APPENDIX A

AIRPORT AND AIRSPACE SIMULATION MODELING AND NOISE/AIR QUALITY MODEL INPUT DATA DEVELOPMENT

This appendix contains background material which supplements the Total Airspace and Airport Modeler (TAAM) version evaluation material and data developed by the Chicago Department of Aviation (CDA) in support of the Proposed Interim Fly Quiet and its alternatives contained in **Chapter 2**, **Chapter 3**, and **Appendix C**. This appendix consists of the following sections:

- A.1 Introduction
- A.2 TAAM Version Evaluation (See also **Attachment A-1**)
- A.3 FAA Review of Air Traffic Assumptions and TAAM Simulations
- A.4 Operational Configurations of the Existing Fly Quiet (See also **Attachment A-2**)
- A.5 Airfield and Airspace Assumptions (See also **Attachment A-3**)
- A.6 Weather Analysis (See also **Attachment A-4**)
- A.7 Proposed Interim Fly Quiet Data Development (See also **Attachment A-5**)
- A.8 Operational Configurations and Runway Rotation of the Proposed Interim Fly Quiet
- Attachment A-1 TAAM Version Evaluation for the Interim Fly Quiet Runway Rotation Plan Re-Evaluation at O'Hare International Airport
- Attachment A-2 Operational Configurations of the Existing Fly Quiet
- Attachment A-3 Airfield and Airspace Assumption Diagrams
- Attachment A-4 Weather Analysis
- Attachment A-5 Methodology for Nighttime Operations for the Proposed Interim Fly Quiet

A.1 INTRODUCTION

TAAM is a computer model which simulates aircraft activity on the ground and in the air. It is capable of modeling gates, taxiways, and runways along with arrival and departure routes in the air for a flight schedule. Each runway configuration is modeled for the complete flight schedule and the results for each configuration are combined to provide an average day set of results. These results provide detailed inputs for the noise and air quality analyses. **Sections A.2** through **A.6** of this appendix describe in more detail the use of TAAM for this Re-Evaluation. The remaining sections discuss the development of the Proposed Interim Fly Quiet data and the alternatives.

A.2 TAAM VERSION EVALUATION

An evaluation of the use of TAAM, specifically TAAM Version 2017.2.1, was performed to assess output compatibility with results from the 2015 Re-Evaluation of the Environmental Impact Statement (EIS), which was modeled using TAAM Version 2014.4. Two 2015 Re-Evaluations of the EIS TAAM simulations were converted to TAAM Version 2017.2.1 and results were consistent with 2015 Re-Evaluation of the EIS results. Therefore, TAAM Version 2017.2.1 was chosen, with Federal Aviation Administration (FAA) approval, to perform the Existing Fly Quiet TAAM modeling. **Attachment A-1** provides information on the version of TAAM used in this Re-Evaluation.

A.3 FAA REVIEW OF AIR TRAFFIC ASSUMPTIONS AND TAAM SIMULATIONS

An FAA Air Traffic Workgroup reviewed the TAAM simulation assumptions and experiments supporting the environmental consequences analyses of this Re-Evaluation of the EIS**.** The FAA Air Traffic Workgroup, consisting of senior FAA Air Traffic representatives from Chicago Air Traffic Control facilities (O'Hare Air Traffic Control Tower, Elgin TRACON, and Aurora Center), reviewed and ultimately approved all configurations modeled through TAAM. Central Service Center and Chicago Airports District Office representatives also participated in the workgroup.

The process for the TAAM simulations for the Re-Evaluation followed the method used for the original EIS simulations completed in 2003-04, and the 2014-15 simulations for the 2015 Re-Evaluation. The work conducted by Ricondo & Associates (City of Chicago Consultant) was done at the direction, oversight, review, and approval of FAA.

The workgroup provided and reviewed operating assumptions, including but not limited to: airspace routings, taxi routings, runway/fix assignments, and throughput numbers. Each simulation experiment included animations that displayed the planned operation of aircraft on the airport and in the airspace. During each review session, the workgroup reviewed the animations and results. Any issues or inconsistenties with the TAAM animations were discussed with Ricondo & Associates, which then made appropriate modifications to the experiments and later delivered the results for additional review and ultimate approval. This process was completed for each configuration.

Based on the workgroup's comprehensive review, the workgroup is satisfied that the TAAM modeling simulation experiments depict a reasonable representation of how the operating configurations would be used at O'Hare.

A.4 OPERATIONAL CONFIGURATIONS OF THE EXISTING FLY QUIET

Operational configurations at O'Hare that were modeled in TAAM are depicted in **Exhibit A-1**, which is presented in **Attachment A-2.** Four operational configurations are listed for the Existing Fly Quiet. There are two west flow configurations and two east flow configurations.

A.5 AIRFIELD AND AIRSPACE ASSUMPTIONS

The airside air traffic movements (i.e., taxiing to or from the terminal buildings to the runway ends), the air traffic flows (i.e., aircraft in flight, arriving or departing), and the associated airspace and procedural configurations that would occur under the Existing Fly Quiet are depicted in a series of graphics presented in **Attachment A-3.**

A.6 WEATHER ANALYSIS

A weather conditions analysis was performed to determine the weighting of operating configurations at O'Hare for the Existing Fly Quiet TAAM simulations. Two weather analyses were performed. The first analysis determined the weighting of airfield operating configurations estimated to occur over a 12-month calendar year (January 1 – December 31). The second analysis determined weighting of operating configurations estimated to occur during a non-consecutive 11-month period representing the Proposed Interim Fly Quiet. Consequently, if approved, the Proposed Interim Fly Quiet could begin in November 2019 through mid-May 2020 (discontinuing during the rehabilitation of 4R/22L) and resume in mid-September 2020 until the end of January 2021. The Proposed Interim Fly Quiet would be in place for approximately 11 months (see **Figure 2-1** for details).

