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MITRE TECHNICAL REPORT

Simulation Analysis of Dual CRDA Arrival Streams to Runways 27 and 33L at Boston Logan International Airport

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Abstract

For much of the winter, northwest winds at Logan International Airport preclude the use of parallel Runways 4L/4R or 22L/22R. Under these conditions, the standard configuration is to use 27 as the primary departure runway and 33L as the arrival runway. Since these runways intersect, the arrival and departure operations cannot be run independently which results in substantial arrival delays, often accumulating to several hours by the evening arrival pushes. Consequently, there is a desire to increase arrival capacity and reduce arrival delay in this configuration by implementing a Converging Runway Display Aid (CRDA) dual arrival stream procedure to Runways 27 and 33L.

This document presents the results of a capacity and delay analysis using the Total Airspace and Airport Modeler (TAAM), and a subsequent communications workload analysis based upon the simulation model output. The simulation and communication models were developed and validated at The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) under the guidance of a study team made up of Boston Tower controllers, managers and representatives from the Air Transport Association (ATA). This analysis quantifies the expected impacts of the procedure in terms of arrival capacity, arrival delay, ground congestion, and communication frequency demand.

A baseline case represents current single stream operations where all arrivals land on Runway 33L. Several alternative simulations represent dual arrival stream scenarios with 25% and 50% of arrivals landing on Runway 27 using a CRDA procedure where arrivals land in coordinated pairs. These simulations are then run with and without existing arrival fix to runway selection requirements. The impacts of headwinds were also investigated by examining how they would impact a theoretical maximum arrival rate. Finally, the output of the simulation is used to determine type, timing, and duration of communications that must take place on local control, crossing coordinator, and landline channels. These messages were mapped to specific times in the simulation and the total demand on each frequency calculated.

The results of the analysis indicate that the potential exists for an increase in airport arrival capacity of six aircraft per hour only if an airspace redesign is accomplished. This airspace redesign is required to eliminate the airport's current arrival fix based runway selection rules so that terminal controllers are able fill either runway's final approach course with aircraft from any arrival fix. If this cannot be done, then attempting a CRDA dual arrival stream would reduce the airport arrival capacity and increase arrival delay. In addition, the implementation of dual arrival streams would increase the overall communication load on the local controller by ten percent and may substantially increase the amount of time the controller is at or above his or her communications comfort level.

KEYWORDS: Boston Logan International Airport, CRDA, Intersecting Runways

Acknowledgments

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Section 1

Introduction

1.1 Background

For much of the winter, strong northwest winds at Logan International Airport (BOS) preclude the use of Runways 4R or 22L for arrivals. Under these conditions, the standard configuration is to use 27 as the primary departure runway and 33L as the arrival runway. There are substantial arrival delays with this configuration, often accumulating to several hours by the evening arrival pushes. As a result, there is a desire to increase arrival capacity and reduce arrival delay during these conditions. The proposal evaluated in this study is to use both 27 and 33L for arrivals and departures, at least during arrival pushes. This is expected increase arrival throughput, reducing arrival delays.

The specific requirements of a dual arrival stream to Runways 27 and 33L were developed by the study team over the course of the project and evolved, as various proposals were deemed infeasible. The final procedure definition is based on the use of the Converging Runway Display Aid (CRDA). This tool allows the controller to vector aircraft onto the “ghost” of a another arrival on a different final approach course. This ghost is displayed on the controller’s radar screen a fixed distance away from the actual target. This helps the controller accurately maintain small separation distances along two final approach paths converging at significantly different angles. The separation and procedural requirements for CRDA operations are defined in Federal Aviation Administration (FAA) Order 7110.110. These requirements were adopted and applied to the specific configuration at BOS with consideration given to maximizing potential arrival capacity, while maintaining appropriate levels of workload and safety.

There is a concern that ground operations will be a constraint to the use of both runways for arrival and departure. While arrivals would not have to cross active runways to get to the passenger terminal, every departure would have to cross a runway that is being used for both arrivals and departures. This might result in either taxiway congestion (if no gaps are created in the arrival or departure stream) or arrival or departure delays (to allow traffic to cross the active runways). A second concern is that the large number of advisories and clearances required for this operation will result in blocked communications and missed communications. While operations on Boston Logan’s parallel runways may be divided between two local control positions, the use of this configuration preclude this division of responsibility because Runways 27 and 33L intersect. This means that a single local controller must coordinate arrivals and departures on two intersecting runways, making communications workload an important consideration.

1.2 Study of Objectives

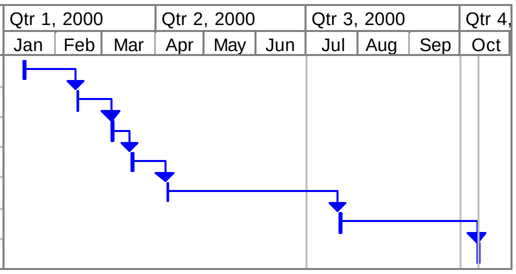
In order to assess any adverse impacts of dual arrival streams and quantify potential increases in airport arrival capacity, a simulation study was requested by the FAA New England Region (ANE). The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) was tasked to conduct the analysis with the input of the both service providers and users of the system. The resulting analysis is designed to produce measures of airport arrival capacity, airport arrival delay, airport surface congestion, and frequency usage. These metrics must be computed for current single arrival stream operations, and dual arrival stream alternatives with two traffic segregation schemes. The traffic segregation schemes were based on a 25/75 split where 25% of arrivals land on Runway 27 and 75% land on 33L, and a 50/50 split where 50% land on Runway 27 and 50% land on 33L. In addition, the impact of 18kt winds from 330 and 270 are also investigated. Finally, the simulation must allow for visual validation and be capable of representing the airport surface and final approach airspace in a single model.

1.3 Project Schedule and Deliverables

The analysis of dual CRDA arrival streams was conducted between January and October, 2000. During this period, the simulation models were developed and validated, several status meetings were held, and preliminary and final results produced and delivered. Table 1-1 presents these activities and their timing throughout the year.

Table 1-1. Boston Dual Arrival Project Timeline

ID	Task Name	Start
1	Project Kick-Off Meeting (Boston)	Thu 1/13/00
2	Validation Visit (McLean)	Mon 2/14/00
3	Validation Visit (McLean)	Mon 3/6/00
4	Presentation of Preliminary Results (Boston)	Fri 3/17/00
5	Validation Visit (McLean)	Fri 4/7/00
6	Presentation of Preliminary Results (Boston)	Thu 7/20/00
7	Presentation of Final Results (Boston)	Thu 10/12/00



The study began in January, 2000 with a project kick-off meeting hosted by BOS Tower. At this meeting, the motivation for the study was discussed, a preliminary project schedule agreed upon, and areas of responsibility assigned to various team members. At this time, CAASD produced a Study Plan outlining the project scope and timeline. By 14 February, CAASD was hosting representatives from Boston Tower for the first TAAM model validation. This resulted in the development of alternative models based on Dependent Converging Instrument Approach (DCIA) procedures. During this period, a communications model was developed based on an MS Access database analysis of TAAM simulation output.

A second validation visit was held 6 March where the Boston study team asked that the procedure being modeled be changed from the DCIA to a Standard Runway Separation (SRS) procedure. This procedure was designed and a new set of simulation models developed.

