertook a very focussed initiative to improve on-time performance [8]. The move was triggered by reductions in on-time performance stemming from the pilot slow-down. An American vice president stated that the initiative would yield some significant improvement in 1997. [8]

3. THROUGHPUT RATE IMPACTS OF THE DFW EXPANSION

This section analyzes the impacts of the DFW capacity expansion on throughput rates. Conceptually, the throughput rate is the rate at which the airport services aircraft. It is the minimum of two quantities: the airport capacity, and the demand for airport

services. The expansion should result in higher maximum throughput rates, assuming that these are capacity constrained rather than demand constrained.

Our analysis employs data from the Airline Service Quality Program (ASQP). Each record of this database corresponds to a non-stop flight and contains, among other things, the flight's scheduled and actual departure/arrival times as well as actual wheel-on and wheel-off times. From the scheduled and actual times, ASQP produces arrival and departure delays used by the U.S. DOT to evaluate on-time performance.

This database includes the actual arrival times for every flight of the ten largest U.S. airlines, which account for about 60 percent of total operations at DFW. The throughput rates presented here therefore underestimate the total rates. The underestimate may not be too severe, however, since it is likely that when throughputs of ASQP flights are at a maximum, they are the dominant traffic.

We focus on arrival throughput. To calculate a maximum rate, we find, for each day in the 1996-97 time period, the shortest time interval over which a specified number, N , of ASQP flights arrive at their gates. N needs to be large enough to yield a stable average, but small enough to avoid lulls in demand. We chose $N=30$. Once the shortest time interval over which 30 ASQP flights arrive at DFW has been identified, we convert the result into an hourly rate, which we term the Daily Maximum Throughput Rate (DMTR).

We expect the DMTR to increase after October 1996 as a result of the capacity expansion. The other factor that will influence the DMTR is weather conditions. We obtained daily DFW weather information from the National Weather Service Global

Surface Summary (GSS). These data are somewhat limited because they provide daily averages only. Thus it is not possible to tell directly from these data whether the airport was operating in IFR or VFR conditions. Nonetheless, the GSS data permit us to roughly control for weather conditions.

The results of our analysis are presented in Table 1. When all days are considered, the average DMTR is 103 for days before the capacity expansion and 115 for days after the expansion, and the difference is clearly significant statistically. The pre-expansion figure is actually higher than the nominal VFR arrival capacity, even though, as noted above, it is based on a just a subset of flights. On the other hand, the post-expansion figure is between the nominal VFR and IFR capacities of 146 and 108.

We use the GSS to categorize days according to weather conditions, and compare pre- and post-expansion DMTRs for days in the same category. We define two categories of inclement weather days--one based on visibility only and the other on a combination of visibility and the presence of particular conditions such as fog, rain, snow, hail, thunderstorms, and tornadoes. We also define a good weather day as one with average visibility of 10 miles or more. For bad days defined based on visibility only, Table 1 reveals that throughput rates increased only slightly, and statistically insignificantly, after the expansion. When the second bad weather category is considered, the apparent effect of the expansion increases, although it is still insignificant, probably because of the small sample sizes. Finally, the results for good weather days resemble those for all days.

Overall, the throughput rates increased after the expansion, but not by as much as expected. While the increases in nominal capacity under IFR and VFR are claimed to be

30 to 60 percent respectively, observed DMTRs increased 13 percent on good days and less on other days. Various explanations for this discrepancy are possible. It may be that our weather data are too coarse, or that more non-ASQP flights were scheduled into peak periods after the expansion, or that in capturing only the best condition of the day the DMTR is not a reliable indicator. It is also conceivable that throughput rates in the post-expansion period were demand limited. Another possibility is that purported capacity gains have simply not been realized.

4. DELAY IMPACTS OF THE DFW CAPACITY EXPANSION

It is expected that total flight delays at DFW will have decreased after the expansion. Furthermore, since the new runway is further from the terminal, taxi times may increase. This section examines these conjectures.

Like the throughput analysis, this one uses the ASQP database as the primary data source. As previously noted, ASQP contains data reported by only ten major air carriers. This is not a serious limitation from a delay analysis standpoint, since these carriers, with their large aircraft, account for the vast majority of delay costs at DFW. A more serious problem is that delays recorded in ASQP are calculated with respect to flight schedules, which are padded in anticipation of delays. To emphasize this, we refer to the ASQP delay as Delay Against Schedule or DAS for short. Finally, the data do not specify the cause of delay, in particular whether a delay results from a capacity limitation at a particular airport.

4.1 Evolution of Arrival Delays at DFW

The time series of monthly average and median arrival DAS for DFW arriving flights presented in Figure 1. The average delay dropped slightly after the runway opened in October 1996. The average DAS over the January 1995 to September 1996 period is 5.92 minutes, while for the November 1996 to December 1997 period it is 5.20 minutes. However Figure 1 reveals that there is high month-to-month variability in the delay change. In the first 11 months after the capacity expansion, delay was lower than the year before in six cases, and higher in five cases. Median DAS levels also changed very little after the runway opening. So, overall, the delay impact does not appear to have been very strong.

Figure 2 reveals no obvious changes in taxi-in and taxi-out times at DFW after the capacity expansion. The average taxi-in time stays at approximately 10 minutes, and the average taxi-out at about 18 minutes. This is surprising in light of the increased taxi distance for aircraft using the new runway. Perhaps the greater distance was offset by a reduction in surface congestion.

From the analysis above, it seems that the DAS diminished slightly after the capacity expansion. However, since the DAS can be manipulated through schedule padding, it may not accurately reflect how the expansion affected operations at DFW. On the one hand, airlines may have reduced schedule padding in response to improved conditions at DFW. It is also possible that American Airlines initiative to improve on-time performance resulted in increased padding. Indeed, a comparison of American's scheduled flight times between DFW and 20 major important destinations in January 1996 and January 1998 reveals that scheduled flight times increased by an average of

approximately 4 minutes. Thus a more refined methodology that controls for such scheduling changes is required. Weather is a second possible confounding factor. Differences in delay between two time periods can often be explained by variations in weather. To control for this, we follow a procedure similar to that used in the throughput analysis.