A.7 PROPOSED INTERIM FLY QUIET DATA DEVELOPMENT

The CDA provided a detailed methodology for the development of the Proposed Interim Fly Quiet flight schedule. This data provided the input for the the nighttime (10:00:00 p.m. to 6:59:59 a.m.) operations for the noise and air quality modeling. Daytime (7:00:00 a.m. to 9:59:59 p.m.) operations remained the same as in the Existing Fly Quiet. The process evaluated each of the six Proposed Interim Fly Quiet configurations and availability of use throughout the modeling period. Each configuration was weighted and combined to provide a final flight schedule for the nighttime period. The methodology is provided in **Attachment A-5**.

A.8 OPERATIONAL CONFIGURATIONS AND RUNWAY ROTATION OF THE PROPOSED INTERIM FLY QUIET

Operational configurations at O'Hare modeled for the Proposed Interim Fly Quiet are depicted in **Appendix C.** Six operational configurations are listed for the Proposed Interim Fly Quiet and shown in **Exhibit C-7**. There are three west flow configurations (two parallel and one diagonal configuration) and three east flow configurations (two parallel and one diagonal configuration). These configurations are rotated on a weekly basis (over eight weeks) throughout the Proposed Interim Fly Quiet period as shown in **Exhibit C-8**. The differences between the Proposed Interim Fly Quiet and the two other alternatives are limited to the number of weeks of rotation for each program.

- Revised Interim Fly Quiet 1 – six weeks, as shown in **Exhibit C-9**
- Revised Interim Fly Quiet 2 – 20 weeks, as shown in **Exhibit C-10**

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ATTACHMENT A-1

TAAM VERSION EVALUATION FOR THE INTERIM FLY QUIET RUNWAY ROTATION PLAN RE-EVALUATION AT O'HARE INTERNATIONAL AIRPORT

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MEMORANDUM [FINAL]

Date: June 27, 2018

To: Ms. Amy Hanson
Environmental Protection Specialist
Federal Aviation Administration – Chicago Airports District Office

From: Joshua Jones

Subject: TAAM VERSION EVALUATION FOR THE INTERIM FLY QUIET RUNWAY ROTATION PLAN RE-EVALUATION AT O'HARE INTERNATIONAL AIRPORT

The Federal Aviation Administration (FAA) is preparing a Written Re-Evaluation to determine potential environmental impacts caused by the implementation of an Interim Fly Quiet Runway Rotation Plan at O'Hare International Airport (O'Hare or the Airport). This memorandum summarizes the evaluation and comparison of two versions of Jeppesen's Total Airspace and Airport Modeler (TAAM), Version 2014.4 and Version 2017.1, to perform modeling analysis for the Re-Evaluation. TAAM is a fast-time computer simulation model used to calculate delay and travel times by simulating aircraft operations on the ground and in the air. Outputs from TAAM provide inputs used for air quality and noise analyses. TAAM was used to support environmental analysis at the Airport on two occasions prior to the Interim Fly Quiet Runway Rotation Plan Re-Evaluation: the FAA-approved O'Hare Modernization (OM) Environmental Impact Statement (EIS), completed in July 2005, and the 2015 Re-Evaluation of the 2005 OM EIS, completed in October 2015. The rationale for the use of TAAM, which is included in Appendix D, Section D.2.2 of the OM EIS, is still valid.

Jeppesen continuously updates TAAM and has released several versions of the software since the completion of the 2005 OM EIS, as well as since the completion of the 2015 Re-Evaluation of the 2005 OM EIS. Currently, Jeppesen releases updates on a quarterly basis. Ricondo performed the TAAM analyses used in the 2005 OM EIS and the 2015 Re-Evaluation of the 2005 OM EIS,[1] and the firm has been contracted to perform the TAAM analysis of the Interim Fly Quiet Runway Rotation Plan Re-Evaluation. As part of this process, Ricondo explored the option of utilizing the current version[2] of the model, TAAM v2017.1, due to numerous enhancements implemented since the release of TAAM v2014.4.

[1] A TAAM Version Evaluation memorandum to support the upgrade of TAAM from v2.0 to v2014.2 for the 2015 Re-Evaluation of the 2005 OM EIS is included in Appendix A, Attachment A-1, of the final report. TAAM v2014.4 was ultimately utilized for the analysis due to the release of subsequent versions.

[2] Initial TAAM modeling for the Interim Fly Quiet Runway Rotation Plan Re-Evaluation was performed in the second quarter of 2017, when TAAM v2017.1 was the current version of the TAAM software. TAAM v2018.1 is the most current version as of April 2018.

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TAAM MODEL UPDATES

TAAM v2014.4, used for the 2015 Re-Evaluation of the 2005 OM EIS, is slightly over two years old. Jeppesen has released nine subsequent quarterly updates to the program; TAAM v2017.1 is the current version. The TAAM evaluation included establishing an understanding of what updates had occurred between TAAM v2014.4 and TAAM v2017.1. In general, the updates relate to fixing bugs, improving the software's ease of use, advancing rule-based logic to depict more realistic real-world operations, and providing new outputs compatible with industry-standard noise and air quality analysis software. Release notes for each version were studied, and notable enhancements are summarized in the following subsections.

