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Performance Evaluation of TMA in Arrival Traffic at IAH

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Dr. Kim received his Ph.D. degree in Electrical Engineering from Texas A&M University, and is currently conducting FAA sponsored research on Traffic Management Advisor (TMA) performance metrics model in which he and his graduate students focus on the comparison analysis of Pre-TMA and Post-TMA arrival traffic patterns and quality of services of NAS.

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1. Introduction

The Traffic Management Advisor (TMA) is a time-based strategic planning tool that provides Traffic Management Coordinators (TMCs) and En Route Air Traffic Controllers the ability to efficiently optimize the capacity of demand-impacted airports [1]. The benefits of TMA are, among others, increased throughput with reduced arrival delays, reduced holding and flight times, and increased departure rates. TMA assists controllers to achieve uniformity of arrival flows which can also lead to an increase in departure rates and a decrease in departure delays. This paper evaluates TMA operational performance on arrival traffic at the IAH in 2003 and 2004. TMA was deployed and operational at IAH from 2004. The data provided by FAA was collected via ASPM and other FAA databases.

The data analysis is focused on the arrival features, including average arrival time, variance and standard deviation of the arrival time for the flights of more than 10 seasonal arrivals, to compare them in 2003 and 2004. The main focus of the analysis is centered on the percentage change in on-time arrivals. In line with the on-time arrival probability, we also analyze the arrival patterns in the rush period.

Lastly, the actual arrival distribution is compared with scheduled arrival time for cumulative arrival pattern and delay feature in the peak arrival times (rush hours) for the Pre-TMA and Post-TMA periods. Also included is the comparison of runway usages and runway entry points.

2. Traffic Management Advisor (TMA)

The TMA has been commended by traffic management coordinators and air traffic controllers for its ability to provide increased and improved situational awareness through its graphical features such as timelines, load graphs, data degradation alerts, plain view

displays, traffic count overlays, aircraft watch windows, sequence lists, rush alerts, and other over lays. Also, TMA computes estimated time of arrival (ETA) of aircrafts to the runway threshold, final approach fix, and meter fix. Simultaneously, it computes the sequences and scheduled times of arrival (STA) to meter fix, outer meter arc, final approach fix, and runway threshold so that each aircraft can meet the sequencing and scheduling constraints entered by the traffic Management Coordinators in such a way to maximize airport and TRACON capacity without compromising safety.

The TMA was first tested and operationally evaluated in one month summer period of 1996 at Fort Worth Air Route Traffic Control Center (ARTCC) for a thirty-nine rush traffic periods [2]. To date, TMA has been installed and currently operational at Oakland (August 2001), Miami (May 2001), Atlanta (June 2001), Los Angeles (June 2001), Denver (September 2000), Minneapolis (June 200), and Houston (June 2003).

3. TMA Operation at IAH

Although TMA became operational at Houston center (ZHU) in June 2003, the full implementation of TMA with time-based metering started in June 2004 [3]. However, partial use of time based metering began in January 2004. During the period of partial operation, IAH opened a new runway (i.e. 8L/26R) parallel to 8R/26L. Upon the opening of the new runway the existing runway 8R/26L was closed for resurfacing until July 2004. Figure 1 illustrates the runway layout of IAH.

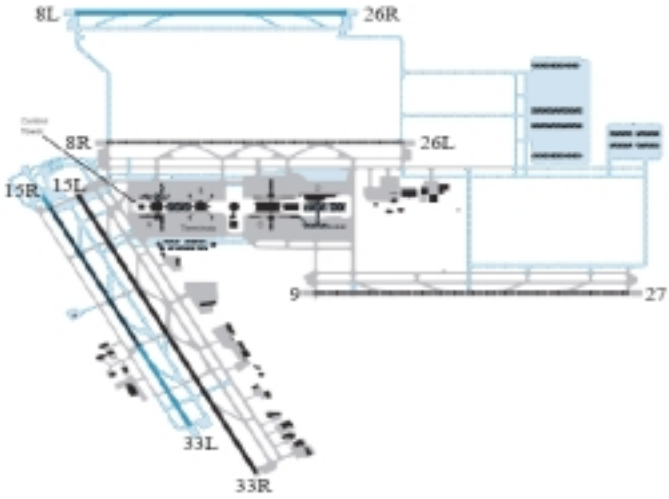

Fig.1. Runway Layout of IAH

Also, implementation work of a triple simultaneous parallel instrument landing system (ILS) approach and departure procedures for Runways 9-27 and its taxi-ways during the same period added more complications to proper estimation of the impact of TMA time-based metering independently of other factors and changes [4].