4.3 Aircraft Travel Time and The Effect of DFW Capacity Expansion

We define the Effective Flight Time (EFT) of a flight as the time between its *scheduled* departure and *actual* arrival. This metric includes departure delay and gate-to-gate travel time, and is insensitive to schedule padding. Therefore, by tracking average EFT instead of average DAS, we avoid any spurious influence resulting from changes in airline scheduling practices.

The EFT is depends on the origin and destination of a flight. To track changes in the EFT for flights going into Dallas, it is necessary to average across flights in a way that maintains a fixed market basket of flight origins. To do this, we first identified all origins that had at least five completed flights into DFW for every day in the period from January 1, 1995 to December 31, 1997. For each such origin airport, we calculated the daily average EFT across its flights to DFW, which we term the Daily Average Flight Time (DAFT). Finally, we calculate the Daily Flight Time Index as a weighted average of the origin-specific DAFTs, with the weights based the origins shares of completed flights into DFW in the first quarter of 1997. The DFTI is analogous to a consumer price index, where the prices are flight times and the commodities are origins.

Having defined DFTI, we now consider how it was affected by the DFW capacity expansion. In doing so, we control for weather conditions using the Surface Climate Data described in the previous section. We retain the same criterion for Normal Weather days average visibility of 10 miles or greater. We use various definitions for inclement weather, including those employed in the throughput analysis.

One further refinement proved desirable. As noted, the distribution of delays is highly skewed, and includes small numbers of extremely long delays. We considered it extremely unlikely that a delay of over 180 minutes for a flight into DFW would be the result of congestion there, and therefore excluded all of the flights with arrival delays larger than 180 minutes. With these flights excluded, the variance of the DFTI decreased significantly.

We calculate the DFTI for days between Jan 1, 1995 through December 31, 1997. In order to examine whether the capacity expansion decreased delay at DFW, we compare DFTIs before and after the capacity expansion for various categories of days meeting our criteria for normal or inclement weather. Table 2 summarizes the results. For normal weather days, as well as days categorized as inclement on the basis of visibility only, the DFTI did not change significantly after the capacity. Significant differences in the DFTI are found for inclement days with reduced visibility, precipitation, and weather events. The magnitudes of these delay reductions are 12 minutes for the most restrictive definition and seven minutes for the less. It therefore appears that only under inclement weather conditions did capacity expansion reduce delays at DFW.

5. AIRLINE ADAPTATION

We now investigate whether and how airlines have adjusted their schedules to take advantage of the increased capacity at DFW. We investigate trends in the following four schedule attributes: number of operations, daily peak rate of scheduled operations, daily schedule concentration, and passenger transfer time. Again, ASQP is the primary data source. Other data sources, including airport activity statistics published by the U.S. Department of Transportation, and passenger itinerary data from the 10 percent ticket survey, are also used.

5.1 Number of Operations

Quarterly DFW departures from 1994 through 1997 are plotted in Figure 4 for three groups of airlines: American Airlines combined with its commuter affiliate Simmons Airlines (AA and MQ), Delta Airlines combined with its affiliate Atlantic Southeast Airlines (DL and EV) and all the other airlines operating at DFW. Figure 3 reveals no significant change in departure activity for any of these groups after the capacity expansion in October 1996. Indeed, activity levels appear considerably more stable--and slightly lower--during the 1996-97 period than in the previous two years, when Delta was retrenching and American expanding at DFW. These results are consistent with the assertions of American Airline executives that, notwithstanding the capacity expansion, high pilot pay scales make expanding operations economically unattractive.

5.2 Daily Peak Rate of Scheduled Operations

The peak rate of scheduled operations is expected to be particularly sensitive to airport capacity limitations. We used ASQP schedule data for the first Tuesday of every

month from January, 1995 through March, 1998 to track changes in daily peak rate of scheduled operations for American Airlines individually and for all ASQP airlines collectively. To estimate the peak rate, we first find the shortest time interval within a day in which a given number of operations are scheduled. As in the throughput analysis, we select 30 operations, a number large enough to produce a stable average but smaller than the number of operations in a connecting bank at DFW. We then convert this interval to obtain the equivalent daily peak rate of scheduled operations. We perform this calculation for three types of operations: arrivals only, departures only and both arrivals and departures.

We find that both the daily peak rates of scheduled arrivals and departures were stable for both AA and all ASQP airlines. However, the result for combined arrivals and departures, shown in Figure 4, reveals an increase in the daily peak rate of combined operations for AA after the capacity expansion, from about 250 per hour to 300 per hour. This suggests that American exploited the increased airport capacity by sharpening its peaks. Interestingly, however, this did not affect the overall level of peaking at DFW.

5.3 Daily Schedule Concentration

While the daily peak rate is a useful measure, it is based entirely on a single, short, period of the day when the peak occurs. It is insensitive to the length of time over which peak or near-peak rates of operations are scheduled, and to the number of peaks.

To overcome these deficiencies, we propose a measure called Hypothetical Deterministic Delay (HDD) as a gauge of the concentration of an airline's daily schedule and the degree of banking. This *hypothetical* delay is a function of the daily flight

schedule and an assumed capacity level (90 operations per hour in our study). The flight schedule can be for arrivals only, departures only, or both arrivals and departures. Figure 5 depicts how HDD is calculated. An airport is viewed as a single-server queuing system. The top curve in the figure represents the cumulative customer arrivals based on the schedule, while the bottom curve, whose maximum slope corresponds to the capacity, represents cumulative customer departures. HDD is simply the area between the two curves. Figure 6 shows the arrivals-only HDD and departures-only HDD for both AA and all ASQP airlines, based on the first Tuesday of every month from January 1995 through March 1998. Figure 8 shows the HDDs for the combined operations.