Automated Standard Instrument Departures / Standard Terminal Arrival Routes Importer

The ability to import Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs) included in Jeppesen's navigation database has been integrated into the model. Previously, modelers had to construct SIDs and STARs in a time-consuming manner by manually inputting each waypoint and any associated altitude or speed restrictions. O'Hare has more than 10 STARs that feed aircraft into more than 6 arrival runways, potentially resulting in a combination of over 60 procedures that had previously been constructed manually. The ability to import these procedures greatly reduces the complexity and time-consuming nature of this task.

Additionally, up-to-date Jeppesen worldwide navigation data, including waypoints, airports, runway layouts, airspace sectors, and routes/airways are included with each TAAM software release.

Improved Rule Logic

Multiple improvements have been made to the rule logic in the model in order to depict more realistic real-world operations. For example, user-defined Generic Modeling Areas (GMAs) can now be queried by aircraft properties rather than simply a count of aircraft. Additionally, the ability to use wildcard characters in rule actions has been implemented.

Parallel Simulation Multi-Runs

The simulation multi-run process has been enhanced to allow multi-runs to be completed in parallel (simultaneously) rather than through a one-run-at-a-time basis. This process takes advantage of multi-core processors available in modern computers, and it significantly shortens the amount of time necessary to complete a multi-run (11 run multi-runs are standard for O'Hare TAAM modeling).

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Generation of Aviation Environmental Design Tool Standard Input Files

The generation of Aviation Environmental Design Tool (AEDT) standard input files has been introduced as a method to input TAAM data into the FAA's AEDT Version 2C. AEDT is used for modeling flight scenarios to estimate fuel consumption and to analyze emissions, noise, and air quality. AEDT is expected to be the noise and air quality analysis tool used for the Interim Fly Quiet Runway Rotation Plan Re-Evaluation.

STATISTICAL COMPARISON

In an effort to compare the differences in results between TAAM v2014.4 and TAAM v2017.1, an experiment from the 2015 Re-Evaluation of the 2005 OM EIS, Experiment 511, was processed using TAAM v2017.1. Results produced by TAAM v2017.1 were compared with those produced using TAAM v2014.4 for the same experiment. Outputs generated by both models were processed using Ricondo's statistical analysis tools, which generated metrics that allowed the results to be directly compared. The metrics, which were also generated as part of the 2005 OM EIS and the 2015 Re-Evaluation of the 2005 OM EIS, include:

- average unimpeded travel time by operational phase for arrivals and departures
- average delay by operational phase for arrivals and departures, including average overall airport delay
- average time in operational phase for arrivals and departures
- number of arrival and departure operations by runway
- hourly arrival and departure throughput by runway
    - peak-hour arrival and departure throughput by runway
- day and night distribution of aircraft movements
- arrival runway overlaps
- modeled flight terminations

Visual Flight Rules (VFR) – 2015 Re-Evaluation of the 2005 OM EIS Experiment 511 (VFR-1 West)

The following tables (**Table 1** through **Table 8**) provide summary-level information on the outputs of the 2015 Re-Evaluation of the 2005 OM EIS Experiment 511 in TAAM v2014.4 and TAAM 2017.1. The full set of results is attached to this memorandum. TAAM v2014.4 results were taken directly from the 2015 Re-Evaluation of the 2005 OM EIS production run. **The statistical outputs from TAAM v2017.1 are intended to be used for comparison with the outputs from TAAM 2014.4. The TAAM v2017.1 statistics do not represent updated results from the FAA-approved 2005 OM EIS, the 2015 Re-Evaluation of the 2005 OM EIS, or the Interim Fly Quiet Runway Rotation Plan Re-Evaluation process results.** The simulation models were run for multiple iterations to account for natural variability that may occur in the simulation models. The values in the following tables represent the average over an 11 run multi-run, except where noted.

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Table 1: Experiment 511 Average Unimpeded Travel Time (Minutes per Operation)

	DEPARTURE			ARRIVAL		
	AIRBORNE	GROUND	TOTAL	AIRBORNE	GROUND	TOTAL
TAAM v2014.4	117.9	9.3	127.2	121.4	9.2	130.5
TAAM v2017.1	118.0	9.3	127.3	121.4	9.2	130.5
Difference	+0.1	--	+0.1	--	--	--

NOTE: The metrics used in Table 1 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 2: Experiment 511 Average Delay per Phase of Operation (Minutes per Operation)

	DEPARTURE GATE DELAY AT O'HARE	DEPARTURE GROUND DELAY AT O'HARE	ARRIVAL GROUND DELAY AT ORIGIN	ARRIVAL AIR DELAY AT O'HARE	ARRIVAL GROUND DELAY AT O'HARE	TOTAL DELAY
TAAM v2014.4	0.5	3.7	0.2	3.5	0.3	4.1
TAAM v2017.1	0.5	3.6	0.2	3.5	0.3	4.1
Difference	--	- 0.1	--	--	--	--

NOTE: The metrics used in Table 2 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

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Table 3: Experiment 511 Average Time in Operational Phase (Minutes per Operation)

	DEPARTURE			ARRIVAL		
	AIRBORNE	GROUND	TOTAL	AIRBORNE	GROUND	TOTAL
TAAM v2014.4	117.9	13.4	131.4	124.9	9.7	134.6
TAAM v2017.1	118.0	13.4	131.4	124.9	9.7	134.6
Difference	+0.1	--	--	--	--	--