A validation trip to present preliminary results and receive approval for metric calculation occurred on 17 March at Boston Tower. At this meeting, the simulation and communications models were demonstrated and all assumptions were reviewed. Upon viewing the simulation, the study team decided to modify some of the separation standards being used for the SRS procedure and modifications were requested to the communication model. In order to ensure an accurately updated simulation and communication model, CAASD hosted a validation meeting in McLean on 7 April 2000. During this visit, the Study Team determined that the SRS scenario being modeled would not be practical in reality and asked that the alternative procedure be changed to one based on use of the Converging Runway Display Aid (CRDA) procedures.

Since the TAAM simulation is unable to pair arrivals as required by the CRDA procedure, a software tool was developed to create CRDA pairs in the simulation and record required delay. Also, the change in project scope made the baseline model incompatible with the alternatives and another baseline model was constructed. After the CRDA software tool was developed, the new alternative scenarios were modeled in TAAM and preliminary results were generated. On 20 July 2000, these preliminary results were presented to the Study Team at Boston along with a demonstration of the procedure. Upon review, the team determined the separation standards originally specified were too conservative and needed to be adjusted in a final round of modeling. Its is this final procedure, its assumptions and results which are presented in this document.

On 12 October 2000, CAASD presented the final results of the analysis to the study team in Boston where they were accepted. To date, CAASD has produced two validated baseline models in TAAM, two alternatives based on DCIA, four alternatives based on SRS, and four based on CRDA procedures. In addition, we have conducted five controller validations, and presented three sets of preliminary results and one final presentation. CAASD has supported the on-going procedure design with quantitative results and visualization, and has coordinated its work with airport users. Finally, in the process of completing this work, CAASD has developed two tools (communications model and CRDA arrival sequencing software) to be used with the TAAM simulation software.

Section 2

Capacity and Delay Analysis

2.1 Methodology

In order to compute the metrics required in this analysis while accounting for the complexities of the procedure and environment, a simulation model was constructed. Simulation models are a type of computer model that account for the interactions among model elements over time. This type of model is used when the impacts of a change in operations cannot be isolated from the rest of the airport environment. The airport environment (or scope of the simulation) in this study includes the ground operations of Boston Logan as well as arrival and departure routes in the immediate airspace. This section outlines the development of this model.

Since the procedure under investigation affects runway usage, altering the runways used for both arrivals and departures, it is clear that aircraft taxi operations would also be impacted. For example, an aircraft landing on Runway 33L in the baseline case may be routed to land on Runway 27 in a dual arrival stream scenario and would have to taxi to its gate from a different position on the airport. Similarly, the changes in arrival runway selection were complimented by altering departure runway selection rules as well in order to balance operations on the two runways. For this reason, it is important to know how ground operations will be impacted by the changes in taxi flow in order to predict congestion, gridlock, or increases in taxi delay.

The simulation of ground operations began with the modification of a TAAM airport layout provided by Embry Riddle Aeronautical University. This layout was compared with airport layouts from other sources and updated to ensure that taxiways, gates, parking positions, runways, buildings, and standoff positions are located correctly. Gate assignment based on aircraft type and airline is included as well as the directionality of taxiways to ensure proper flow of arrivals and departures around the gate area. The use of standoff positions allows aircraft to wait in an appropriate location until a gate becomes available during peak periods. Finally, touchdown points based on aircraft category are specified separately for the two runways to ensure that landing roll distances, runway exit usage, runway occupancy times, and wake turbulence considerations at the runway intersection are modeled correctly.

The traffic schedule upon which the simulation is based represents a typical busy day arrival push operation. Specifically, a five-hour period from 3:00 pm to 8:00 pm is included in the simulation.

A key element of the proposed dual arrival stream procedure is the assignment of arrival and departure runways. In a single arrival stream case, all arrivals land on Runway 33L and most depart on 27 (the exceptions being turboprop departures from the Golf intersection, and heavy low performance aircraft needing the additional length of 33L on departure). In the dual arrival stream case, this strategy is modified so that the arrival and departure runway selections are based on arrival or departure fixes which eliminates route crossings in the airspace. In order to achieve an equal number of arrivals on Runways 27 and 33L in the 50/50 traffic split case, and three times the number of arrivals on 33L as on 27 in the 25/75 traffic split case, these rules were adapted as necessary by the validation team. Finally, specific arrival routes and departure procedures are included in the simulation to correctly route aircraft through the airspace and to account for speed and altitude restrictions along their paths.

The most critical element of the simulation study is the procedure itself and the separation requirements for the baseline and alternative scenarios. For the single arrival stream (referred to as the baseline) case all arrivals land on Runway 33L forming a single arrival stream with visual separation. The visual separation between successive arrivals is set to be an average of 2.7 nm. In the dual arrival stream (or alternative) cases, arrivals land in CRDA pairs. For each pair, the first arrival must land on Runway 27 and the second on Runway 33L. This takes advantage of the longer distance between the threshold and runway intersection on Runway 27 and ensures the first arrival will be on the ground and no longer generating wake vortices in the intersection of the two runways. The two arrivals are separated by 1 nm at the runway intersection so that when the 27 arrival is in the runway intersection, the 33L arrival is 1 nm away. The next CRDA pair to land is a full wake turbulence separation behind the previous pair. For example, if a 33L arrival is a B757, then the next arrival to 33L (whether a member of a CRDA pair or not) must be at least 5 nm behind. If an arrival lands without another paired aircraft, then full wake turbulence separation is applied before and after this arrival.

Unfortunately, TAAM does not provide a facility for enforcing the pairing of aircraft on final and a separate process performs the spacing outside of the simulation. Two points in space are identified to serve as injection points for aircraft in the simulation, one on the final approach course for Runway 27 and a corresponding point for 33L. The injection point on the final approach for Runway 27 is 20 nm from the runway intersection, the corresponding injection point on the final of Runway 33L is slightly more than 21 nm from the runway intersection. If two arrivals are injected into the simulation at these points at the same instant, they will land on their respective runways as a pair with 1 nm between them as defined in the procedure. This technique requires the use of a pre-processor to modify the TAAM timetable. This pre-processor must identify potential CRDA pairs based on scheduled arrival time, and then apply small amounts of delay to ensure that pairs land with only 1 nm between them, while non-paired aircraft have wake turbulence separation. The processor also sums the total delay applied to all aircraft to enforce the requirements of each procedure. The result is a modified timetable for each scenario and an associated sequencing delay figure.

Several simulation scenarios were constructed in addition to baseline and 50/50 and 25/75 traffic split cases already described. While reviewing preliminary results, it was found that using existing runway assignment schemes resulted in reduced arrival capacity and increased arrival delay in all cases. Two additional cases were created (one each for the 50/50 and 25/75 traffic split cases) where runway assignment was flexible so that the most efficient arrival flow could be modeled. In order to realize this scenario, an airspace redesign effort would be required to allow for arrival routes from any arrival fix to either runway. These additional scenarios are referred to as airspace redesign cases. After completion and validation of the simulation model, the various scenarios are ready for metrics generation.

In addition to the simulation analysis described above, a separate analysis assesses the theoretical arrival capacity and the impact of wind for the various scenarios. This analysis is a simplified view of the procedures based only upon physical separation standards, aircraft speed, and average fleet mix and reduces the procedure to a series of formulas. This analysis serves to clearly demonstrate the procedures, support results of the simulation analysis, and account for wind effects.

2.2 Assumptions

While simulation models allow for the investigation of complex interactions between elements of the study, these models require extensive validation and simplifying assumptions to ensure the model produces accurate results. This section describes the efforts taken to validate the simulation models and the assumptions made in order to build accurate representations of reality.