Figure 6 reveals some interesting dynamics. Beginning in early 1995, all four HDD values drop sharply. The arrival HDDs stabilize in late 1995, and then jump back upward beginning in July 1996, just before the new runway opening. The departure HDDs, in contrast, continue to drift downward throughout this period. Figure 7 shows a somewhat similar pattern for the combined arrival and departure operations of all ASQP airlines. This increase implies that the airlines collectively scheduled their arrivals and departures with higher concentration after the capacity expansion than they did in the months leading up to it. However, the role of the expansion in triggering this increase is clouded by two factors: the even higher HDD levels observed throughout most of 1995, and the decline in HDD beginning in late 1997.

5.4 Passenger Transfer Time

One of the most important impacts of airline scheduling at hub airports is passengers transfer time. In this section, we consider the impact of the DFW capacity expansion on passenger transfer time, focusing on American Airlines passengers.

In theory, a passenger connection can be made between any arrival flight and any departure flight with a later scheduled departure time. But we consider a pair of flights serving an O-D market to form a connection if they satisfy the following conditions:

- (1) The scheduled departure time is later than the scheduled arrival time by at least a certain amount. According to Official Airline Guide (OAG), this amount is 30 minutes for passengers transferring between AA flights at DFW.
- (2) For every arrival flight, no more than one departure flight is chosen as a possible connecting flight--the one that satisfies Condition (1) and whose scheduled departure time is the closest to the scheduled arrival time.
- (3) For every departure flight, no more than one arrival flight is chosen as a possible connecting flight--the one that satisfies Condition (1) and whose scheduled arrival time is the closest to the scheduled departure.

We now propose a method for tracking changes in transfer times for passengers connecting through DFW on American. Among the 8,000 American markets that are served through DFW, we consider the 2,300 which, based on the DOT 10 percent ticket survey, had the largest number of passengers connecting through Dallas on American in the first quarter of 1997. These markets account for 80% of American's DFW connecting traffic in that period. For each market, the connecting flights are selected using the algorithm described above.

For a given market on a given day, we use two indices, I_1 and I_2 , to measure the availability of connections to passengers. The first is the mean transfer time, the second is the inverse of the sum of the inverses of all the transfer times. More precisely,

$$I_1 = \frac{\sum_{i=1}^N T_i}{N},$$

and

$$I_2 = \frac{1}{\sum_{i=1}^N \frac{1}{T_i}},$$

where T_i is the i th transfer time and N is the total number of connections in the given market on the given day. We propose the second index, I_2 , in order to capture the fact that an additional transfer opportunity is better for passengers even if this extra one takes longer than the average of the rest.

These two indices are first calculated for each selected individual market, and then averaged using weights based on the numbers of passengers connecting on American through DFW in the first quarter of 1997, to derive overall indices for a given day. These indices were calculated based on American's schedule on the first Tuesday of every month from January 1995 through March 1998, and are plotted in Figure 8.

Figure 8 reveals that both indices have fluctuated around 10-15 percent over the period of study. The fluctuations exhibit seasonal patterns, with transfer times taking their lowest values in the early part of the year and their highest values during the summer

months. This may result from American building in extra connecting time to accommodate higher passenger flows during the summer. After the capacity expansion, both indices were stable for three months, before plummeting in the first quarter of 1997. Index 1, the mean connecting time, reached new lows during this time. Since the first quarter of 1997, however, both indices have trended upward. For whatever reasons, the benefits of the capacity expansion in reducing passenger transfer times have proved to be short lived.

5.5 Summary

In this section, four measures have been used to learn whether and how airlines may have adapted to the capacity expansion at DFW. The total number of operations has not changed. American Airlines peak rate of daily scheduled (arrival and departure) operations increased after the expansion. The concentration of operations as measured by the all-airline HDD also increased after the expansion, but declined subsequently. Passenger transfer times show marked post-expansion decline, but have since climbed back to pre-expansion levels.

6. CONCLUSIONS

In this paper, we developed several new measures and used them, in conjunction with several existing measures, to study the impact of a large airport capacity expansion at DFW in October 1996. We considered both operational impacts and ways in which airlines operating at DFW may have adapted to the new capacity. Among the new measures are:

- Daily Maximum Throughput Rate: the maximum rate at which an airport serves flights over the course of a day;
- Daily Flight Time Index: a measure of the average aircraft travel time (from the scheduled departure time to the actual arrival time) of domestic flights destined for a given airport on a give day;
- Daily Peak Rate of Scheduled Operations: a measure of the highest concentration of operations of a given day at a given airport,
- Hypothetical Deterministic Delay: a measure of the concentration of operations throughout a given day at a given airport, and
- Daily Passenger Transfer Time Index: a measure of the convenience of passenger transfer (in terms of the length of transfer time) and the availability of transfer opportunities offered by a given airline at a given airport on a given day.

On the basis of these measures we find evidence that the DFW expansion had a broad range of impacts. Throughput rates increased, although by not as much as expected. Changes in the DFTI suggest a reduction in delay, but this effect is confined to days with

inclement weather. During such days, delays declined by 7 to 12 minutes per flight, depending on the weather criteria used. Based on the proportion of days with inclement weather (10 percent in the after period based on the more stringent criteria), this suggests an overall delay reduction of around 1.2 minutes per flight.

Some adaptation to the new capacity by airlines operating at DFW has been observed. American Airlines daily peak rate of operations increased, and its average transfer times decreased for a few months after the expansion. Also, the major airlines operating at DFW collectively scheduled their operations with a higher concentration in the period after the runway opened than they had in 1996. The role of the capacity expansion in causing these changes is uncertain. Labor problems at American, along with its initiative to increase on-time performance, are confounding factors. It is also curious that some of the trends observed in the months just after the runway opening have since reversed themselves.