NOTE: The metrics used in Table 3 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 4: Experiment 511 Simulated Operations by Runway

	DEPARTURE RUNWAY			ARRIVAL RUNWAY			
	28R	22L	33	27R	27L	28R	28C
TAAM v2014.4	694	605	151	385	560	23	480
TAAM v2017.1	694	610	146	384	564	23	477
Difference	--	+5	-5	-1	+4	--	-3

NOTE: The metrics used in Table 4 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 5: Experiment 511 Peak Arrival and Departure Throughput by Runway (Rolling Hour)

	DEPARTURE RUNWAY			ARRIVAL RUNWAY			
	28R	22L	33	27R	27L	28R	28C
TAAM v2014.4	65	56	34	42	44	11	43
TAAM v2017.1	64	55	34	42	44	11	43
Difference	- 1	- 1	--	--	--	--	--

NOTE: The metrics used in Table 5 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

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Table 6: Experiment 511 Day/Night Operations Percentage

	DAYTIME			NIGHTTIME		
	DEPARTURES	ARRIVALS	TOTAL	DEPARTURES	ARRIVAL	TOTAL
TAAM v2014.4	95.5%	94.1%	94.8%	4.5%	5.9%	5.2%
TAAM v2017.1	95.5%	94.1%	94.8%	4.5%	5.9%	5.2%
Difference	--	--	--	--	--	--

NOTE: The metrics used in Table 6 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 7: Experiment 511 Arrival Runway Overlaps

	ARRIVAL RUNWAY OVERLAPS
TAAM v2014.4	0
TAAM v2017.1	0
Difference	--

NOTE: The metrics used in Table 7 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 8: Experiment 511 Aircraft Terminations

	DEPARTURES	ARRIVALS	TOTAL
TAAM v2014.4	1	3	4
TAAM v2017.1	1	3	4
Difference	--	--	--

NOTE: The metrics used in Table 8 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

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Instrument Flight Rules (IFR) – 2015 Re-Evaluation of the 2005 OM EIS Experiment 516A (IFR East)

The following tables (**Table 9** through **Table 16**) provide summary-level information on the outputs of the 2015 Re-Evaluation of the 2005 OM EIS Experiment 516A in TAAM v2014.4 and TAAM 2017.1. The full set of results is attached to this memorandum. TAAM v2014.4 results were taken directly from the 2015 Re-Evaluation of the 2005 OM EIS production run. **The statistical outputs from TAAM v2017.1 are intended to be used for comparison with the outputs from TAAM 2014.4. The TAAM v2017.1 statistics do not represent updated results from the FAA-approved 2005 OM EIS, the 2015 Re-Evaluation of the 2005 OM EIS, or the Interim Fly Quiet Runway Rotation Plan Re-Evaluation process results.** The simulation models were run for multiple iterations to account for natural variability that may occur in the simulation models. The values in the following tables represent the average over an 11 run multi-run, except where noted.

Table 9: Experiment 516A Average Unimpeded Travel Time (Minutes per Operation)

	DEPARTURE			ARRIVAL		
	AIRBORNE	GROUND	TOTAL	AIRBORNE	GROUND	TOTAL
TAAM v2014.4	118.2	10.0	128.2	125.1	15.7	140.8
TAAM v2017.1	118.6	10.5	129.1	125.1	15.7	140.9
Difference	+0.4	+0.5	+0.9	--	--	+0.1

NOTE: The metrics used in Table 9 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

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Table 10: Experiment 516A Average Delay per Phase of Operation (Minutes per Operation)

	DEPARTURE GATE DELAY AT O'HARE	DEPARTURE GROUND DELAY AT O'HARE	ARRIVAL GROUND DELAY AT ORIGIN	ARRIVAL AIR DELAY AT O'HARE	ARRIVAL GROUND DELAY AT O'HARE	TOTAL DELAY
TAAM v2014.4	8.6	11.3	0.0	4.2	0.5	12.3
TAAM v2017.1	9.5	11.2	0.0	4.1	1.0	12.9
Difference	+0.9	- 0.1	--	-0.1	+0.5	+0.6

NOTE: The metrics used in Table 10 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 11: Experiment 516A Average Time in Operational Phase (Minutes per Operation)

	DEPARTURE			ARRIVAL		
	AIRBORNE	GROUND	TOTAL	AIRBORNE	GROUND	TOTAL
TAAM v2014.4	118.2	29.9	148.1	129.4	16.2	145.5
TAAM v2017.1	118.6	31.2	149.8	129.2	16.7	145.9
Difference	+0.4	+1.3	+1.7	-0.2	+0.5	+0.4

NOTE: The metrics used in Table 11 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

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Table 12: Experiment 516A Simulated Operations by Runway

	DEPARTURE RUNWAY		ARRIVAL RUNWAY				
	09R	10L	09L	09R	10L	10C	10R
TAAM v2014.4	780	670	514	6	53	420	455
TAAM v2017.1	780	670	515	5	53	420	455
Difference	--	--	+1	-1	--	--	--

NOTE: The metrics used in Table 12 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 13: Experiment 516A Peak Arrival and Departure Throughput by Runway (Rolling Hour)

	DEPARTURE RUNWAY		ARRIVAL RUNWAY				
	09R	10L	09L	09R	10L	10C	10R
TAAM v2014.4	61	51	44	6	20	36	41
TAAM v2017.1	62	55	44	5	20	36	41
Difference	+1	+4	--	-1	--	--	--