The first step is the validation of simulated ground operations. The airport layout was compared with Jeppessen charts of the airport, tower diagrams of taxiway and gate layout, and finally with Computer Aided Design (CAD) drawings maintained by the Massachusetts Port Authority (MassPort). These sources validate the physical dimensions and layout of all significant aspects of the ground operation model. The gate assignment scheme is based on airline and airframe and comes from consensus between Tower controllers and airline representatives on the validation team. The usage of standoff positions and runway exits, and the location of runway touchdown points is provided by Tower staff. Finally, the entire model was run and approved by the validation team, and then approved through visual inspection by the study team.

Next, the traffic schedule was reviewed to ensure the correct number, type, and timing of operations. Enhanced Traffic Management System (ETMS) data from 7 January 2000 was used as the source of the simulation timetable so that an actual day’s operations would be modeled. This timetable was compared to radar data for the same period, and the number and timing of operations modified to match reality. The validation team also reviewed the airline and fleet mix in the timetable and found them to be consistent with reality. Under the guidance of the study team, this traffic file was truncated to include only operations during a five hour period found to be the most busy.

Finally, the baseline operation was validated through comparisons with Automated Radar Terminal System (ARTS), and both single and dual arrival procedures were validated through repeated visual inspection and review of preliminary quantitative results by the study team. The visual validation sessions covered runway selection, runway exit usage, and departure and arrival routing.

2.3 Results

The simulation results show the potential for an increased arrival rate over the baseline case coming only from the dual CRDA arrival case with a 50/50 traffic split and airspace redesign. The arrival capacity results for the various scenarios are presented in Figure 2-1.

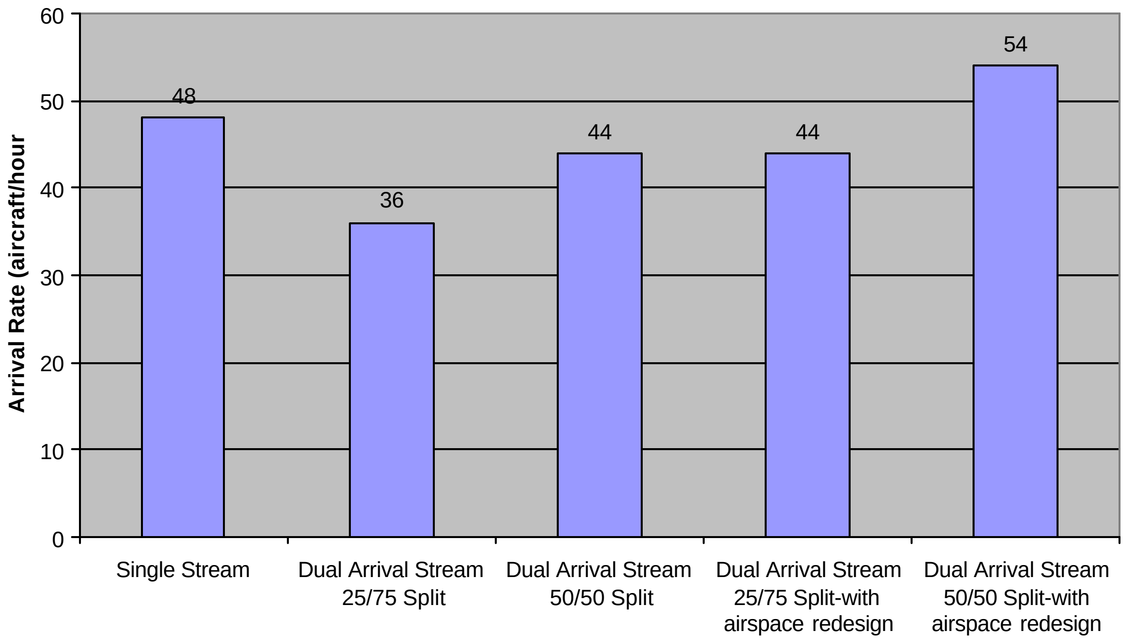


Figure 2-1. Simulated Arrival Capacity for Baseline and Alternative Cases

It is evident in Figure 2-1 that the current single arrival stream case is preferable to any implementation of the 25/75 traffic split. Further, the baseline case is preferable to any case where existing runway assignment criteria are used.

Next, the arrival delay observed in the simulation mirrors the arrival capacity results. Here, the arrival delay increases in all cases except the dual arrival stream case with airspace redesign. These delay statistics only cover the delay incurred for spacing of aircraft on final to meet the separation requirements of the various procedures. They do not include other types of arrival delay and therefore isolate only the impacts of the procedural change. These results are presented in Figure 2-2.

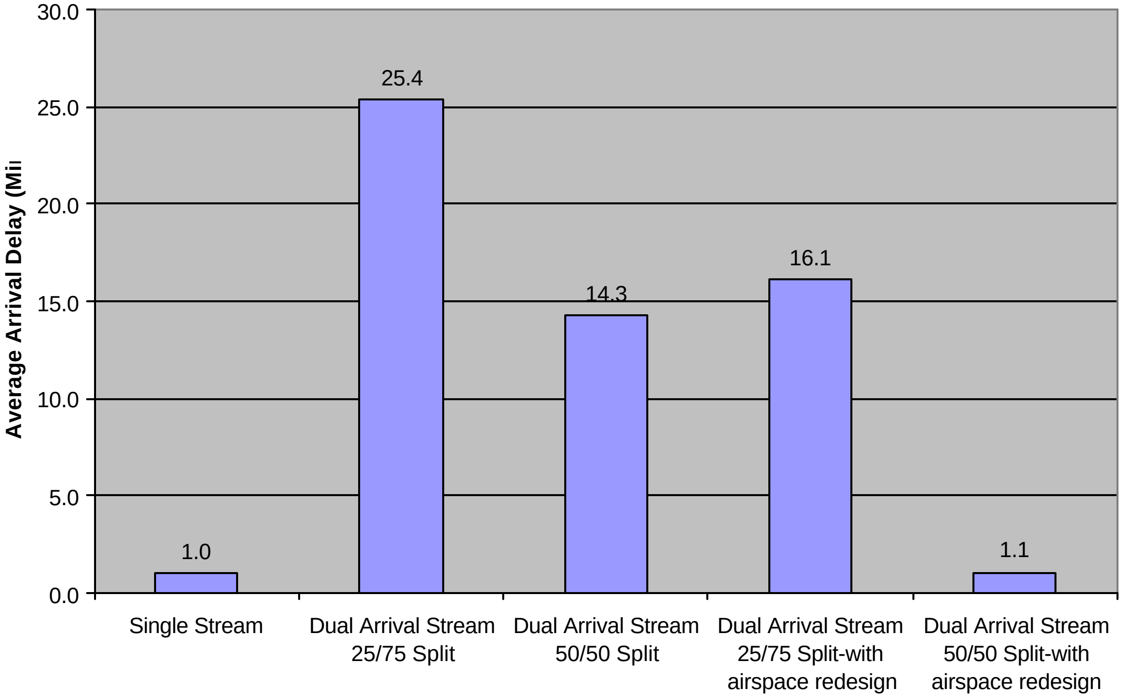


Figure 2-2. Simulated Arrival Delay for Baseline and Alternative Cases

Again, it is evident in Figure 2-2 that the current single arrival stream case is preferable to any implementation of the 25/75 traffic split. Further, the baseline case is preferable to any case where existing runway assignment criteria are used.

The impacts the dual arrival procedure on taxi operations were measured quantitatively through review of taxi delay number computed by the simulation. These results are presented in Figure 2-3.