Despite our observation of some impacts on the operations at DFW and some responses by airlines operating at DFW, the changes are much less drastic than expected. This is perhaps because the airport authority, in anticipation of possible serious delays in the future, expanded the capacity and successfully prevented serious delay problems from arising at DFW. The airport has thus been able to remain on the fairly flat part of the demand-capacity-performance curve.

The measures and methodology employed in this research are applicable to many similar studies. Additional ones are being planned. We are particularly interested in

studying cases in which the airport was more severely congested prior to the capacity expansion.

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WEATHER CONDITION	CONSTRAINTS	AVERAGE MDTR		SIGNIFICANCE LEVEL
		BEFORE	AFTER	
NORMAL WEATHER	Visibility>=10 miles	104.93 arr/hr	119.47 arr/hr	0.0001
	Visibility<=7 miles	102.81 arr/hr	105.26 arr/hr	Not Significant
	Visibility <=8 miles	88.64 arr/hr	96.46 arr/hr	0.15
	Precipitation>0 Weather Event>=2			
ALL WEATHER	None	103.15 arr/hr	115.27 arr/hr	0.0001

Table 1: Average MDTR before and after Expansion, by Weather Condition

WEATHER CONDITION	CONSTRAINTS	AVERAGE DFTI		SIGNIFICANCE LEVEL
		BEFORE	AFTER	
NORMAL WEATHER	Visibility \geq 10 miles	156.19 min.	155.59 min.	Not Significant
	Arrival delays \leq 180 minutes	154.78 min.	154.73 min.	Not Significant
	Visibility \geq 10 miles			
INCLEMENT WEATHER	Visibility \leq 9 miles	169.34 min.	165.71 min.	Not Significant
	Visibility \leq 8 miles	175.75 min.	168.89 min.	Not Significant
	Visibility \leq 7 miles	169.04 min.	169.5 min.	Not Significant
	Arrival delays \leq 180 minutes	181.37 min.	173.89 min.	Not Significant
	Visibility \leq 8 miles			
	Arrival delays \leq 180 minutes	183.54 min.	171.14 min.	0.05
	Visibility \leq 8 miles			
	Precipitation $>$ 0 Weather Event \geq 2			
ALL WEATHER	Arrival delays \leq 180 minutes	175.93 min.	168.55 min.	0.05
	Visibility \leq 9 miles			
	Precipitation $>$ 0 Weather Event \geq 1			
ALL WEATHER	Original	159.58 min.	158.69 min.	Not Significant
	Arrival delays \leq 180 minutes	157.27 min.	157.48 min.	Not Significant

Table 2: Average DFTI Before and After the Capacity Expansion, by Weather Condition