NOTE: The metrics used in Table 13 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 14: Experiment 516A Day/Night Operations Percentage

	DAYTIME			NIGHTTIME		
	DEPARTURES	ARRIVALS	TOTAL	DEPARTURES	ARRIVAL	TOTAL
TAAM v2014.4	92.4%	94.4%	93.4%	7.6%	5.6%	6.6%
TAAM v2017.1	89.4%	94.4%	91.9%	10.6%	5.6%	8.1%
Difference	-3.0%	--	-1.5%	+3.0%	--	+1.5%

NOTE: The metrics used in Table 14 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

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Table 15: Experiment 516A Arrival Runway Overlaps

	ARRIVAL RUNWAY OVERLAPS
TAAM v2014.4	0
TAAM v2017.1	0
Difference	--

NOTE: The metrics used in Table 15 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

Table 16: Experiment 516A Aircraft Terminations

	DEPARTURES	ARRIVALS	TOTAL
TAAM v2014.4	1	1	2
TAAM v2017.1	2	4	6
Difference	+1	+3	+4

NOTE: The metrics used in Table 16 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., June 2017.

An unanticipated difference in both departure ground time and departure gate delay was noticed when Experiment 516A was run through TAAM v2017.1. Upon further analysis, a software bug was discovered that resulted in a miscalculation of departure separation for aircraft departing to dependent departure fixes, leading to increased departure ground and delay times. For example, the default departure runway for northbound departures is Runway 9R. When a northbound aircraft needs a longer departure runway, it will depart Runway 10L. A northbound departure from Runway 10L needs to wait for the previous northbound departure from Runway 9R (and vice-versa) to achieve the required departure separation, in minutes or nautical miles, before being released for takeoff. In the case of Experiment 516A run in TAAM v2017.1, an aircraft departing Runway 10L to a northbound fix was observed to be holding short of Runway 10L without departing, even though the preceding departure and the next six departures on Runway 9R were not northbound (or dependent) departures. However, the seventh aircraft in the queue for Runway 9R was a northbound departure, and TAAM v2017.1 was inadvertently waiting for this aircraft to depart Runway 9R prior to releasing the departure on Runway 10L. This ultimately led to the departure queue on Runway 10L growing increasingly longer, and it resulted in increased departure ground and departure gate delay times for subsequent departing aircraft on Runway 10L. The delays were exacerbated by departure/arrival dependencies between Runways 10L and 10C when operating under IFR.

Jeppesen was notified of the issue and verified the existence of the departure separation bug. During subsequent conversations with the technical support personnel, four options were discussed for moving

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forward with TAAM modeling for the Interim Fly Quiet Runway Rotation Plan Re-Evaluation. The four options are listed as follows from least ideal to most ideal.

- Utilize TAAM v2017.1 and change the Put Aircraft in Lineup Queue setting from "early" to "at runway hold line." The current setting, "early," means that aircraft are put in the lineup queue when they reach the runway hold line or when they stop behind aircraft already in the lineup queue. Any further delays accumulated by aircraft at this point are reported as runway delays. By changing the setting to "at runway hold line," aircraft are placed in the lineup queue only when they reach the runway hold line. Any delays accumulated by aircraft behind the aircraft at the runway hold line are reported as taxiway delays, not runway delays. Changing this setting would result in a runway departure queue for any given runway never exceeding one, except in the case for runways with multiple departure points. Many existing rules are present in the O'Hare models, which are dependent on testing departure lineup queue lengths in order to properly balance departure runways; thus, changing this setting may result in a change in runway use.
- Utilize TAAM v2017.1 and change the Departure Sequencing Optimization setting from "limited" to "full." The current "limited" setting means that when adding an aircraft to the lineup queue, TAAM may insert the aircraft into the queue only if it will not result in extra delays for other aircraft already in the lineup queue. Otherwise, TAAM adds the aircraft to the end of the queue, regardless of the total added delay. By changing the setting to "full," TAAM tries to account for all factors that affect delay, such as spacing and runway dependencies, and it places the aircraft in the queue in a position that will minimize total overall delay. While changing this setting may better reflect real-life optimization methods now used by O'Hare air traffic controllers, it would differ from the setting used in the 2005 OM EIS and the 2015 Re-Evaluation of the 2005 OM EIS. Changing this setting may also result in a change in runway use and runway throughput.
- Utilize TAAM v2014.4. This option maintains consistency with the 2015 Re-Evaluation of the 2005 OM EIS. However, this option does not permit the Interim Fly Quiet Runway Rotation Plan Re-Evaluation team to take advantage of the upgrades offered by later versions of TAAM, such as the output of standard AEDT files. Additionally, technical support for any potential issues found with this version would be limited to providing work-arounds, as Jeppesen has stated that it will provide patches and updates only for the most current version of TAAM.
- Request a bug patch to be issued for TAAM v2017.2. TAAM v2017.2 was released on July 7, 2017, and it contains minor updates to the software that are perceived to be negligible to the Interim Fly Quiet Runway Rotation Plan Re-Evaluation modeling effort. Jeppesen was not able to incorporate the bug fix into the TAAM v2017.2 release; however, Jeppesen stated that they would be willing to provide a patch for this version. An expected timeline for receiving the patch is forthcoming. Assuming that the patch eliminates the departure separation miscalculation issue, moving forward with a patched TAAM v2017.2 would allow the Interim Fly

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Quiet Runway Rotation Plan Re-Evaluation team to take advantage of the features offered in newer versions of TAAM, while maintaining consistency with the 2015 Re-Evaluation of the 2005 OM EIS.