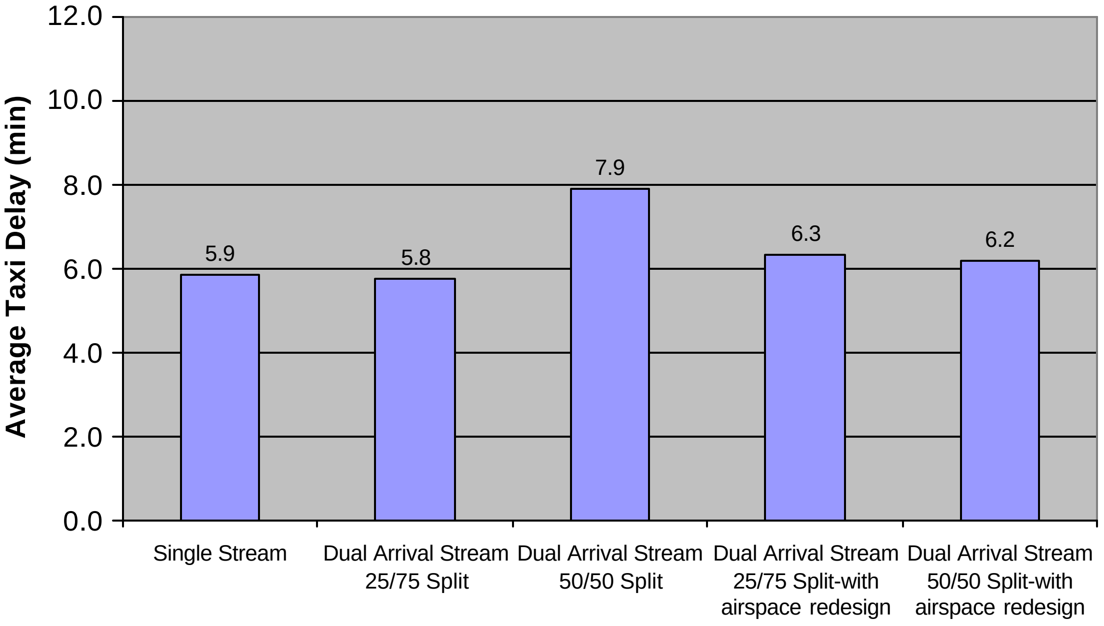
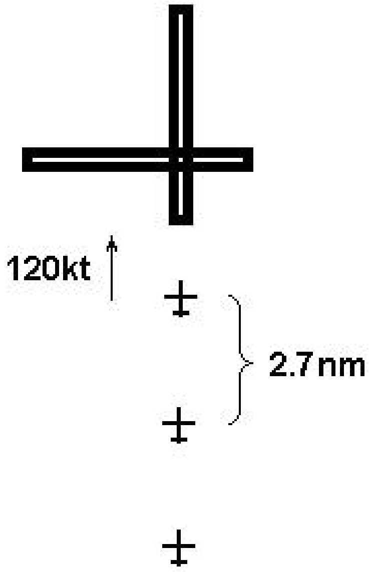


Figure 2-3. Average Taxi Delay for the Baseline and Alternative Cases

Figure 2-3 shows how the total taxi delay for the average aircraft changes as a result of modifications to the arrival procedure. For example, in the baseline case, the average aircraft will incur 5.9 minutes of delay while taxiing to, or from, its gate. These results indicate no significant increase or decrease in taxi delay between the different scenarios. Visual inspection of the ground simulation offered no gridlock or noticeable increases in congestion between the cases.

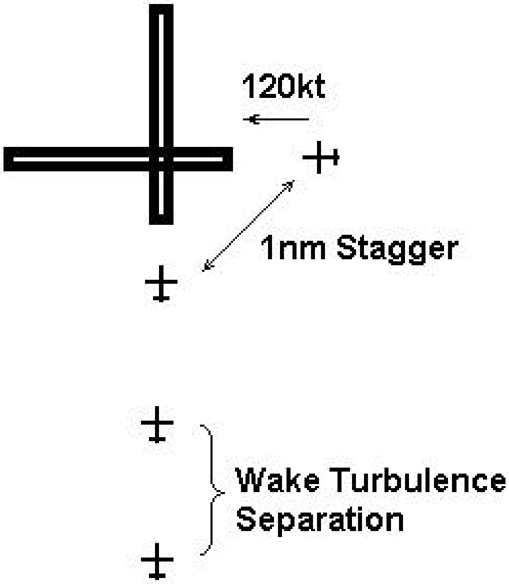
The simulation results concerning arrival capacity are supported by a theoretical analysis. This analysis indicates that the baseline single arrival stream case is capable of landing approximately 44 aircraft per hour. This is demonstrated in Figure 2-4.



$$\begin{aligned}
&\text{Theoretical Arrival Capacity} \\
&= (\text{aircraft velocity}) \big/ (\text{arrival separation}) \\
&= \frac{120\,nm}{hr} \bullet \frac{1\,ac}{2.7\,nm} \\
&\approx 44\ ac/hr
\end{aligned}$$

Figure 2-4. Theoretical Baseline Arrival Capacity Analysis

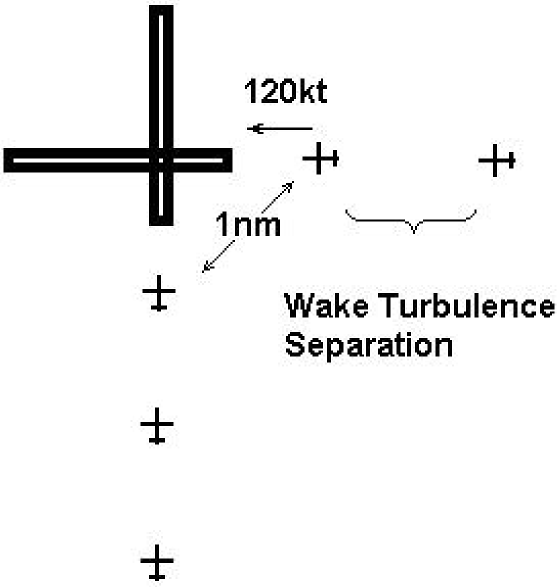
This analysis indicates that the baseline single arrival stream procedure is capable of accepting 44 aircraft per hour given the current separation standards and aircraft speeds on final. Similarly, the reduction in arrival capacity observed in the simulation for the dual arrival stream case with a 25/75 traffic split is illustrated in Figure 2-5.



$$\begin{aligned}
&\text{Theoretical Arrival Capacity}\\
&= (\text{aircraft velocity}) \big/ (\text{arrival separation})\\
&= \frac{120\,nm}{hr} \bullet \frac{4ac}{3(AvgWakeSep)nm}\\
&= \frac{120\,nm}{hr} \bullet \frac{4ac}{3(4.26)nm}\\
&\approx 37\, {}^{ac}\!\big/_{hr}
\end{aligned}$$

Figure 2-5. Theoretical Dual 25/75 Traffic Split Arrival Capacity Analysis

The potential arrival rate in the 25/75 traffic split case is reduced from the 44 aircraft per hour baseline rate to a rate of 37 aircraft per hour. This is a result of half of all arrivals landing outside of a CRDA pair thereby requiring full wake turbulence separation. Finally, the potential for increasing the airport's arrival capacity is demonstrated in Figure 2-6.