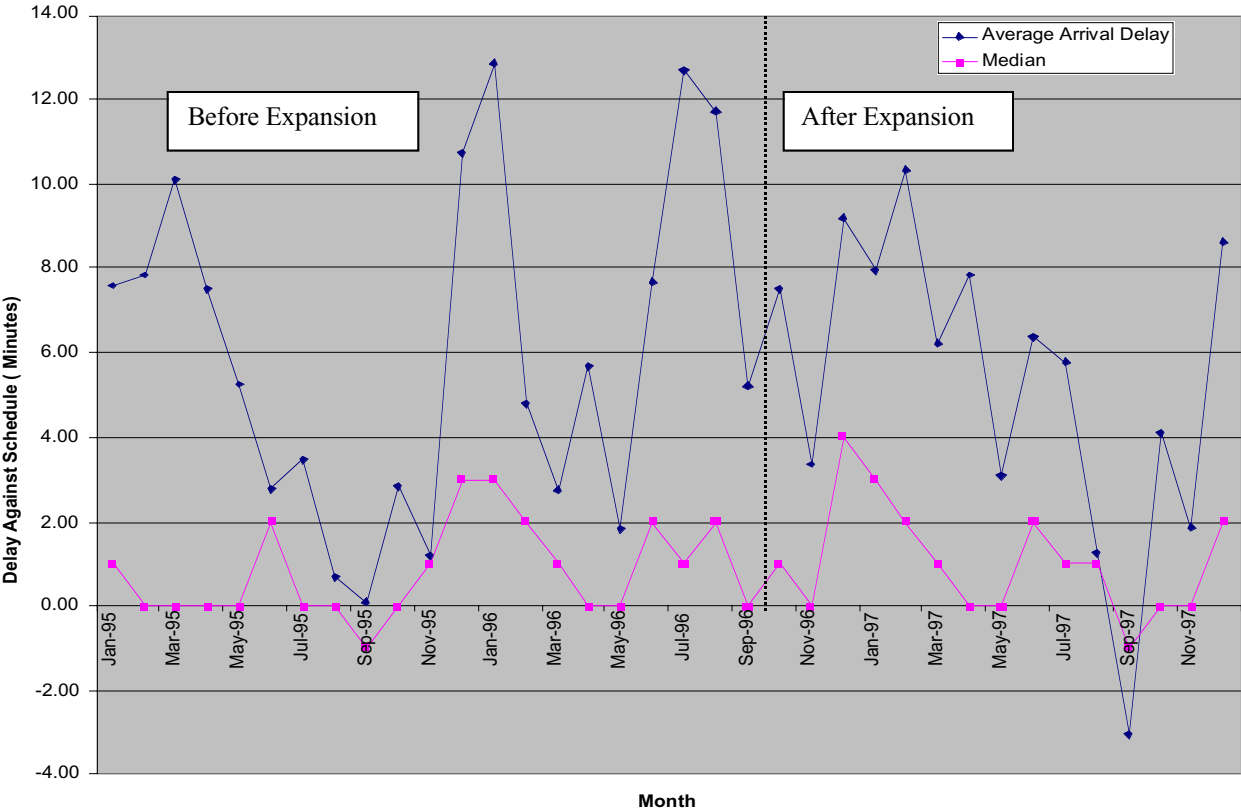


Figure 1: Averages of Arrival Delay vs. Medians of Arrival Delay

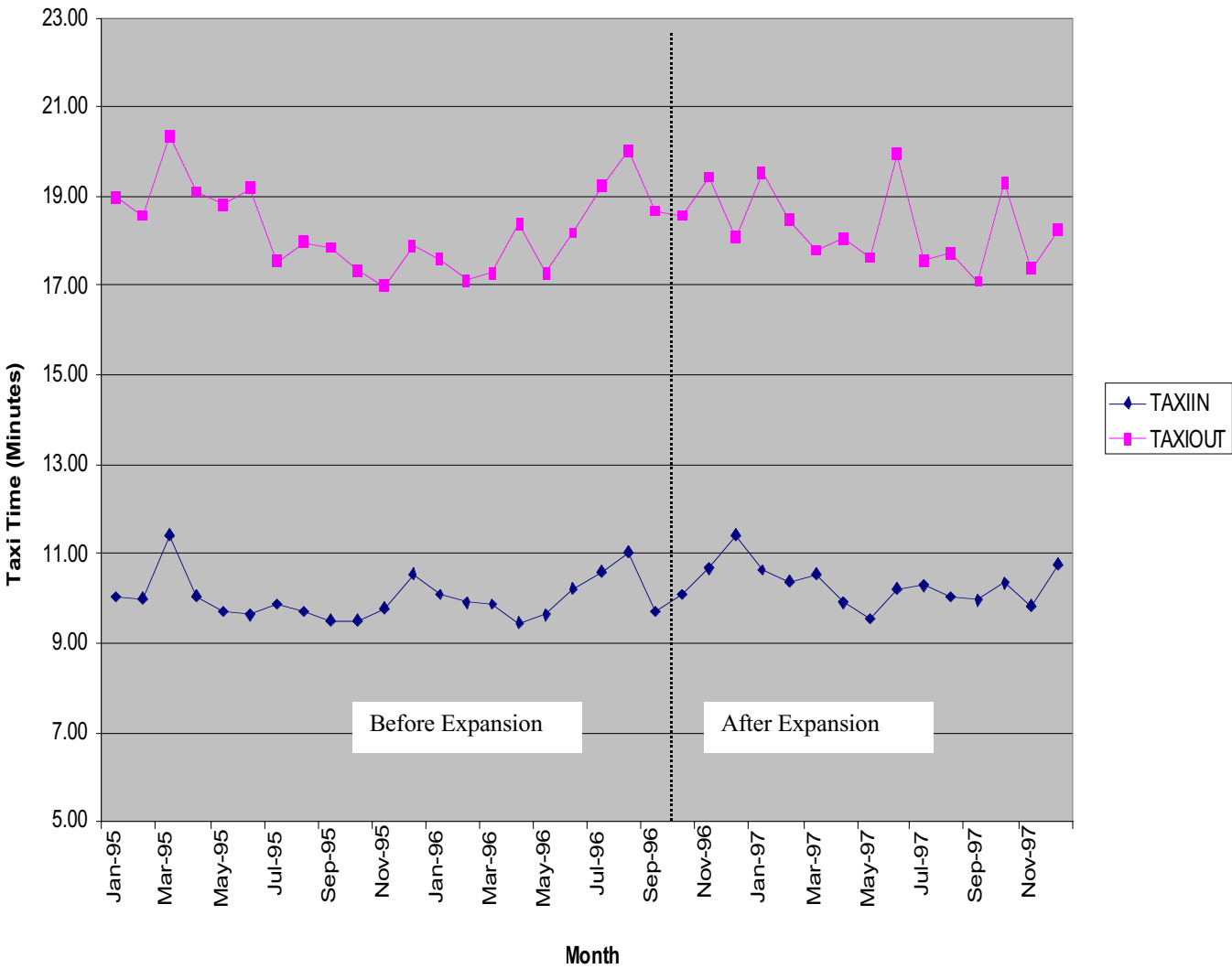