This paper evaluates TMA operation on arrival traffic at the George Bush Intercontinental airport (IAH) in 2003 and 2004 based on the data provided by FAA. In the analysis, only those flights of more than 10 seasonal arrivals, called trigger flights, are considered. The three analyses are conducted to evaluate TMA operational performance at IAH: runway usage or utilization comparison between Pre-TMA period (year 2003) and Post-TMA period (June -August 2004), arrival traffic delay comparison, and arrival

traffic distribution comparison. In some cases, the partial-TMA period (January-May 2004) is included in the operational performance measurement.

4. Runway Usage Analysis

If we state a conclusion first on the runway usage at IAH, we can say that IAH had a 23 percent increase in the number of trigger flights in 2004 compared with 2003. Figure 2(a) -(d) display monthly arrival distribution of trigger traffic on the runways at IAH over all operating periods of 2003 and 2004. We see runways 9/27, 8/26, and 15R/33L had 14.7%, 25.1%, and 171.2 % increases of traffic operation in 2004 compare with 2003. However, runway 15R/33L (often scheduled for general aviation only) had 11.3 % decrease in traffic operations in 2004. Also, we can observe that there was a steady percentage increase in trigger traffic arrivals on runway 8 / 26, runway 9 / 27, and runway 15R /33L. However, runway 9 / 27 experienced 4.4 % and 7.6 % decrease of utilization in July and August 2004. Runway 15L / 33R was the least utilized one.