Theoretical Arrival Capacity

$$
\begin{aligned}
&= {}^{(\text{aircraft velocity})}\!\big/\!{}_{(\text{arrival separation})} \\
&= \frac{120nm}{hr} \bullet \frac{2ac}{1(AvgWakeSep)nm} \\
&= \frac{120nm}{hr} \bullet \frac{2ac}{4.26nm} \\
&\approx 56\, {}^{ac}\!\big/\!{}_{hr}
\end{aligned}
$$

Figure 2-6. Theoretical Dual 50/50 Traffic Split Arrival Capacity Analysis

In this case, every aircraft lands with a CRDA pair and the arrival capacity increases to 56 aircraft per hour. This is assuming that there is consistent arrival demand on the airport and that aircraft present themselves for arrival at the appropriate location.

The runway configuration under investigation is used only when winds from the northwest preclude arrivals on other runways. For this reason, the impacts of typical winds are investigated in this study to understand how these capacity numbers may be affected under realistic conditions. The following illustrations show how the theoretical arrival capacities already presented are affected by winds. Figures 2-7 and 2-8 demonstrate this impact on the baseline single arrival stream case.

$$\begin{aligned}
&\text{Theoretical Arrival Capacity}\\
&= {}^{(\text{aircraft velocity - headwind})}\!\big/\!{}_{(\text{arrival separation})}\\
&= \frac{(120-18)nm}{hr} \bullet \frac{1ac}{2.73nm}\\
&\approx 37\ {}^{ac}\!/\!{}_{hr}
\end{aligned}$$

Figure 2-7. Impact of 18kt Wind from 330 on Single Stream Arrival Capacity

$$\begin{aligned}
&\text{Theoretical Arrival Capacity}\\
&= {}^{(\text{aircraft velocity - headwind})}\!\big/\!{}_{(\text{arrival separation})}\\
&= \frac{(120-18(\cos(330-270))nm}{hr} \bullet \frac{1ac}{2.73nm}\\
&= \frac{(120-18(0.5))nm}{hr} \bullet \frac{1ac}{2.73nm}\\
&\approx 41\ {}^{ac}\!/\!{}_{hr}
\end{aligned}$$

Figure 2-8. Impact of 18kt Wind from 270 on Single Stream Arrival Capacity

This analysis shows that when the single arrival stream to Runway 33L encounters a headwind from 330, the ground speed of that flow is reduced and the arrival capacity falls to 37 aircraft per hour. However, when the wind is a quartering headwind from 270, the ground speed on final does not decrease as much and the arrival rate is 41 aircraft per hour.

When the dual arrival streams encounter a headwind, the situation is slightly different. Regardless of where the wind is coming from (330 or 270), the dual arrival procedure will experience a reduction in arrival capacity commensurate with a full headwind for both arrival streams. The reason is that if one stream is slowed by a headwind, the other stream must slow down as well so that its arrivals do not get ahead of their proper positions in the CRDA pair. In this case, the controller must slow the second arrival stream artificially using speed control or vectoring so that CRDA pairs are spaced correctly at the intersection. Figures 2-9 and 2-10 show the impact of an 18kt wind from 270 or 330 on the arrival capacity for the CRDA dual arrival stream case with a 25/75 traffic split, and a 50/50 traffic split respectively.

$$\begin{aligned}
&\text{Theoretical Arrival Capacity}\\
&= (\text{aircraft velocity - headwind}) \big/ (\text{arrival separation})\\
&= \frac{(120-18)nm}{hr} \bullet \frac{4ac}{3(AvgWakeSep)nm}\\
&= \frac{102nm}{hr} \bullet \frac{4ac}{3(4.26)nm}\\
&\approx 32\, {}^{ac}\!\big/_{hr}
\end{aligned}$$

Figure 2-9. Impact of 18kt Wind from 270 or 330 on 25/75 Dual Arrival Stream Capacity

$$\begin{aligned}
&\text{Theoretical Arrival Capacity}\\
&= (\text{aircraft velocity - headwind}) \big/ (\text{arrival separation})\\
&= \frac{(120-18)nm}{hr} \bullet \frac{2ac}{1(AvgWakeSep)nm}\\
&= \frac{102nm}{hr} \bullet \frac{2ac}{4.26nm}\\
&\approx 48\, {}^{ac}\!\big/_{hr}
\end{aligned}$$

Figure 2-10. Impact of 18kt Wind from 270 or 330 on 50/50 Dual Arrival Stream Capacity

This analysis demonstrates the significant impact winds have on arrival capacity in the dual arrival stream cases. In the 25/75 traffic split case, the arrival capacity drops from 37 to 32 aircraft per hour, and from 56 to 48 aircraft per hour in the 50/50 traffic split case.

Section 3

Communication Analysis

3.1 Methodology

While there is debate regarding impacts of dual arrival streams on the operation of the airport, another concern is the impact on the controllers responsible for executing the procedure. In order to gauge this impact, an analysis of the communications workload was designed to quantify any changes to the use of the frequencies used by the local controller. The results are presented in terms of a concept called “frequency demand” that is a measure of the amount of voice channel required during a specific period of time.

In order to estimate the changes in frequency demand between the baseline and alternative cases, the TAAM simulation models developed for the capacity and delay analysis were used. These models already encompass a validated view of operations at the airport using the different procedures, and provide enough output data upon which to base a frequency demand analysis. Specifically, post-processing tools search the TAAM output for messages that correspond to events requiring voice communication. These events are recorded and mapped to specific phraseology on a particular frequency with an appropriate duration. The timing of these events are used to identify at what point during the simulation they occurred and a plot of frequency demand is generated. This process was carried out for the local control frequency, the crossing coordinator frequency, and the landline connection between the two positions.

The first step in this analysis is the documentation of all standard communications taking place on the three frequencies of interest. This is done by working with a controller team to step through every combination of taxi, arrival and departure operation at the airport in the runway configuration of interest. For example, these include cases where aircraft are immediately cleared to depart, must taxi into position and hold for departure, must hold short of runway crossings, or receive wake turbulence advisories. The possible communications scenarios in this study may be described by sixteen different cases with several additional variations.

The next step is to document the standard phraseology used by controller and pilot at every step in each scenario. The simulation and airport diagrams were used to illustrate the scenarios and the validation team indicated what was said on each frequency at the appropriate time. Once all messages had been documented and mapped to a particular situation and time in each scenario, the duration of each message was computed by recording the amount of time it required for a controller to issue the clearance.

Finally, particular time stamped messages in the TAAM simulation output are mapped to events in the simulation corresponding to communication events in actual operation. These TAAM output messages are then extracted from the output files by first saving them as database files. Structured Query Language (SQL) queries then output the duration and timing of communications on the three frequencies. This frequency demand can then be plotted to show how much time during a particular five-minute window the frequency would have been in use in order to accomplish all of the communications required during that period.

3.2 Assumptions/Validation

The communication model was validated in terms of the timing and circumstance of each message, and in terms of the message phraseology and duration. The sixteen different communication scenarios were developed interactively with the validation team and repeatedly reviewed and presented until each one was individually approved. The messages themselves where similarly developed and approved. The duration of each message was calculated by timing members of the validation team, and a sample of pilots and former air traffic controllers on the CAASD staff.

This approach requires some important assumptions that must be considered when reviewing the results. First, the analysis assumes best-case communications where there are no stuck microphones, missed transmissions, requests for read backs, and pilots always accept clearances. In addition, it is assumed that communications do not limit what is happening in the simulation. If a controller’s workload increases to the point where he or she cannot issue instructions in a timely manner, aircraft will be delayed. This feedback effect between controller and simulation is not a capability of TAAM and does not occur in this model.