Figure 2: Taxi-in and Taxi-out Times Comparison

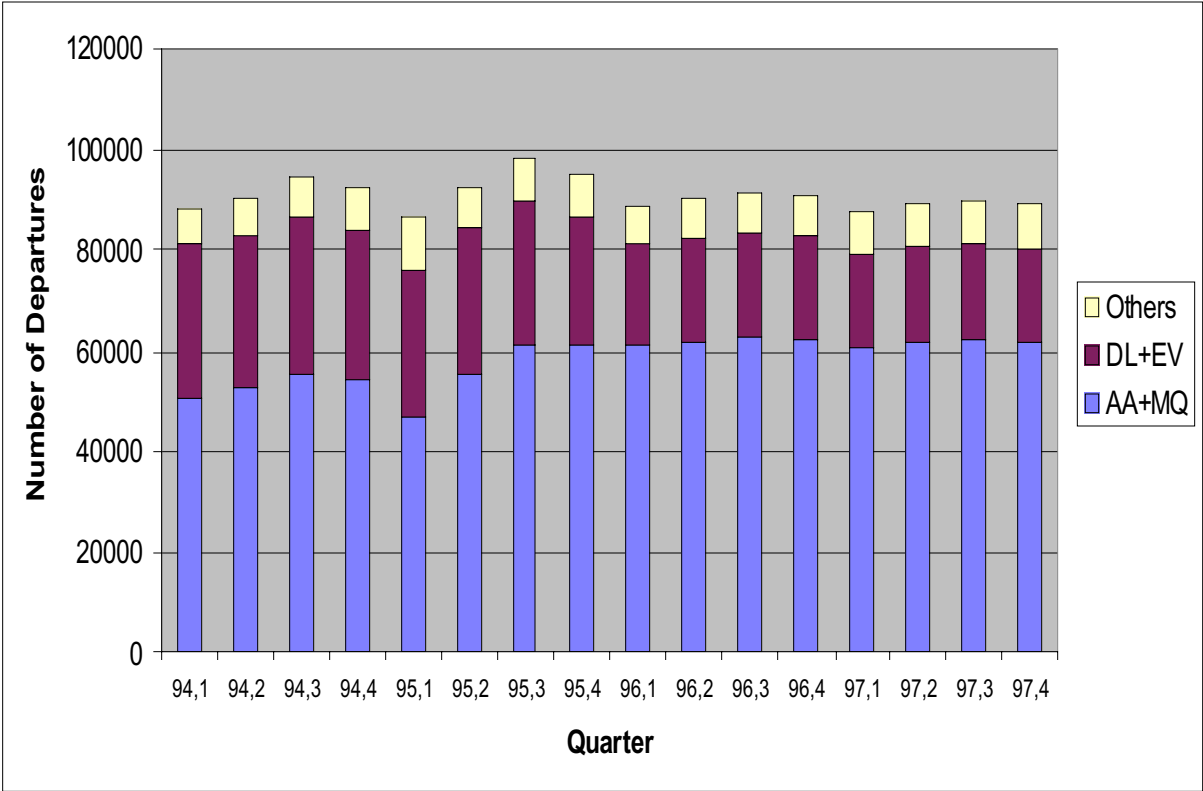


Figure 3: Departures from DFW

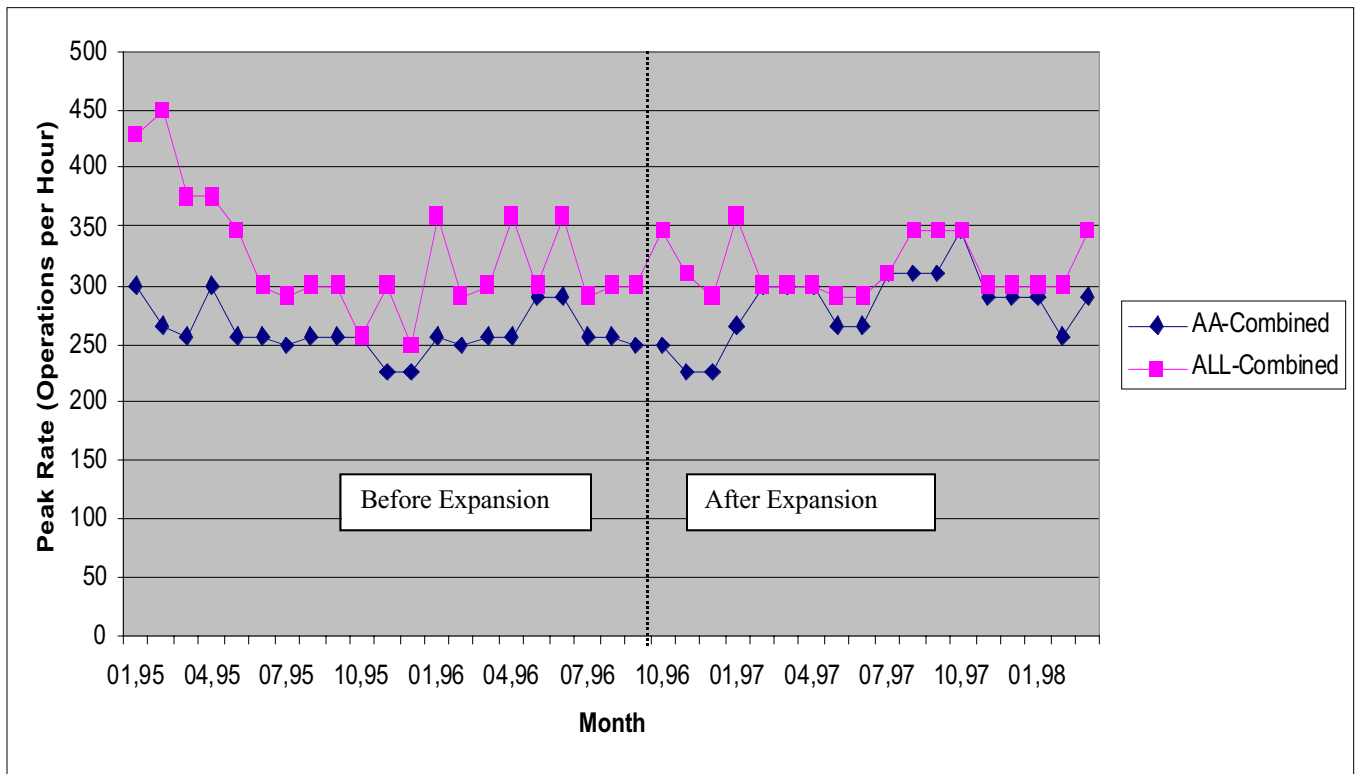


