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Measuring the Benefits of NextGen Metroplex in Convective Weather: Case Study of North Texas Metroplex

Yu Zhang[1] and Hualong Tang[2]
University of South Florida, Tampa, FL 33620, USA

Dave Knorr[3] and Almira Ramadani[4]
Federal Aviation Administration, Washington DC 20024, USA

A key component of the goals of the Next Generation Air Transportation System (NextGen) is to safely improve the efficiency of the National Airspace System (NAS) by enhancing efficiency in metroplexes. Based on the use of precise satellite-based navigation, Time Based Flow Management (TBFM), and other advanced techniques and tools, the benefits of a metroplex have been identified through research, indicating that it is capable of making airspace more efficient with less queueing delay and more throughput. However, those studies focused only on operations in normal weather conditions; special weather conditions such as convection were not considered. This study investigated the quantitative impacts of a metroplex under representative operation conditions in convection. Investigations included identification of representative convective weather conditions, analysis of historical radar tracking data in a post-metroplex period, development of queuing system-based models of Terminal Radar Approach Control (TRACON) facility arrival operations with and without metroplex for the North Texas Metroplex, and simulations to evaluate airspace performance in terms of TRACON throughput and arriving delays. Simulation analyses showed an average 27% increase in TRACON throughput with peak demand of 15 minutes, with 2.39 minutes saved per arrival flight at Dallas/Fort Worth International (DFW) and 1.65 minutes saved per arrival flight at Dallas Love Field (DAL) when a metroplex is implemented. The increase in TRACON throughput and arrival time saved by a metroplex climbs as traffic grows; however, the efficiency gains reach a limit when traffic grows 40%.

I. Introduction

A large increase in demand within the National Airspace System (NAS) is forecasted by the Federal Aviation Authority (FAA), the US Joint Planning and Development Office (JPDO), and others, and a large portion of that growth is expected to be in metropolitan areas. Increasing efficiencies in metroplexes—metropolitan areas with multiple airports and complex air traffic flows—is a significant component in the Next Generation Air Transportation System (NextGen) for improving NAS efficiency. Based on the merits of introducing advanced techniques and tools—for instance, Performance-Based Navigation (PBN)—FAA, in collaboration with other aviation stakeholders, is working to improve flight route efficiency and airport access through metroplex programs by optimizing airspace and procedures. It is expected that a metroplex can reduce fuel burn and aircraft exhaust emissions, which can impact not only the local region but also the entire NAS, in which 21 metroplexes are identified by FAA [1].

The dependencies and interactions between multiple airports in metropolitan areas cause inefficiency in terminal area operations. Among these issues, multi-airport departure merge over common departure was ranked as the top issue for metroplexes, with very high impact [2]. The benefits of metroplexes have been investigated and assessed by several studies. Some generic models have been formulated to assess the potential impacts of a metroplex in addressing its inefficiencies by spatial and temporal approaches [3][4]. To capture more detail and a more realistic environment, a

[1] Associate Professor, Department of Civil and Environmental Engineering
[2] Graduate Research Assistant, Department of Civil and Environmental Engineering
[3] Division Manager, NextGen Systems Analysis and Modeling
[4] Branch Manager, NextGen Systems Analysis and Modeling

generic model was extended and adjusted to a specific metroplex or by using simulation tools such as Airport and Airspace Delay Simulation (SIMMOD) to simulate operation conditions. The results of this research show that decoupling the Standard Instrument Departure (SID) existing fixes and Standard Terminal Arrival (STAR) entry fixes, adjusting temporal arrival scheduling, and adding an additional en-route transition can improve throughput and reduce arrival delay [3]. Using more precise and accurate satellite-based navigation than a legacy navigational system, metroplexes are capable of making the airspace more efficient with less queueing delay and more throughput.

However, special weather conditions such as convection have not been considered in past research. Convective weather often blocks airspace and disrupts air routes in and out of airports, which leads to serious delays in the NAS. Although convective weather occurs infrequently, the magnitude of its impact on the NAS is much more significant than that of recurrent delays and cancellations caused by intrinsic variation of air traffic operations on normal days. Understanding the quantitative impacts and benefits of metroplex capabilities in convective weather is necessary for establishing a basis for future design and improvement. Previous studies used either data from baseline operations, which include historical traffic operated under conditions without a metroplex, or a data set generated from other seed traffic data. This study aimed to quantify the benefits of a NextGen metroplex under convective weather conditions with historical data in a post-metroplex period. The North Texas Metroplex was used as the study area, with only the Dallas/Fort Worth International (DFW) and Dallas Love Field (DAL) airports considered, as they are geographically next to each other and produce most of the flows within this area. First, representative convective weather conditions from a post-metroplex period were identified and historical flight trajectory data in the North Texas Metroplex were analyzed. Second, queueing system-based models were developed to capture Terminal Radar Approach Control (TRACON) facility arrival operations with and without metroplex. Third, simulations were conducted to quantify the performance of operations with and without metroplex by different levels of arrival demand.