3.3 Results

The results of the frequency demand analysis are presented in this section. Figure 3-1 is a plot of the amount of time, per five-minute bin, that would be required to complete all necessary communication on the local controller frequency.

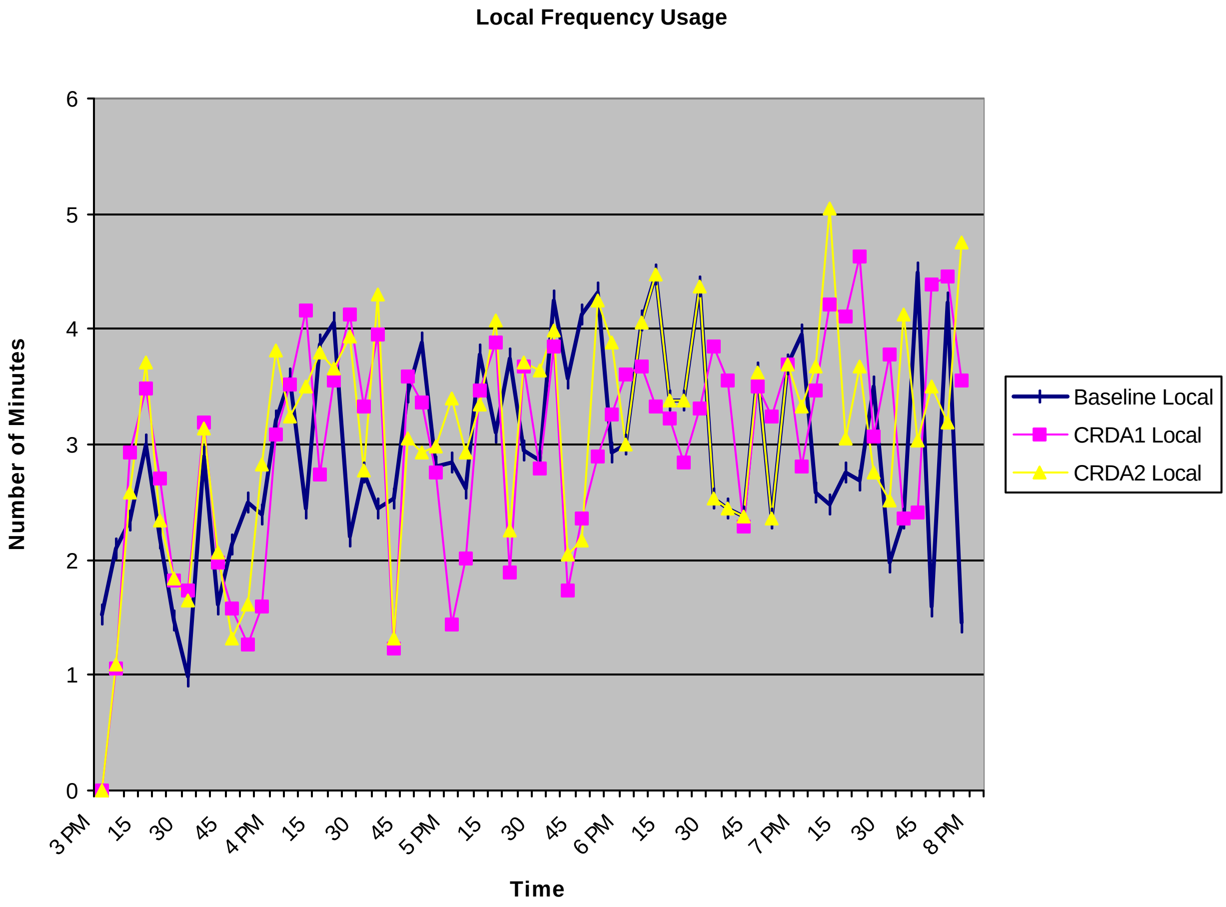


Figure 3-1. Local Control Frequency Demand per Five-Minute Interval for Baseline and Alternative Cases

Since the local controller must listen and communicate on the landline in order to coordinate with the crossing controller, the frequency demand for this channel is presented in Figure 3-2.

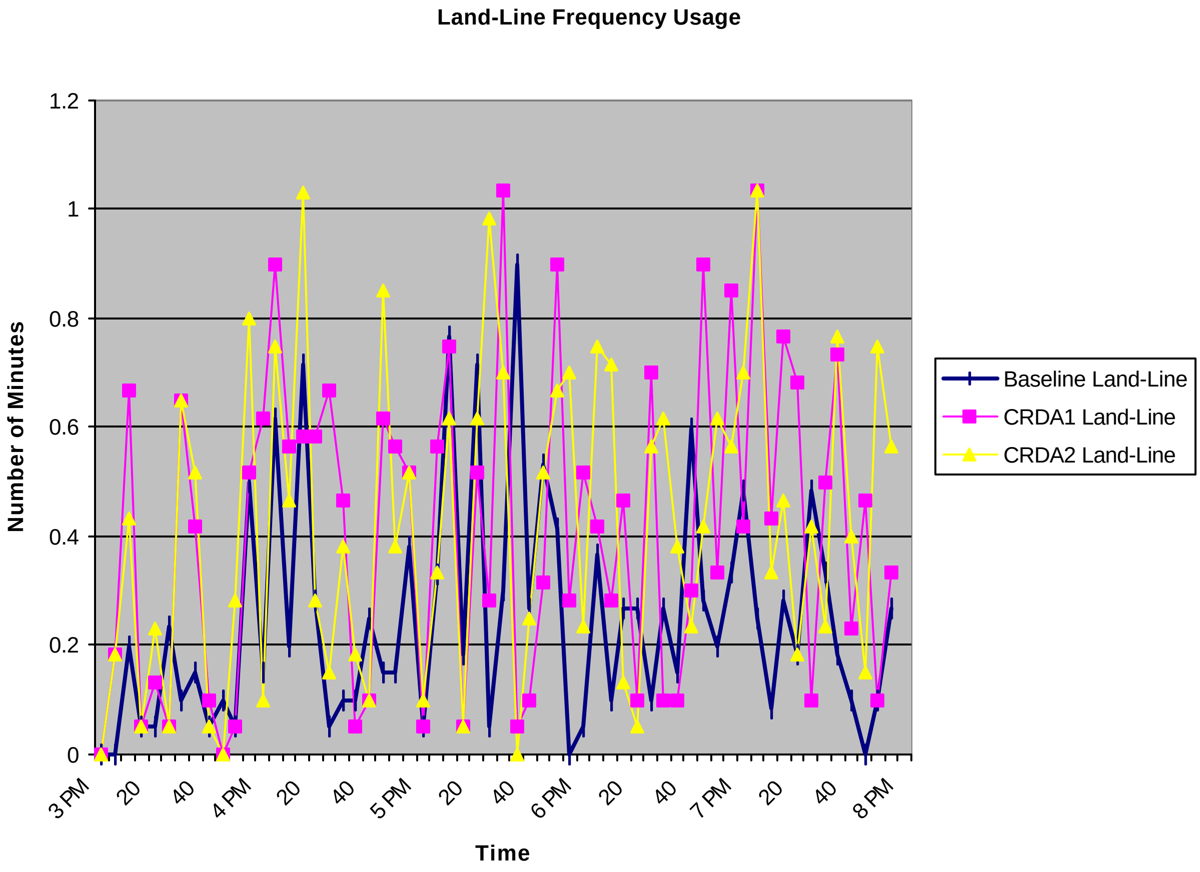


Figure 3-2. Landline Demand per Five-Minute Interval for Baseline and Alternative Cases

In order to estimate the impact on the total frequency demand for the local controller, the local control and landline communications demand curves are added together. This plot is presented in Figure 3-3.