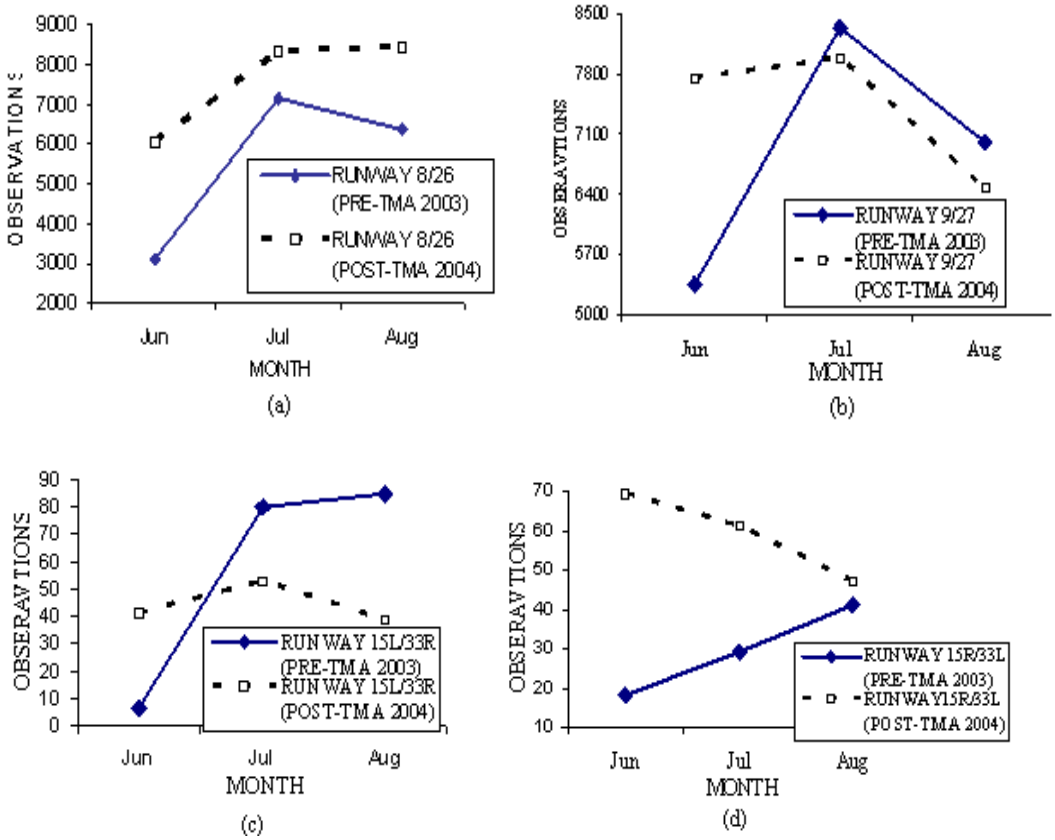

Fig. 2. IAH Runway Arrival Distributions

We also analyze the entry point of landing approach at each runway. Figure 3 illustrates the numbers and pattern of trigger traffic arrivals' approach points at each runway in 2003 and 2004. We see that there was a 98.8% difference between trigger traffic on runway 26 and runway 8 in 2003 (Pre-TMA period) but it reduced to 58.5% in 2004 (Post-TMA period). This can be interpreted as some sort of better balanced allocation of approaching points 8 and 26 of the 8/26 runway. Similarly, the approach at 27 accommodated 98.9 % of trigger traffic arrivals in 2003. However, in 2004 (Post-TMA period), trigger traffic at the approaching point 9 increased from 1.1 % to 3.2 % in the runway 9/27. There was no triggered arrival at the approaching points 33R and 33L in both 2003 and 2004.

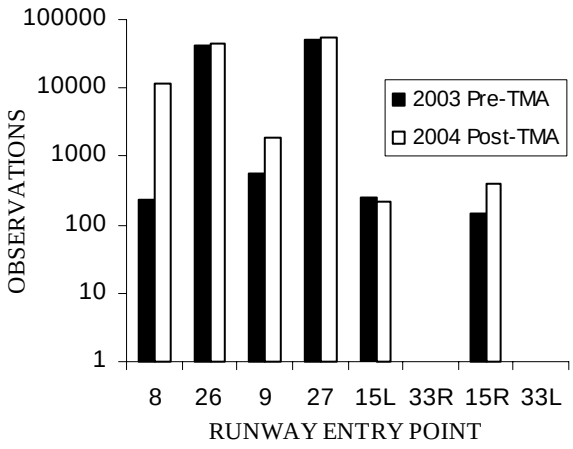

Fig. 3. Arrival Traffic at Runway Entry Points

4. Performance Metrics

We introduce performance metrics that vary by arrival flights, and they are: average arrival delay, arrival delay variance, average excessive time delay for the flights with arrival delays of greater than 15 minutes, unreliability (Number of delayed flights out of total arrivals in excess of 15 minutes), average of arrival time variance, variance of arrival time variance, and distribution distortion index (DDI). The first four as shown in Table I are the performance metrics of the rush arrival delay analysis, and the next three are for rush arrival pattern analysis. The latter analysis considers only actual arrival times.

Table I. Performance Metric Definitions

Variable	Description
Average arrival delay	Average of the difference between scheduled and actual arrival time over all flights
Arrival delay variance	Variance of the difference between scheduled and actual arrival time
Average >15 min arrival delay	Average excessive time delay for the flights with arrival delays greater than 15 minutes
Unreliability	Fraction of flights whose arrival delays are greater than 15 min
Average of Arrival time variance	Average of monthly arrival time variance of all UIFs
Variance of Arrival time variance	Variance of monthly arrival time variance of all UIFs
Distribution Distortion Index (DDI)	Degree of distortion in arrival pattern

Metrics such as average delay, variability of delay, and unreliability are used to compare the quality of service provided at IAH in the view of on-time arrival during the pre-TMA period of January to May 2003, the partial-TMA period of January to May 2004, and the post TMA period of June to August 2004.

The "average" and the "variance" of "arrival time variance" define the variability in flight arrival times. "Average arrival delay" and "arrival delay variance" are somewhat closely related to the customary approach of evaluating NAS performance because it pertains to delay. The third metric reiterates more on extended delays beyond scheduled arrival time plus 15 minute (i.e. STA + 15 min), which is traditionally "on-time arrival". The fourth metric depends on both the variance and mean of aircraft delay, and it represents a

standard metric for service reliability or unreliability. The last metric, distribution distortion index (DDI), reflects the degree of distortion of arrival pattern from the desired distribution of uniformity. Details on DDI are described in chapter 6. Each metric is evaluated for all uniquely identified flights (UIF). Since the call sign of a flight alone cannot uniquely identify a flight, we use four attributes in uniquely defining flights for our analysis: call sign, departure airport, runway, and arrival month of the year.

Using the metrics, our focus is to obtain a snap short of the arrival delay and distribution for the periods in the Pre-TMA and Post-TMA operation corresponding to the three peak arrival periods 1256 to 1356 (rush hour 1), 1557 to 1657 (rush hour 2) and 1857 to 1957 (rush hour 3) minutes in local time.