This paper is organized as follows. Section II summarizes the results of a literature search on evaluating NextGen capabilities and methods for evaluating metroplex performance in convective weather. Section III demonstrates the evaluation approach used to analyze the North Texas Metroplex performance in convective weather. Section IV presents the configuration of simulation models and simulation results. Section V provides concluding remarks.

II. Literature Review

Previous research on evaluating NextGen capabilities was reviewed, and four major types of approaches to assess its performance were identified: queueing model, Human-in-the-loop (HITL) simulation, simulation tools, and experiment.

Evaluation methods of NextGen capabilities can be traced back to NAS performance modeling. Early research used the queueing model approach to model inefficiencies in airports as well as airspace [5]. In recent years, Timar et al. evaluated the throughput impacts of implementing RNAV SID and STAR procedures to help improve metroplex efficiency [3] by formulating generic models to evaluate baseline inefficiency and RNAV- and STAR-enabled mitigation. The results showed that STAR and RNAV can increase the throughput in RNAV routes. In turn, the generic model was extended to the North California Metroplex to quantify the benefits of NextGen PBN. Ren et al. [4] also developed a generic metroplex model based on a linked-nodes queueing process to evaluate the spatial and temporal impacts from a metroplex and found that temporal scheduling and route segregation can reduce delays in terminal area airspace.

HITL is a commonly-used approach to evaluate system performance. The Multi-Aircraft Control System (MACS) provides high-fidelity display emulations for air traffic controllers/managers as well as user interfaces and displays for confederate pilots and experiment managers [6]. It also can provide a real-time dynamic simulation environment with realistic aircraft trajectories and associated radar messages. Swenson et al. [7] evaluated the Terminal Area Precision Scheduling and Spacing (TAPSS) system through HITL on MACS and compared its performance to baseline air traffic control (ATC) operation using Traffic Management Advisor (TMA). Thipphavong et al. [6] used the same method to measure the efficiency benefits of TAPSS in terms of level segments reduction, flight distance, and time savings for arrivals to Los Angeles International Airport. They also quantified the performance of a Terminal Sequencing and Spacing (TSS) system for PBN arrivals, which was created to facilitate sequencing and merging arrival flows that have both standard ATC routes and PBN RNAV/RNP [8]. To better model current operations, TAPSS was assessed under a terminal routing infrastructure that more closely resembles current practices using HITL [9].

Many modeling and simulation tools also have been developed for performance assessment when new techniques or concepts are introduced to the existing or future system. Fast-time simulation can be a highly-effective and cost-efficient mechanism for studying air traffic management concepts and technologies [10]. The US Joint Planning and Development Office (JPDO) analyzed NextGen capabilities related to high-density operations [11] by using NAS-wide modeling and simulation tools integrated from a number of other modeling and simulation tools. Capacity-related benefits were assessed at a high level. The National Aeronautics and Space Administration (NASA) developed the Airspace Concept Evaluation System (ACES) for assessment of the impact of advanced ATM concepts. Saraf et al. [12] used ACES to study the potential benefits of a Multi-Airport Departure Planner in the New York metroplex. The

Metroplex Simulation Environment (MSE) is another platform that can be used to rapidly-assemble a purpose-built simulation [10]. Clark conducted the simulation in the New York terminal area space using SIMMOD to assess the metroplex model [4]. Although there are a number of simulation and modeling tools that can satisfy air traffic simulation needs, they tend to be expensive and difficult to use, and extensive training is needed for configuring and running them.

In the process of NextGen initiatives being developed and implemented, evaluation of their performance was conducted through modeling, simulation, and subject matter expert surveys; however, few were conducted using an experimental approach. Guzhva et al. [13] used experimental settings in a real-time operating environment to assess the impact of Aircraft Arrival Management Systems (AAMS). The main challenge was to ensure the similarity of the operational environment and other system conditions between operations with and without AAMS.