Figure 4: Daily Peak Rate of Scheduled Operations

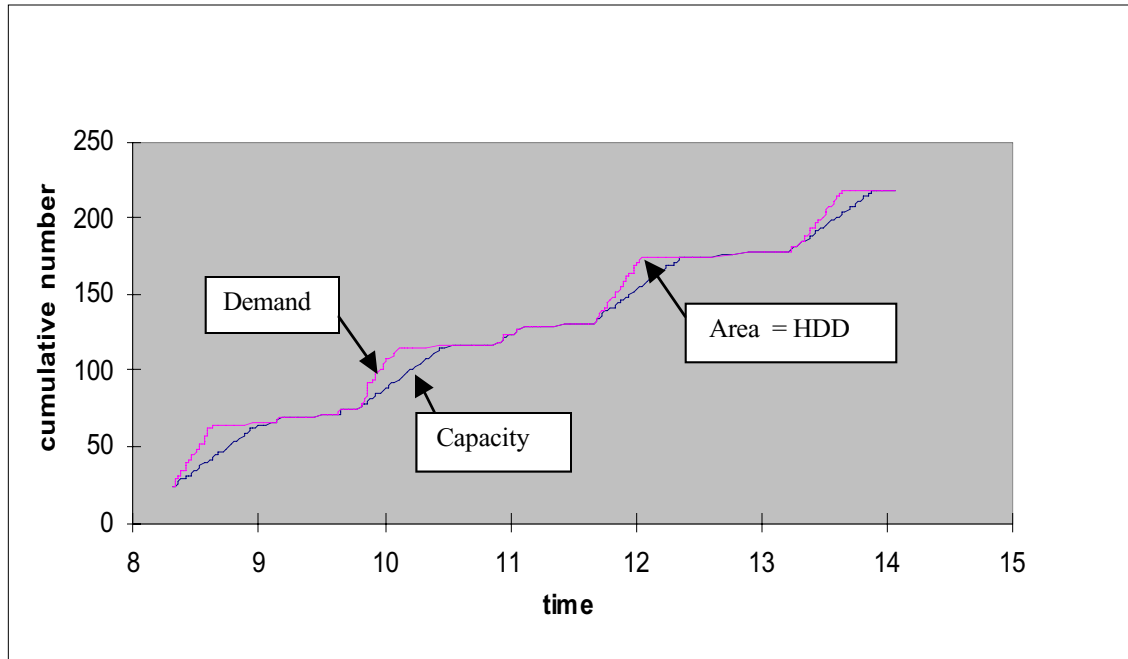
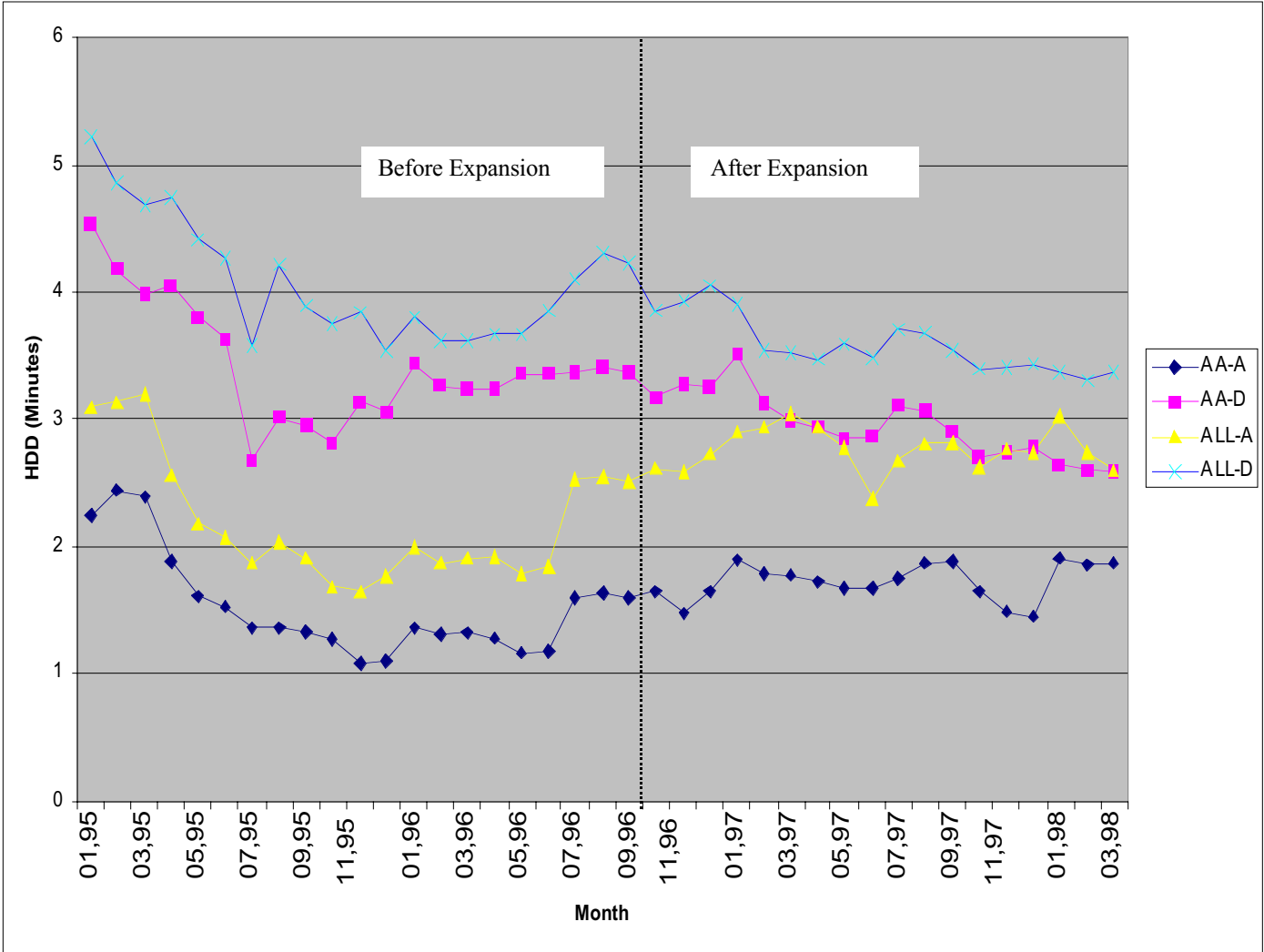