STATISTICAL COMPARISON – PATCHED VERSION OF TAAM V2017.2

Jeppesen provided Ricondo a patched version of TAAM v2017.2, referred to as v2017.2.1, on July 21, 2017. Experiments 511 and 516A from the 2015 Re-Eval were both processed using TAAM v2017.2.1 to determine whether the departure separation bug was resolved. Statistical outputs for Experiment 511 processed using TAAM v2017.2.1 were indiscernible from the outputs processed using TAAM v2017.1; those statistical outputs having been presented previously in Table 1 through Table 8.

The following tables (**Table 17** through **Table 24**) provide summary-level information on the outputs of the 2015 Re-Evaluation of the 2005 OM EIS Experiment 516A in TAAM v2014.4 and TAAM v2017.2.1. The full set of results is attached to this memorandum. TAAM v2014.4 results were taken directly from the 2015 Re-Evaluation of the 2005 OM EIS production run. **The statistical outputs from TAAM v2017.2.1 are intended to be used for comparison with the outputs from TAAM 2014.4. The TAAM v2017.2.1 statistics do not represent updated results from the FAA-approved 2005 OM EIS, the 2015 Re-Evaluation of the 2005 OM EIS, or the Interim Fly Quiet Runway Rotation Plan Re-Evaluation process results.** The simulation models were run for multiple iterations to account for natural variability that may occur in the simulation model. The values in the following tables represent the average over an 11 run multi-run, except where noted.

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Table 17: Experiment 516A Average Unimpeded Travel Time (Minutes per Operation)

	DEPARTURE			ARRIVAL		
	AIRBORNE	GROUND	TOTAL	AIRBORNE	GROUND	TOTAL
TAAM v2014.4	118.2	10.0	128.2	125.1	15.7	140.8
TAAM v2017.2.1	118.2	10.5	128.6	125.1	15.6	140.8
Difference	--	+0.5	+0.4	--	-0.1	--

NOTE: The metrics used in Table 17 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., August 2017.

Table 18: Experiment 516A Average Delay per Phase of Operation (Minutes per Operation)

	DEPARTURE GATE DELAY AT O'HARE	DEPARTURE GROUND DELAY AT O'HARE	ARRIVAL GROUND DELAY AT ORIGIN	ARRIVAL AIR DELAY AT O'HARE	ARRIVAL GROUND DELAY AT O'HARE	TOTAL DELAY
TAAM v2014.4	8.6	11.3	0.0	4.2	0.5	12.3
TAAM v2017.2.1	8.3	11.2	0.0	4.1	0.6	12.1
Difference	-0.3	-0.1	--	-0.1	+0.1	-0.2

NOTE: The metrics used in Table 18 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., August 2017.

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Table 19: Experiment 516A Average Time in Operational Phase (Minutes per Operation)

	DEPARTURE			ARRIVAL		
	AIRBORNE	GROUND	TOTAL	AIRBORNE	GROUND	TOTAL
TAAM v2014.4	118.2	29.9	148.1	129.4	16.2	145.5
TAAM v2017.2.1	118.2	30.0	148.2	129.2	16.2	145.5
Difference	--	+0.1	+0.1	-0.2	--	--

NOTE: The metrics used in Table 19 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., August 2017.

Table 20: Experiment 516A Simulated Operations by Runway

	DEPARTURE RUNWAY		ARRIVAL RUNWAY				
	09R	10L	09L	09R	10L	10C	10R
TAAM v2014.4	780	670	514	6	53	420	455
TAAM v2017.2.1	781	669	515	5	53	420	455
Difference	+1	-1	+1	-1	--	--	--

NOTE: The metrics used in Table 20 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., August 2017.

Table 21: Experiment 516A Peak Arrival and Departure Throughput by Runway (Rolling Hour)

	DEPARTURE RUNWAY		ARRIVAL RUNWAY				
	09R	10L	09L	09R	10L	10C	10R
TAAM v2014.4	61	51	44	6	20	36	41
TAAM v2017.2.1	60	51	44	5	20	36	41
Difference	+1	--	--	-1	--	--	--

NOTE: The metrics used in Table 21 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., August 2017.

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Table 22: Experiment 516A Day/Night Operations Percentage

	DAYTIME			NIGHTTIME		
	DEPARTURES	ARRIVALS	TOTAL	DEPARTURES	ARRIVAL	TOTAL
TAAM v2014.4	92.4%	94.4%	93.4%	7.6%	5.6%	6.6%
TAAM v2017.2.1	93.2%	94.4%	93.8%	6.8%	5.6%	6.2%
Difference	+0.8%	--	+0.4%	-0.8%	--	-0.4%

NOTE: The metrics used in Table 22 are single-run statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., August 2017.

Table 23: Experiment 516A Arrival Runway Overlaps

	ARRIVAL RUNWAY OVERLAPS
TAAM v2014.4	0
TAAM v2017.2.1	0
Difference	--

NOTE: The metrics used in Table 23 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., August 2017.

Table 24: Experiment 516A Aircraft Terminations

	DEPARTURES	ARRIVALS	TOTAL
TAAM v2014.4	1	1	2
TAAM v2017.2.1	1	3	4
Difference	--	+2	+2

NOTE: The metrics used in Table 24 are 11 run multi-run average statistics.
SOURCES: Federal Aviation Administration, 2015 Re-Evaluation of the 2005 OM EIS, October 2015; Ricondo, Inc., August 2017.