This study sought to quantify the difference in airspace performance in terms of TRACON throughput and flight arrival delays under convective weather conditions with and without metroplex implementation. An intuitive method was to conduct a before-and-after study by analyzing historical data as done by Guzhva et al. [13]. However, many external factors could challenge the performance evaluation between pre- and post-metroplex operations. For instance, Converging Runway Operations (CRO) was applied to DFW on April 2, 2014; such change affects about 12% of arrivals to DFW and makes flights experience 1.3–1.6 minutes of additional delay to land on parallel runways instead of crossing runways 13/31, according to an ongoing study by MITRE. Furthermore, it is difficult to find two similar convective weather conditions with the same operational inputs and similar other constraints to conduct the comparison. Therefore, we developed queueing system-based models of TRACON arrival operations with and without metroplex under convection. Modeling was supported by analyzing historical radar tracking data to characterize metroplex arrival operations and derive modeling parameters for simulation. A simulation to evaluate the operation performance with and without metroplex by different traffic levels also was conducted.

III. Evaluation Approach

FAA completed a redesign of airspace in the North Texas Metroplex to make it more efficient with improved access to its airports. One route structure was added at the NW corner post of the TRACON, which made the NW entry fix decoupled. This change separated the flows to DFW and DAL, where flights previously shared the same entry fix and had to vector off-route due to capacity limitations. Our task was to identify the impacts from these operational changes due to a metroplex under convection in which TRACON airspace encounters a big loss in capacity.

In support of formulating the queueing system-based models of TRACON arrival operations with and without metroplex under convection, representative convective weather conditions were identified and historical radar tracking data were analyzed to capture a realistic operating environment.

A. Convective Weather Conditions Identification

This task identified the time periods in which the airspace was blocked and the TRACON airspace was facing a large capacity loss due to convective weather. It is desirable to find a convection period in which one or multiple corner posts were blocked (other than NW), as the loss of corner posts would have very large impacts on the TRACON airspace capacity. By analyzing flight trajectory during such time periods and simulating the scenarios with no metroplex implementation, the performance difference between with and without metroplex could be obtained. Given this purpose, a two-step exploration was applied using the Aviation System Performance Metrics (ASPM) database and GIS tools for visualizing flight trajectory data.

Considering wind speed, ceiling, visibility, severity of local weather conditions, thunderstorms reported at nearby weather stations (within 50 miles), and en-route thunderstorms, the overall weather impact (WI) value from the Weather Factors module of ASPM was derived from the historical relationship between the weather and the percent on-time arrivals at that airport. It was categorized based on the severity of weather impact by airport by hour at four levels—None, Minor, Moderate, and Severe. The time periods with WI of Moderate or Severe were those likely operated under convective weather conditions. Thus, in the first step, the time periods were identified when the weather impact of DAL and DFW were moderate or severe during the study period, a post-metroplex implementation time period from July 1–August 31, 2015.

In the second step, for all listed time periods, historical radar tracking data were played back in QGIS, and the scenarios when the corner post other than NW was blocked were identified. The radar tracking data during the study period used in this research was provided by FAA, which includes trajectory information such as track ID, aircraft ID, aircraft type, track latitude, track longitude, ground speed, distance from arrival airport, etc., for each flight from the origin airport to DFW and DAL. The open-source GIS client QGIS was used to visualize, manage, edit, and analyze the trajectory data.

Several scenarios were found with corner posts blocked from these high weather impact events. Among them, the event on July 8 (13:30–15:15) was selected as the representative convective scenario for two reasons (see Fig. 1). First, the NE corner post, which was blocked, had the highest throughput, on average, out of all four corner posts. When this corner post was blocked, there was a large loss in TRACON airspace capacity. Second, the NE corner post is close to

the NW corner post. Many flights are rerouted to the NW corner post in this convective weather scenario, which made this scenario a desirable case to analyze the performance difference between with and without metroplex.