Figure 5: Method of HDD



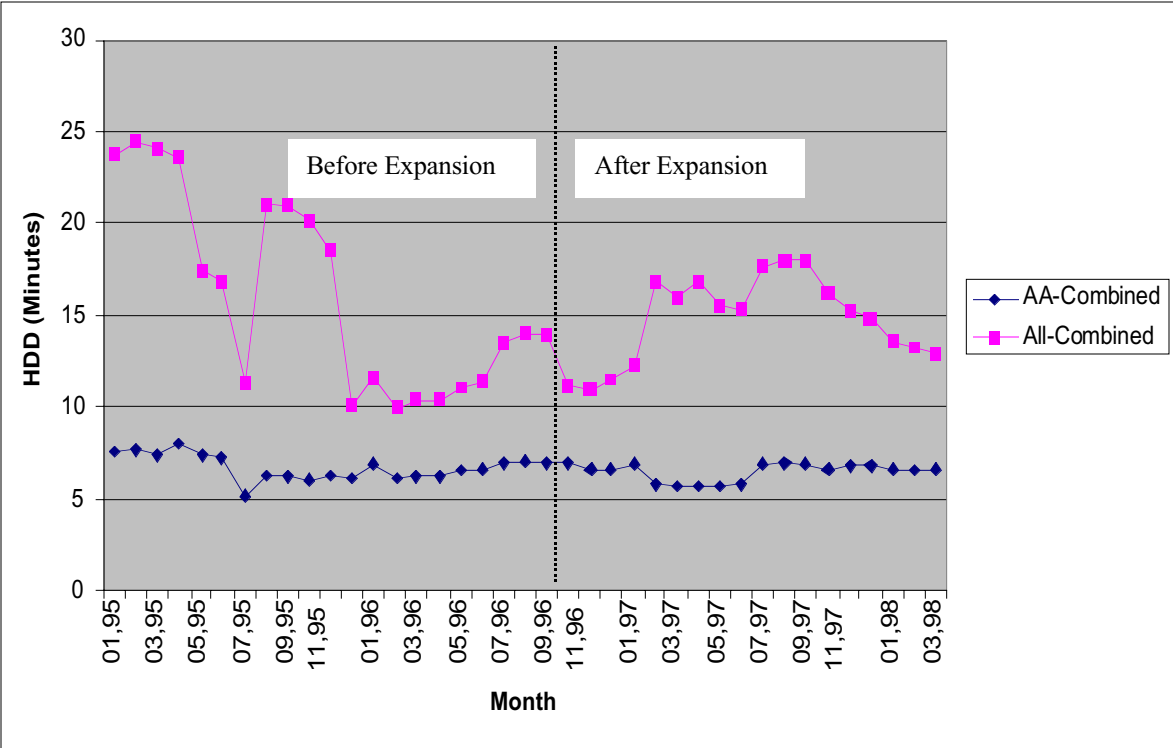


Figure 7: HDD for Combined Arrivals and Departures

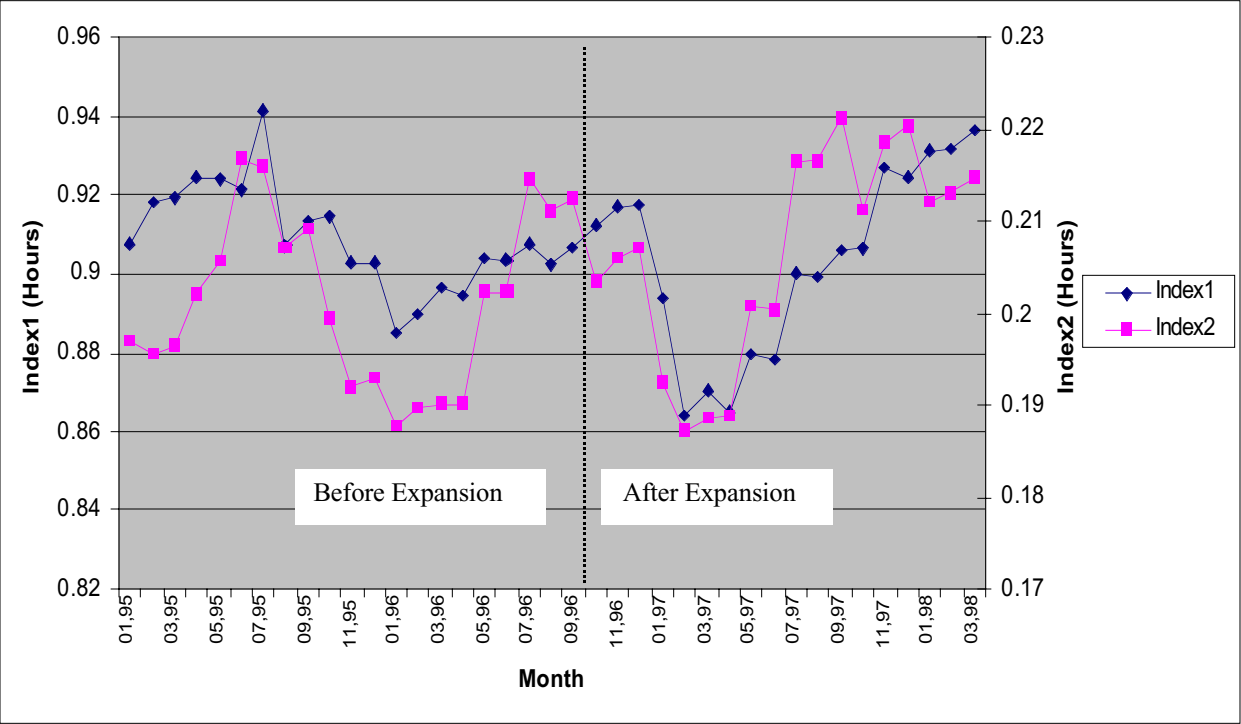


Figure 8: Passenger Transfer Time at DFW

LIST OF TABLES

Table 1 — Average MDTR before and after Expansion, by Weather Condition

Table 2 - Average DFTI Before and After the Capacity Expansion, by Weather Condition

LIST OF FIGURES

Figure 1 — Averages of Arrival Delay vs. Medians of Arrival Delay

Figure 2 — Taxi-in and Taxi-out Times Comparison

Figure 3 — Departures from DFW

Figure 4 — Daily Peak Rate of Scheduled Operations

Figure 5 — Method of HDD

Figure 6 — HDD for arrivals and departures only

Figure 7 — HDD for combined Arrivals and Departures

Figure 8 — Passenger Transfer Times at DFW