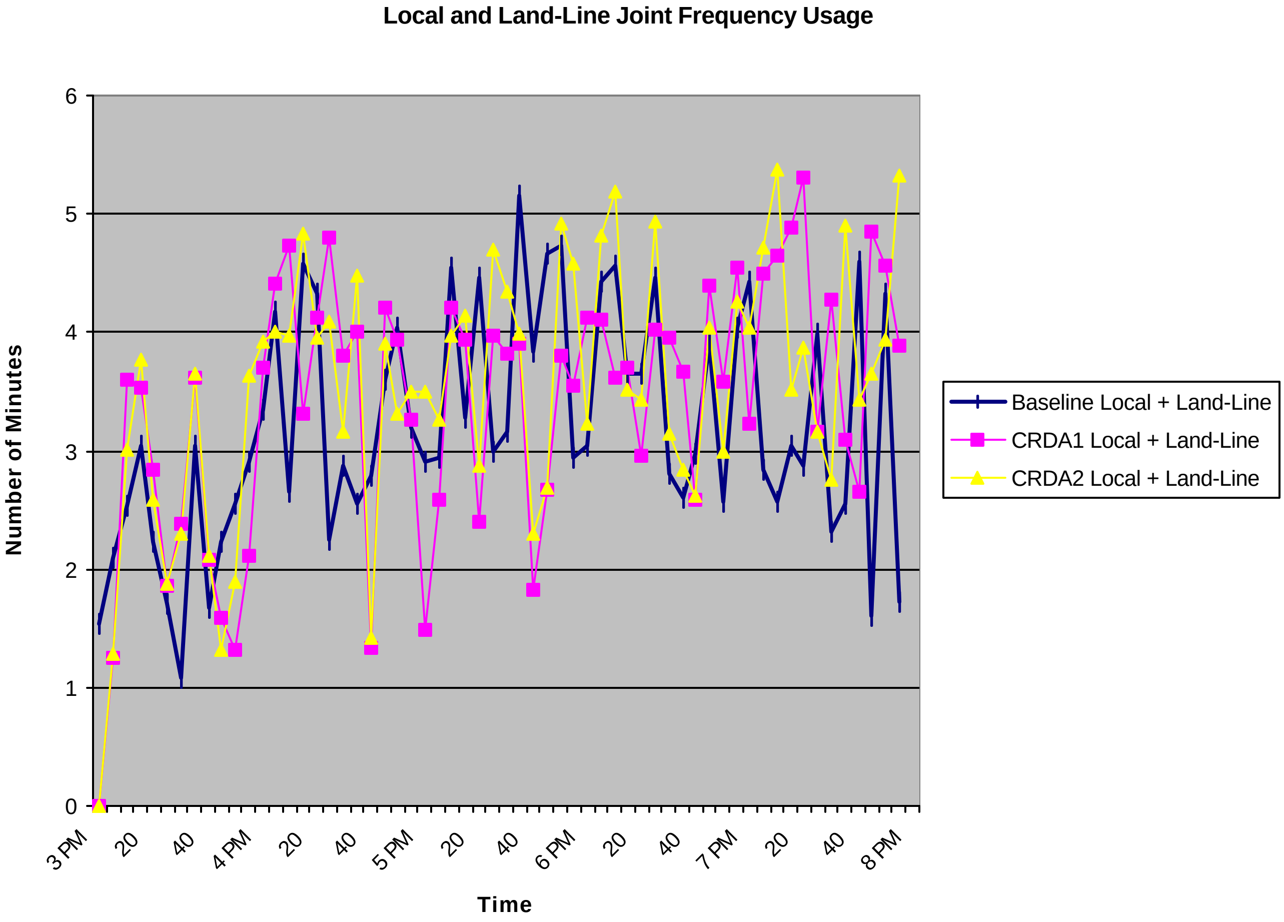


Figure 3-3. Combined Local Control Frequency and Landline Demand per Five-Minute Interval for Baseline and Alternative Cases

In this plot, we can see that the peaks in the CRDA dual arrival stream cases are higher and more numerous than the corresponding peaks in the baseline case. In some instances, the communication demand in a five-minute period exceed the five-minute maximum. This indicates that during some periods of the arrival push, the controller would not have time to issue every command necessary to avoid delaying aircraft even if he or she did nothing other than issue clearances.

While these graphs demonstrate the impacts over time, it is difficult to see the overall impact. Figure 3-4 is a graph of the average frequency demand per five-minute interval for baseline and alternative cases.

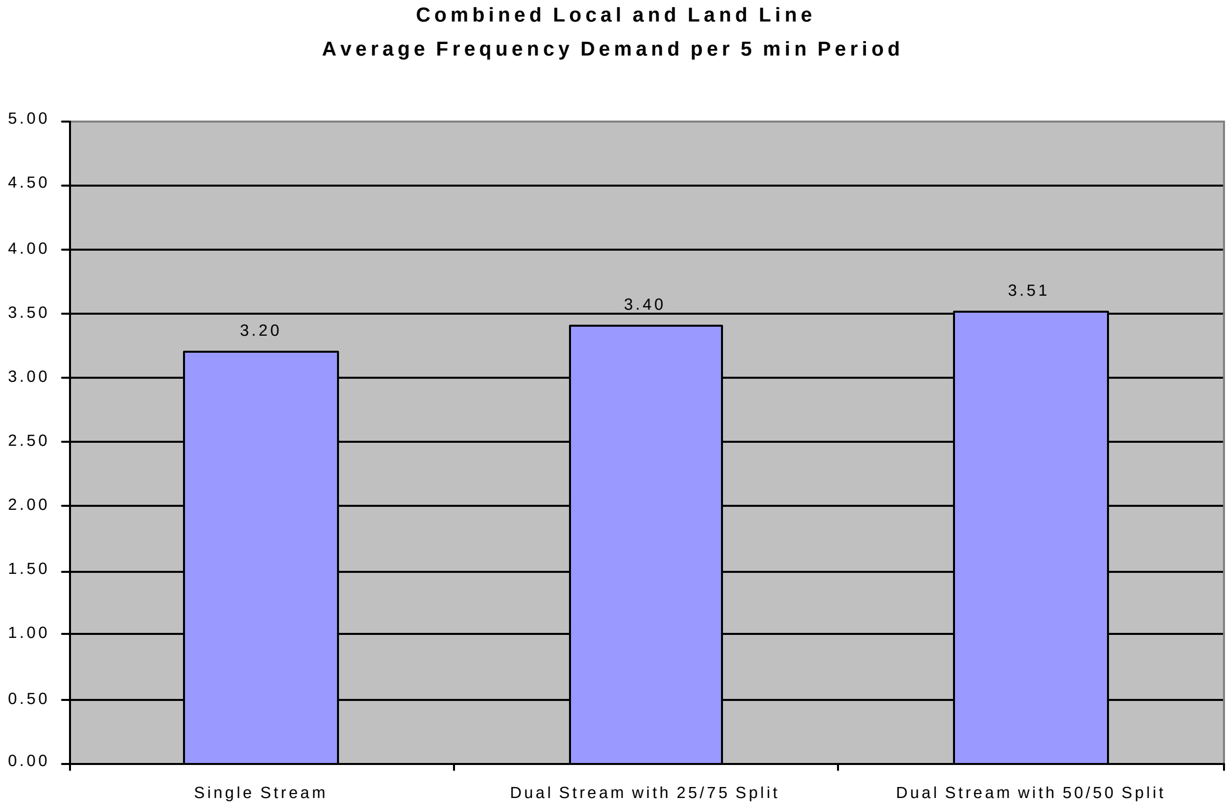


Figure 3-4. Average Frequency Demand per Five-Minute Interval on Combined Local and Landline Channels for Baseline and Alternative Scenarios

Figure 3-5 indicates a 6% increase in overall frequency demand for the 25/75 traffic split dual arrival stream case over the baseline, and a 10% increase for the 50/50 traffic split case.