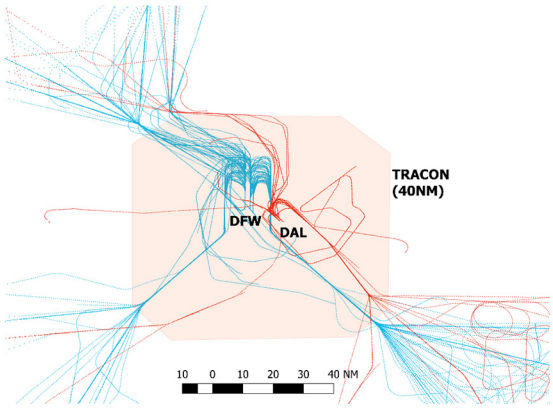


Fig. 1 Representative convective weather scenario, July 8, 2015, 13:30–15:15.

B. Historical Radar Tracking Data Analysis

In practice, operations may not always be consistent with the implementation of a program due to uncertainties and complexities inside the system, so it was necessary to analyze operations after implementation of a metroplex based on its initial plans.

After analyzing the historical radar tracking data in the post-metroplex period, it was observed that even though all the entry fixes of TRACON airspace were totally decoupled and flows going to DAL and DFW were supposed to be segregated, DAL and DFW flows were sharing the same entry fix at the NW and SW corner posts. DFW flows were found using a DAL entry fix regularly at the NW corner post, particularly in times of heavy traffic (see Fig. 2). This could be explained by the large difference in arrival demand between DAL and DFW—in 2015, DFW had 785,777 scheduled arrivals and DAL had only 135,033. When capacity utilization of the DAL entry fix is low but capacity utilization of DFW is very high, DFW flows can be shared by the DAL entry fix for alleviating the burden from the DFW entry fix. The proportion of DFW flows shared by the DAL entry fix in convection in Fig. 2 (33.3% for convection but close to 0% for normal weather times) was observed to be much larger than other normal weather times. This might be because the DAL entry fix is closer to the blocked NE corner post than the DFW entry fix, so some DFW flights that were rerouted from the NW corner post chose the closer entry fix to enter TRACON. Another possibility was that the DFW entry fix cannot accommodate these increased rerouted flights, so the DAL entry fix helped to share those DFW flows. Only a small number of DAL flows were found using the DFW entry fix at the SW corner post, which may result from some uncertainties in the system at a specific time period.

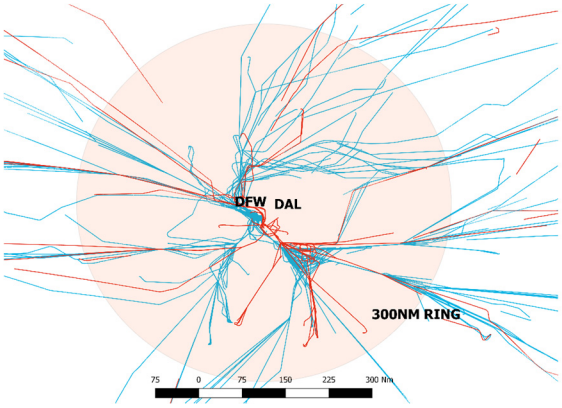


Fig. 2 Shared entry fix at NW corner post in convection, July 8, 2015, 13:30–15:15.

When reviewing the distributions of transition time from different entry fixes to different airport runways, all transition times can be approximated to normal distribution except two route segments—the DAL entry fix of the NW corner post to DAL and the DAL entry fix of the SW corner post to DAL. In fact, two different routes from the SW and NW corner posts to DAL were found in the tracking data. Thus, two different routes were needed to be built into the simulation model for DAL flights coming through the NW and SW corner posts.

C. Development of Queueing System-Based Model

As noted, the DAL entry fix of the NW corner post shared some flows going to DFW in post-metroplex, so it was considered to be a shared entry fix for both DFW and DAL flows in the model, whereas fixes of other corner posts were all considered totally decoupled. It was still considered that the SW corner post decoupled because only a small number of DAL flows were found using the DFW entry fix. In the queueing system-based model, three constraints from entering the entry fix and arriving at the airport were considered (see Fig. 3):

1) Separation between aircraft at TRACON entry fix
2) TRACON transition time
3) Runway capacity

In addition to the separation requirement at the TRACON entry fix, an entry fix buffer or meter fix buffer was added to reduce the risk of separation loss when flights missed their targeted arrival time at the entry fix. TRACON transition time represents the time of aircraft flying from each TRACON entry fix to the runway threshold. Although jets and turboprops have different speeds that lead to different TRACON transition times, only 1.5% of all aircraft in the data set were turboprops, so they were not taken into consideration. Flights at lower altitudes consume more fuel than those at high altitudes; thus, it is more economical to absorb the delay in Center airspace than in TRACON. Nevertheless, to enhance the utilization of runway capacity, it is better to have more aircraft in TRACON to provide sufficient arrival demand. Therefore, to deal with the tradeoff between runway efficiency and fuel consumption, a delay margin was introduced to balance these two goals—if the anticipated delay exceeds the delay margin, the aircraft will not be allowed to go through entry point; instead, it will be held in Center airspace temporarily.