5. Differential Analysis of Rush Arrival Delays

We first analyze the average and variance of arrival delay in the 3 rush periods in 2003 and 2004. Figure 4 reveals that average delay in all three rush periods reached their individual peaks in June 2004 before any noticeable improvement. Similarly, noticeable improvement did not start until June 2004. Again, the rush period 3 reveals the greatest improvement with low average delay in the post-TMA period of June to August 2004. Figure 5 shows that the variance of the 2004 rush period 3 is much higher than others, however, it also shows that the variances of July and August 2004 are much lower than those of the pervious months'.

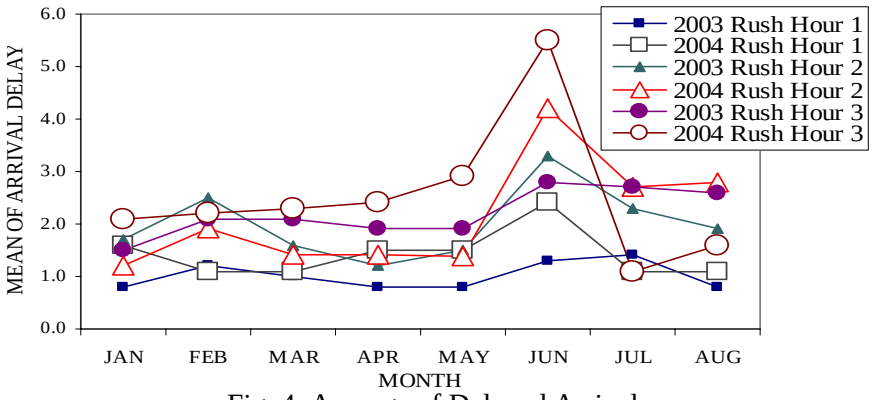

Fig. 4. Average of Delayed Arrival

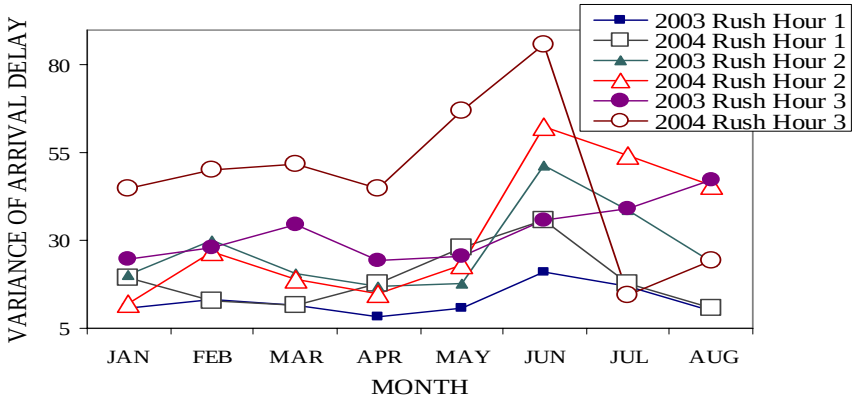

Fig. 5. Arrival Delay Variance

Next analysis is about the average excessive delay time of the flights which arrived more than 15 minutes after the scheduled arrival times. Figure 6 shows most notably that the values in minute of the mean of delayed arrivals over 15 min, of June to August 2004, are much lower than any other excessive delay averages.