Finally, the communication demand for the combined landline and local controller channels may be further analyzed to demonstrate the impact of the proposed procedural change on the local controller's work environment. Figure 3-5 is a plot of the amount of time the local controller's combined communication demand is above certain thresholds. The y-axis is the threshold, or percentage of available frequency used, and the x-axis is the amount of time during the arrival push the communication demand is above that threshold. For example, the point where the baseline curve intersects the 80% threshold occurs about at 25% of the time on the x-axis. This indicates the controller will be using 80% of his or her available frequency 25% of the time. The results of the baseline and 25/75 traffic split and 50/50 traffic split cases are presented together.

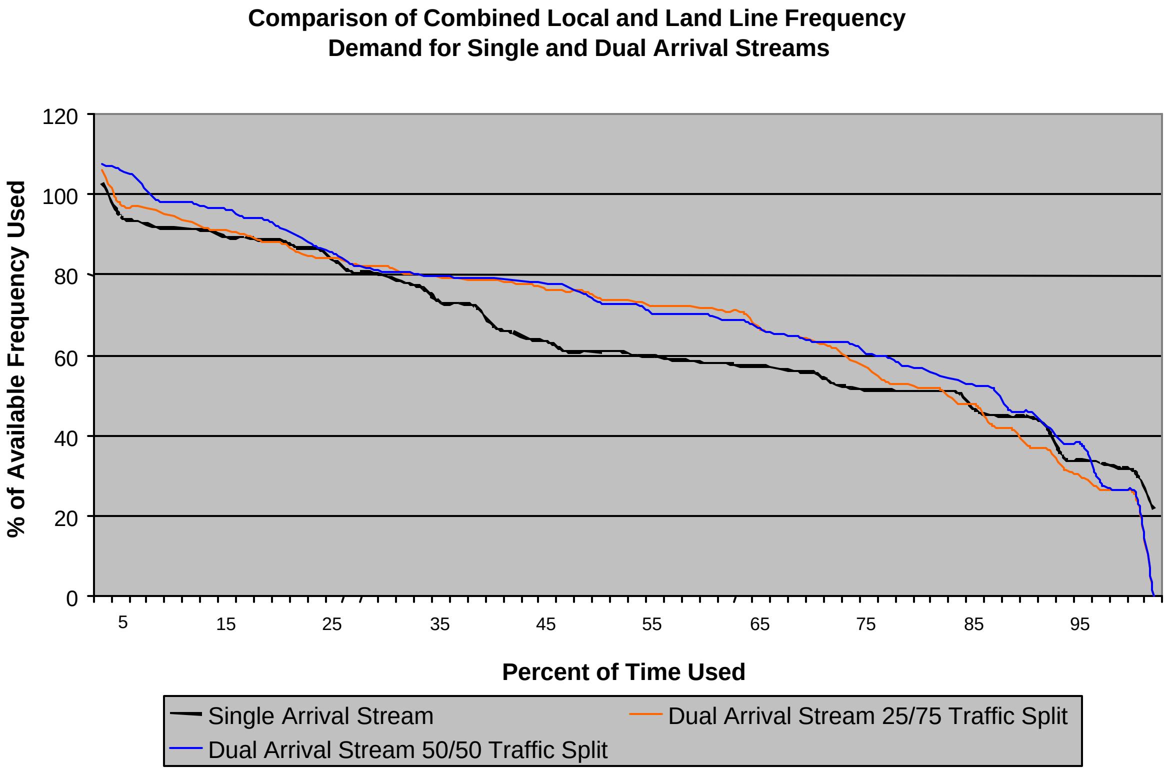


Figure 3-5. Comparison of Baseline and Alternative Frequency Demand by Percentage of Time Above Threshold

In this graph, it is possible to see when the impact of the procedural change will be felt. Specifically, the greatest difference between the baseline and dual arrival stream frequency demand curves occurs in the range of 50% or greater frequency usage. This indicates that the increase in communication workload will be felt during the busiest half of the day. One important consideration is the fact that the controller has an unknown comfort level above which the communications demand is greater than he or she is able to adequately address. This corresponds to some point on the y-axis. For example, if this comfort level is 70% (meaning that the controller cannot consistently respond to all communications when the demand gets above 70% of the available frequency), then the difference between the baseline and dual arrival stream cases is significant. By moving to the right from the 70% point on the y-axis, the amount of time that the controller must operate above his or her comfort level is first found when intersecting the line for the single arrival stream case. Dropping down to the x-axis identifies this point to be at 37% of the time, or that in terms of communication demand the controller must operate above his or her comfort level 37% of the time during a single stream arrival push. Continuing along the 70% comfort level until intersecting the dual arrival stream cases, and then dropping down to the x-axis indicates a much higher percentage of time, specifically 62% of the time. Thus, assuming a 70% communication demand comfort level, the controller would have to spend 25% more time above his or her comfort level in order to accomplish the required communication in the dual arrival stream case.

Section 4

Conclusions

The results of this analysis indicate that the arrival capacity of Boston Logan when in a 33L/27 configuration may be increased by using dual CRDA arrival streams. However, in order to achieve this increased arrival rate, the terminal controller must be able to feed the final approach course of both runway equally and from any arrival fix regardless of aircraft type. This would likely require a terminal airspace redesign and cooperation from pilots who may be required to land on the shorter Runway 27. This could be accomplished without increasing arrival delay or causing additional ground congestion.

If two arrival streams, each containing 50% of the arrival traffic, cannot be consistently maintained so that each aircraft can take advantage of a paired arrival (if available) then the dual arrival stream procedure is not recommended. In the cases where a 25/75% traffic split was modeled, and cases where aircraft selected runways based on current arrival fix selection rules, the airport capacity was reduced and arrival delay increased over the current single arrival stream case. This is due to the requirement for full wake turbulence separation between consecutive arrivals to the same runway. In these cases, a significant number of arrivals land without a paired arrival on the other runway.

In addition to the requirements for a consistent paired arrival flow regardless of aircraft arrival fix or type, the local controller would have to adjust to a 10% increase in arrival push communication load. This is the result of the additional coordination required when landing and departing two runways simultaneously. This increase will be felt during the busiest periods of the arrival push and, assuming a 70% frequency demand comfort level, the controller would be required to work an additional 15 minutes per hour above his or her comfort level.

List of References

1. Federal Aviation Administration, *Federal Aviation Administration Order 7110.110,* Department of Transportation, Washington, DC.

Glossary

ANE	FAA New England Region
ARTS	Automated Radar Terminal System
ATA	Air Transport Association
BOS	Logan International Airport
CAASD	Center for Advanced Aviation System Development
CAD	Computer Aided Design
CRDA	Converging Runway Display Aid
DCIA	Dependent Converging Instrument Approach
FAA	Federal Aviation Administration
ETMS	Enhanced Traffic Management System
MassPort	Massachusetts Port Authority
SQL	Structured Query Language
SRS	Standard Runway Separation
TAAM	Total Airspace and Airport Modeler