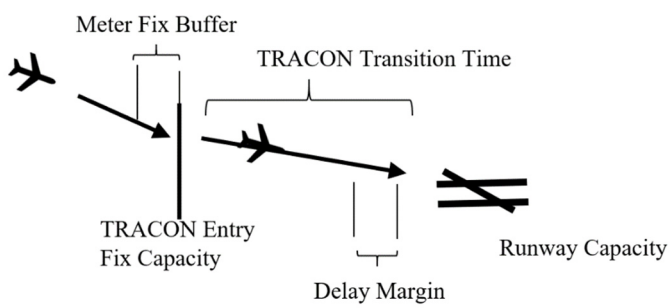


Fig. 3 Constraints in the model.

Based on the analysis of historical radar tracking data, the metroplex route structure in the queueing system-based model for post-metroplex is illustrated in Fig. 4. The DAL entry fix (at the NW corner post) is shared by DFW and DAL flows, and flight routes are fully decoupled when going through other corner posts. There are two different route segments for DAL flights flying from the NW and SW corner posts. The flying times between the corner post and the runway end vary by the route the aircraft flies. A longer route takes DAL flights nearly an additional 4 minutes, on average, transitioning from the NW corner post to DAL runways, and an additional 5.5 minutes, on average, from the SW corner post to DAL runways. There are two route segments from the NE corner post to DFW. Normally, only the lower route is open, but both upper and lower routes are open when facing heavy traffic.

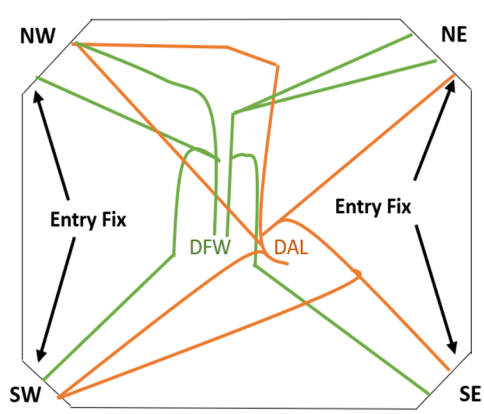


Fig. 4 Route structure in post-metroplex.

D. Validating the Queueing System-Based Model

The purpose of validating the model is to derive the correct simulation parameters that could mimic a real operational environment. The model was validated with data from 08:45–09:30 on July 16, 2015, a time period with heavy traffic demand on a normal weather day (Fig. 5). Note that although the delay margin was introduced in the simulation model, there was no need to use it in validating the model, as the validation dataset consists of historical arrival data and flights already were adjusted to meet the delay margin requirement in TRACON airspace.

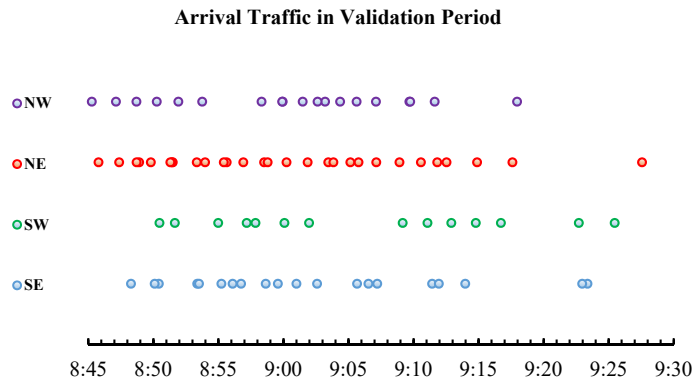


Fig. 5 TRACON arrival traffic in validation.

During the validation time period, aircraft were flying Visual Flight Rules (VFR) and took the longer route segment to DAL from both the NW and SW corner posts. There were two route segments going from the NE corner post to DFW (shown in Fig. 4). The TRACON entry fix service rate was calculated by dividing the FAA separation requirement by average fix-crossing speed. The minimum in-trail separation of 5 NM was used, plus a meter fix buffer of 4 NM, which is regarded as a conservative bound. Given the speed, the distance separation to time separation was converted. The time separation was 56–101 seconds for a range of 5–9 nautical miles (NM). The en-route transition time was set as the mean time obtained from historical data for each route segment from TRACON entry point to the airport runway. The runway service rate was set as 90% of the maximum arrival rate (flights per 15 min) in July 2015.