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NOISE AND AIR QUALITY MODEL COMPATIBILITY

Ricondo worked with Harris Miller Miller & Hanson (HMMH), the FAA's third party contractor for the Interim Fly Quiet Runway Rotation Plan Re-Evaluation, to assess the compatibility of TAAM Version v2017.2.1 with the tools that will be used to evaluate noise and air quality.

HMMH found that the key TAAM metrics that would influence the results of the air quality analyses of the Interim Fly Quiet Runway Rotation Plan Re-Evaluation include travel and delay times such as those shown in Tables 1, 2, and 3. Key TAAM metrics that would influence the results of the noise analyses of the Interim Fly Quiet Runway Rotation Plan Re-Evaluation include runway-use statistics and day/night splits of operation, such as those shown in Tables 4 and 6. The fact that the comparative results between TAAM v2014.4 and TAAM v2017.2.1 are so similar for all of these statistics, when tested for the most commonly occurring runway configuration and weather conditions represented by the 2015 Re-Evaluation of the 2005 OM EIS Experiments 511 and 516A, suggests that any TAAM model differences, when combined across all experiments, will have little bearing on noise or air quality results developed for the Interim Fly Quiet Runway Rotation Plan Re-Evaluation.

TAAM VERSION UTILIZED FOR THE INTERIM FLY QUIET RUNWAY ROTATION PLAN RE-EVALUATION

TAAM Version v2017.2.1 was ultimately utilized for running the simulation models utilized in the Interim Fly Quiet Runway Rotation Plan Re-Evaluation.

cc:
Aaron Frame, Chicago Department of Aviation
Kristina Woodward, Ricondo
Kevin Markwell, Ricondo
Erik Wilkins, Ricondo
11010735 – 0601 – 12

p:\simulation\kord_fly-quiet\admin\taam version evaluation\$taam version memo\interim fly quiet re-evaluation taam version evaluation_final - 20180627.docx

ATTACHMENT A-2

OPERATIONAL CONFIGURATIONS OF THE EXISTING FLY QUIET

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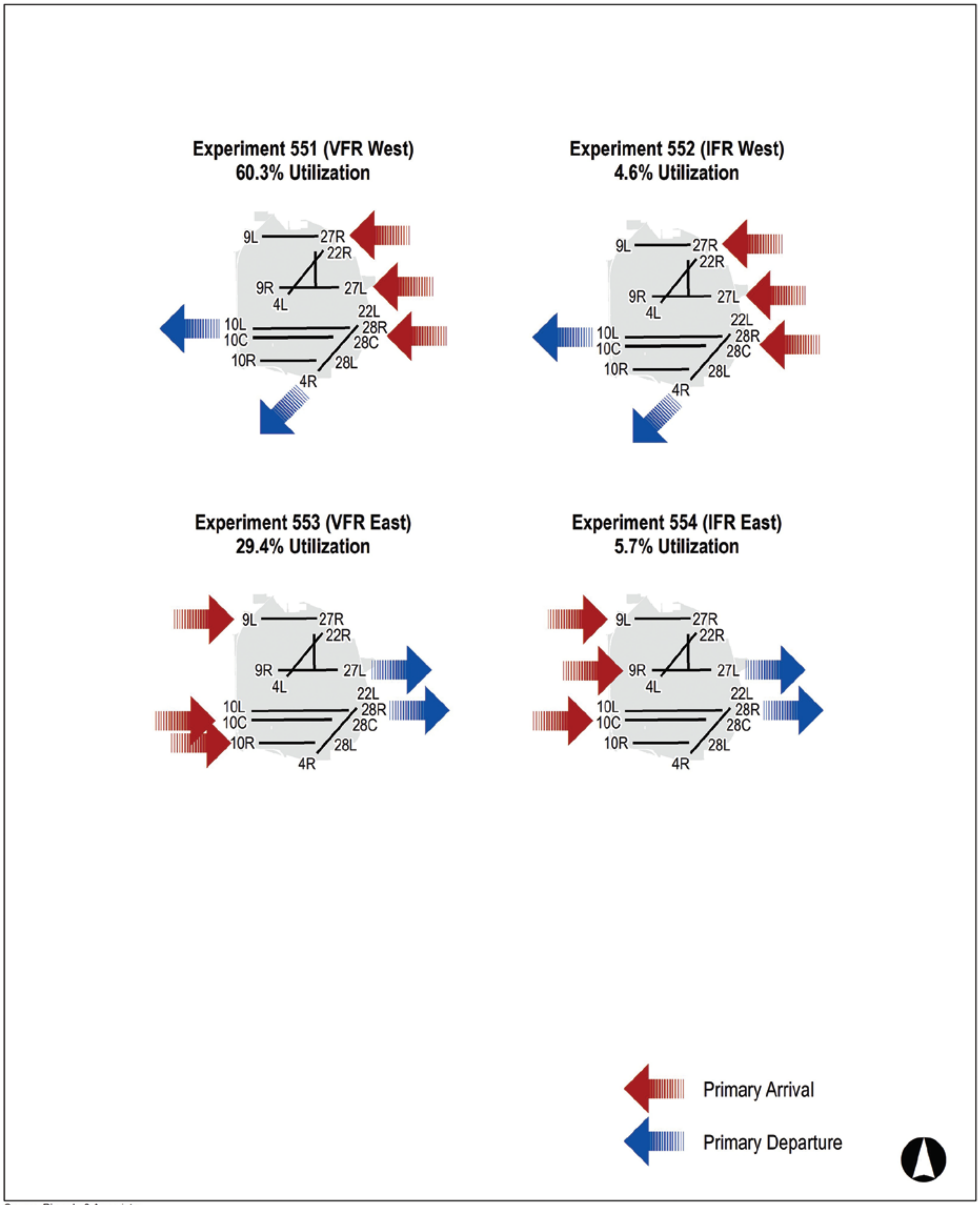