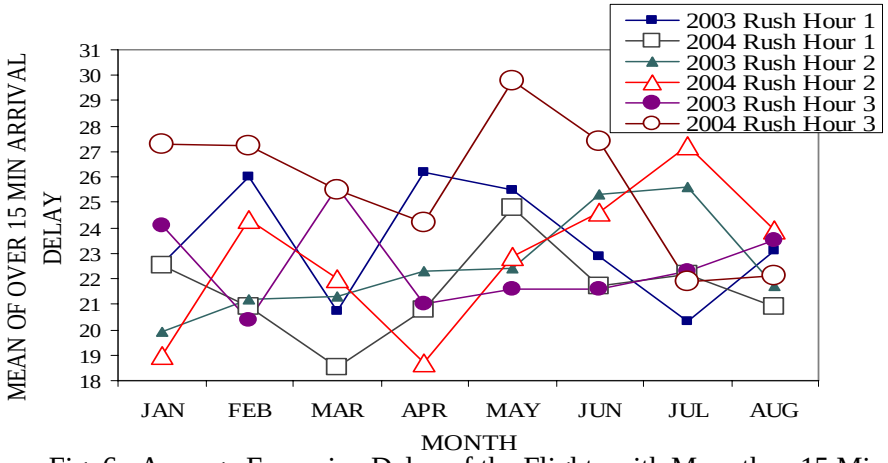

Fig. 6. Average Excessive Delay of the Flights with More than 15 Minute Delay

Lastly, we observe the portion of the flights which experienced delays in excess of 15 minutes, out of all the arrivals. This metric could be interpreted as the unpredictability of arrivals. Figure 7 shows that the unpredictability reached its peak in June 2003 and 2004 for all three rush periods. However, we see that the unreliability of arrivals began to improve from June 2004 where the greatest improvement occurred in rush period 3. Thus, we can conclude that the unpredictability of arrivals at IAH drastically reduced in the post-TMA period.

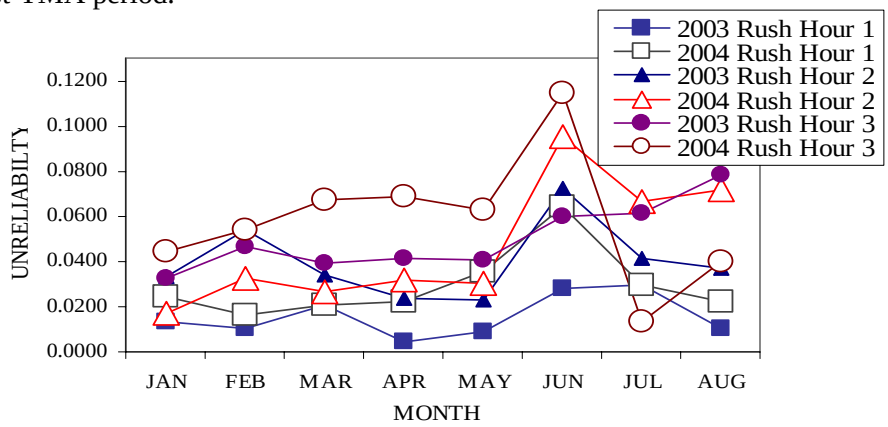

Fig. 7. Portion of the Flights Which Experienced More Than 15 Minute Delay

6. Differential Analysis of Rush Arrival Patterns

This analysis has nothing to do with the conventional "on-time" arrival probability or similar terms. Rather, this analysis is to observe how a group of UIF arrives at IAH, i.e., the pattern of arrivals. If the variance of the arrivals is big, then expected arrival time would be hardly predictable. Instead, if the arrival time variance is low, then it would be easier to correctly predict their arrival times.

Figure 8 shows that average of the variance of UIF arrival times was lower throughout the rush hour 1 of 2004 compared with 2003. However, peak arrival period of rush period

2 generated high variance which began to reduce in July of 2004 compared with 2003. The rush period 3 of 2004 also generated high variance which reached its peak in June 2004.

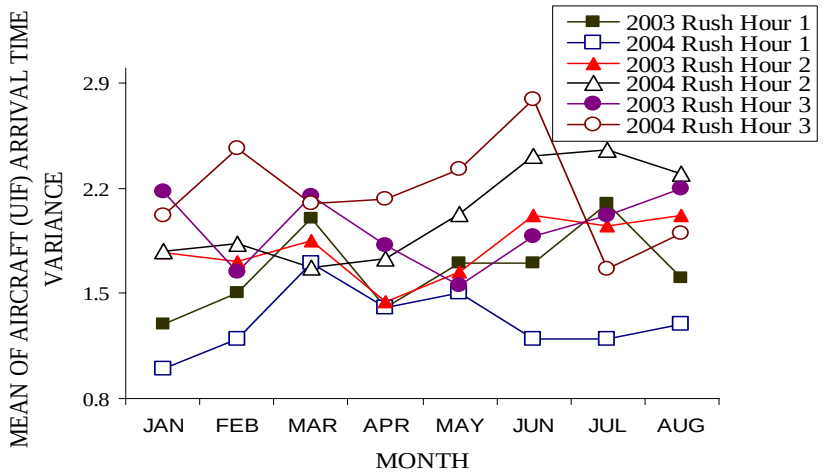

Fig. 8. Average of Arrival Time Variance

Figure 9 presents the variance of the variances of each UIF arrival time, and it reveals that the rush periods 2 and 3 of 2004 had greater variability during the early parts of 2004, compared with 2003. From June 2004, both rush periods1 and 3 experienced reduced amount of variation. Also, the rush period 2 of 2004 maintained low level of arrival time variance compare with 2003.