Validation maneuvers try to adjust the service rate, meter fix buffer, and en-route transition time to make the arrival traffic in the metroplex as similar to the historical traffic as possible. Because real arrival traffic data were used as the demand input in validation, aircraft were maneuvered by Center controllers before entering TRACON to meet the delay margin requirement. The maximum delay of all aircraft flying from the entry fix to the airport runway was approximated to the delay margin under a high demand period. Therefore, the delay margin was set as the maximum delay derived in the validation, 2.37 minutes. Table 1 compares the entry fix service rate derived from validation with the declared capacity, which is 85–90% of maximum throughput capacity [14]. The service rates derived from validation were similar to declared capacity but slightly conservative (Table 1). Note that the historical arrival rate going to DAL was very small, which does not reflect the real entry point capacity, so the 5 NM plus 4 NM buffer was used to simulate the capacity of DAL entry fixes.

Table 1 Entry Fix Service Rate

		NW	NE	SW	SE
DFW	History (85% maximum)	11.9	10.2	7.7	9.4
	Validation	10	9	8.9	8.9
DAL	History (85% maximum)	6.0	4.3	4.3	5.1
	Validation	8.9	8.9	8.9	8.9

IV. Simulating Convective Weather Scenarios

From the radar tracking data of representative convective weather scenarios (13:30–14:15 on July 8, 2015), aircraft were flying Instrument Flight Rules (IFR), the NE corner post was blocked during this time period, and there was no route going through the NE corner post (see Fig. 1 for visualization of historical radar tracking data). DAL flights going through the SW corner post took the shorter route segment to DAL, and DFW flights going through the NW corner post took the longer route segment to DFW. As the NE corner post was blocked in the convective weather scenario, flights that were supposed to go through this corner post were rerouted to go through other corner posts. Fig. 6 shows the comparison of the throughput of each corner post in the period of convective weather with the benchmark, i.e., the average throughput of each corner post on normal weather days in July 2015. It shows the increase of

DFW-bound flows at functional corner posts. It also seems that ATC sacrificed DAL-bound flights to accommodate more DFW-bound flights during convective weather periods.

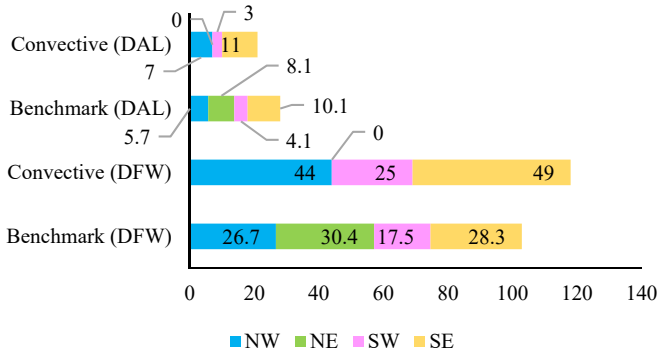


Fig. 6 Corner post throughput in the benchmark and convective weather.

A. Simulation Configuration

Analysis of the historical trajectories in the chosen convective weather scenario shows that when the NE corner post was blocked, no flights were rerouted to the SW corner post. This could be because that these two corner posts are too far away from each other. Thus, in this study, it was assumed that all flights originally going through the NE corner post would be rerouted to the NW and SE corner posts when that corner post was blocked. The proportion of rerouted DFW-bound flights to the NW and SE corner posts were 54% and 46%, respectively, obtained by analyzing historical data.

Flights may face additional en-route transition time when they are rerouted to other corner posts when the NE corner post was blocked. According to historical trajectories in the convective weather scenario, Fig.7 depicts the routes for aircraft rescheduled to the NW and SE corner posts when the NE corner post was blocked. The shaded area bounded by solid red lines in Fig. 7 covers the possible rerouted routes to the NW corner post and the area bounded by dotted red lines covers the original routes to the blocked NE corner post. The distance differences between rescheduled routes and normal routes were 44.3–92.7 NM. Flights rerouted to the SE corner post took two major routes. When compared with original routes, rerouting leads to an additional 40.5–72 NM distance. With an average ground speed of 420 knots from a 300 NM radius to the corner post, the additional flying time needed to get to the NW corner post was 6.33–13.24 minutes and additional flying times to the SE corner post was 5.79–10.29 minutes. In this study, we assumed that the additional en-route transition time due to rerouting is normally distributed (two different distributions for rescheduling to the NW and SE corner posts) to capture the randomness in the system. In the simulation, the additional flying time was randomly generated, and the rescheduled aircraft was inserted into the traffic flows of the NW and SE corner posts accordingly.

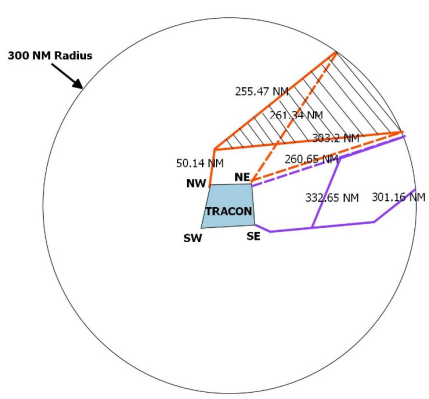
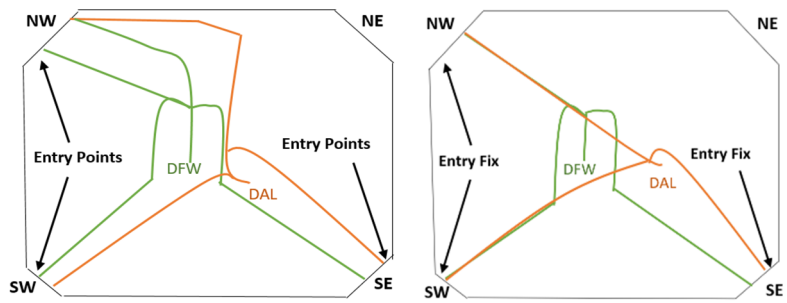


Fig. 7 Rerouted routes when NE corner post blocked.

The arrival traffic demand in a convective weather scenario is significantly low compared to high demand. This is probably due to the enabling of the Ground Delay Program (GDP) to hold departure flights at their original airports. In this case, although the airport runway capacity is normal, given that the corner post was blocked in the metroplex airspace, air traffic controllers might have taken actions to hold the affected inbound flights at their original airports.

Using this subjectively-influenced traffic demand would result in errors in evaluation outcomes. In addition, a relatively low traffic level is not able to test the real capabilities of a metroplex. Therefore, the peak-hour flight demand data used to validate the queueing system-based model was used again for the simulation under a convective weather scenario. It was assumed that no flights were canceled and that all DFW flights that originally went through the NE corner post were rescheduled to the NW and SE corner posts according to the proportions obtained in historical data. It was assumed that DAL flights that originally went through the NE corner post were rescheduled to its nearest corner posts (NW and SE) 50/50. Also, given that the DAL entry fix of the NW corner post shared some DFW flows and is closer to NE corner post than DFW entry fix, it was assumed that all rerouted flights from the NE to the NW corner post would go through the DAL entry fix of the NW corner post.

TRACON route structure under convective weather scenario with metroplex and without metroplex are shown in Fig. 8. For the pre-metroplex operation, both the NW and SW corner posts had the shared fix, whereas the other two corner posts had a segregated route structure.



(a) (b)

Fig. 8 TRACON structure (a) with metroplex and (b) without metroplex in convective weather scenario.

B. Simulation Results

The queueing system-based model developed within the different TRACON structure was used to conduct the simulation for convective weather scenarios with and without metroplex implementation. The delay margin in TRACON was determined by validation previously (2.37 min). If an aircraft encounters a delay (arrival queueing delay at the airport) more than the margin value, it is controlled in the Center airspace before entering meter fix. Under the condition of satisfying the delay margin, with-metroplex can absorb more delays (average 0.22 min) in TRACON than without-metroplex, which implies that metroplex can help reduce the delay propagation to the Center airspace (see Table 2).