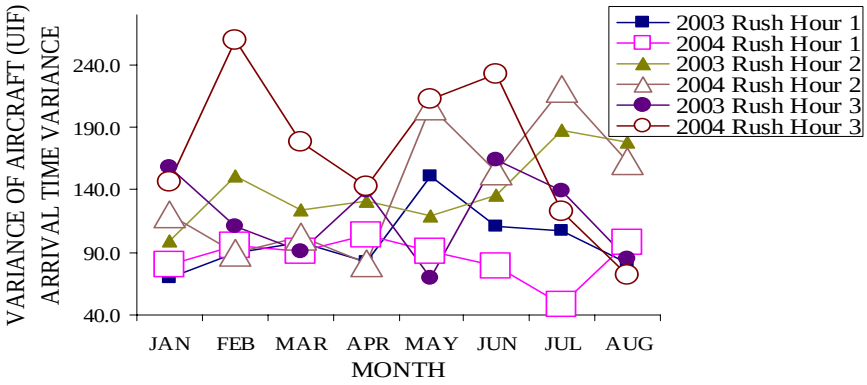

Fig. 9. Variance of Arrival Time Variance

Next, we describe the analysis performed using the seventh metric (i.e. DDI). We define DDI of an outcome as a statistical measure of distortion from the ideal distribution of uniformity. Without presenting a mathematical definition, we can simply define the DDI as a measure of "how evenly distributed are the arrivals across the 15 minute intervals of a rush period." The ideal arrival distribution would be one in which each 15 minute has the same number of arrivals, and in this case the DDI value is set to 0. In an extreme case where all the arrivals occur in a 15 minute interval and all the other 15 minute intervals have no arrival at all, then in this case DDI is set to 1. In other words, lower DDI indicates well-balanced arrival traffic and less overloaded airport resources.

We apply the DDI to the first six months of 2003 and 2004. The resulting DDIs are depicted in Figure 10. We can clearly see that DDIs for 2004 are lower than those of 2003 except of March, in which they are identical in both years. Meanwhile, June 2004 had the lowest distortion, which coincided with the first month of the full TMA operation at IAH.

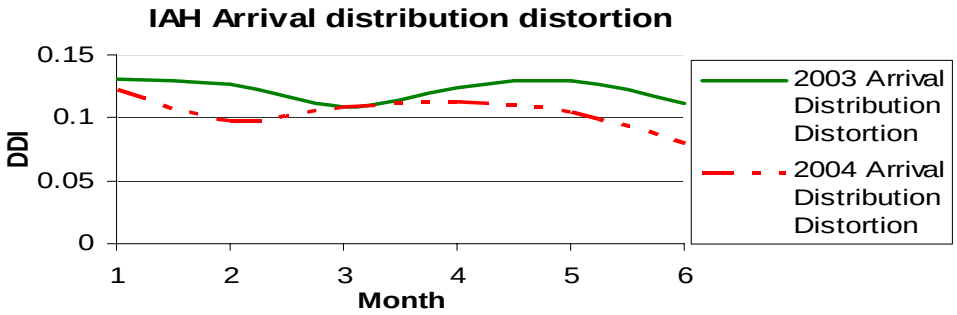

Fig. 10. Distributed Distortion Index of 2003 and 2004 Arrivals in Rush Periods

7. Conclusions

The measure of performance evaluation of TMA is performed for the arrival traffic operations at IAH. Our evaluation of TMA performance at IAH is solely based on the actual and schedule arrival data obtained from FAA. The runway allocation assessment analysis performed in this paper shows improvement in balanced flight distribution to the runways. Also, the delay analysis consistently indicates the reduction of the arrival delay from June 2004 which coincidentally was the start month of the full capacity TMA operation. The distribution distortion index shows that, for three rush hour periods, January – June 2004 has better arrival distribution compared with the same period in 2003. The improved arrival distribution in 2004 could reduce controller work load and increase arrival traffic awareness. Also, the variance of the arrival times was much lower in the period of the full operation Post-TMA.

8. Acknowledgment

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9. Reference

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