Table 2. Arrival Queueing Delay (min)

	DFW w/o Metroplex	DFW with Metroplex	DAL w/o Metroplex	DAL with Metroplex
Average	0.14	0.41	0.20	0.20
Maximum	0.74	1.28	0.72	0.72
Deviation	0.17	0.40	0.28	0.28
	With Metroplex		**Without Metroplex**	
Average	0.37		0.15	

The simulation results in peak-hour demand under a convective weather scenario are shown in Table 3. During this 45-minute simulation, metroplex saves a total of 87 minutes for arrival queueing at DFW and about 5 minutes for arrival queueing at DAL. The average queueing time saved per flight at DFW is 1.8 minutes and at DAL is 0.5 minutes. It also shows that a metroplex can accommodate 17% more arrival flights to DFW for the most congested 15-minute time window (30–45 min) and accommodate 70% more arrival flights at the NW corner post in the most congested 15 minutes (15–30 min).

Table 3 Simulation Results in Peak-hour Demand

Metroplex	DFW	DAL	NW Corner
More arrivals accommodated in peak 15-min window	16.7%	-	70%
Cumulative queueing time saved (min)	86.89	4.98	117.81
Average queueing time saved per flight (min)	1.81	0.50	5.39

We further increased the peak-hour arrival traffic demand used in the simulation by 15%, 30%, and 45% to investigate the performance of metroplex in response to the different demand increases in the future. Increased traffic followed the Poisson distribution to capture the randomness of arrival time at the TRACON boundary. We also conducted the simulation in different arrival traffic demands. The simulation was run 1000 times; the TRACON throughput in the peak 15-minute time window (in which the TRACON has the largest number of flights entering the TRACON boundary) by different arrival traffic levels are shown in Fig. 9. Metroplex increased the TRACON throughput by 27%, on average, in the peak-hour demand, 28% when peak-hour demand increased by 15%, 33% when peak-hour demand increased by 30%, and 26% when peak-hour demand increased by 45% (see Fig. 10). In terms of the arrival airports, metroplex saved 2.39 minutes, on average, for DFW arrival queueing time in peak-hour demand, 2.48 minutes when peak-hour demand increased by 15%, 4.1 minutes when demand peak-hour demand increased by 30%, and 3.95 minutes when peak-hour demand increased by 45%.

Fig. 9 TRACON throughput in peak 15-minute time window.

As illustrated in Fig. 10, the average TRACON throughput shows a steady growth as arrival traffic increased from peak-hour demand to 130% of peak-hour demand. However, the TRACON throughput rarely increased (0.2 increase per 15 min) when demand increased from 135% to 145% of peak-hour demand. Meanwhile, the average queueing time saved by metroplex for DFW decreased from 4.1 to 3.95 minutes when arrival demand increased from 130% to 145% of peak-hour demand. This result indicated that the capabilities of metroplex to improve TRACON throughput and reduce arrival queueing waiting time may reach its limit when demand increases to somewhere between 130% and 145% of peak-hour demand.

Fig. 10 Average TRACON throughput and saved arrival queueing time.

V. Conclusion

The objective of this research was to quantify the impacts of NextGen metroplex on flight operations from entering TRACON to landing on airport runways under convective weather conditions. The performance metrics of interest

were corner post throughput, runway throughput, and arrival queueing delays. A simulation-based research approach was applied by developing a queueing system-based model considering three operational constraints in the metroplex—separation between aircraft at meter fix, en-route transition time from meter fix to the runway threshold, and runway capacity. The model was validated with historical radar track data and verified modeling parameters were obtained to characterize the metroplex operations for further simulation. In addition, weather impact data in ASPM and a visualization tool were used to identify convective weather operation scenarios. This step could be saved if convective weather information was readily available.

The simulation results show that a NextGen metroplex could help increase the throughput of affected corner posts when TRACON faces a critical capacity loss, e.g., blocking of one corner post, under convective weather. For the 45-minute time period simulated in this study, DFW was able to receive 16.7% more arrivals with metroplex, an increase that improves airport capacity utilization. In addition, flight delays decreased with a NextGen metroplex implemented. In simulated cases, flights to DFW and DAL saved an average of 1.81 minutes and 0.50 minutes per flight, respectively, in arrival queueing time. The benefits of a metroplex increase as arrival traffic demand grows, but the capabilities of a metroplex reach a limit when demand increases to 130–145% of peak-hour demand.

In this study, some assumptions were made for simulating operations before metroplex implementation due to lack of data. If more data were available, more refined models could be developed. Only one representative convective scenario was identified with the NE corner post blocked. With more radar track data and convective weather information, additional simulation scenarios could be run, and more comprehensive performance evaluation results obtained.

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