Source: Ricondo & Associates

Chicago O'Hare International Airport
Written Re-Evaluation of the O'Hare Modernization Environmental Impact Statement for the Interim Fly Quiet Runway Rotation Plan

Existing Fly Quiet Modeled Airfield Operating Configurations

▶ Exhibit A-1

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ATTACHMENT A-3

AIRFIELD AND AIRSPACE ASSUMPTION DIAGRAMS

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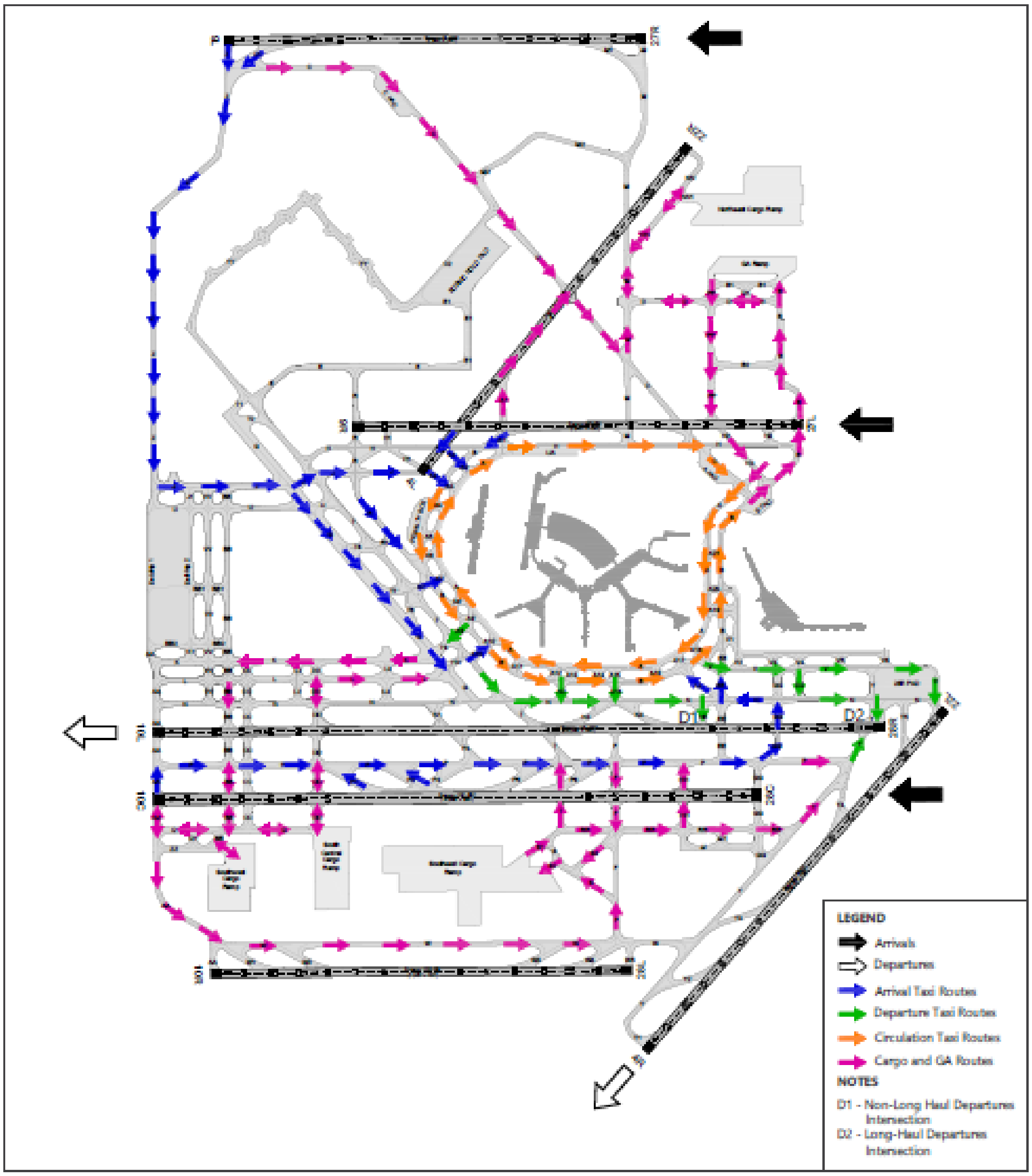
FIGURE A-1
EXPERIMENT 551: VFR WEST TAXIWAY ROUTES

O'HARE INTERNATIONAL AIRPORT AUGUST 2018

[DRAFT]



SOURCES: O'Hare International Airport, Airport Layout Plan, September 2005; Ricondo & Associates, Inc., August 2017.
PREPARED BY: Ricondo & Associates, Inc., August 2017.

Taxiway Routes
Experiment 551: VFR West

Interim Fly Quiet Runway Rotation Plan Re-Evaluation
Simulation Data Package [3-2]

FIGURE A-2
EXPERIMENT 551: VFR WEST AIRSPACE ROUTES

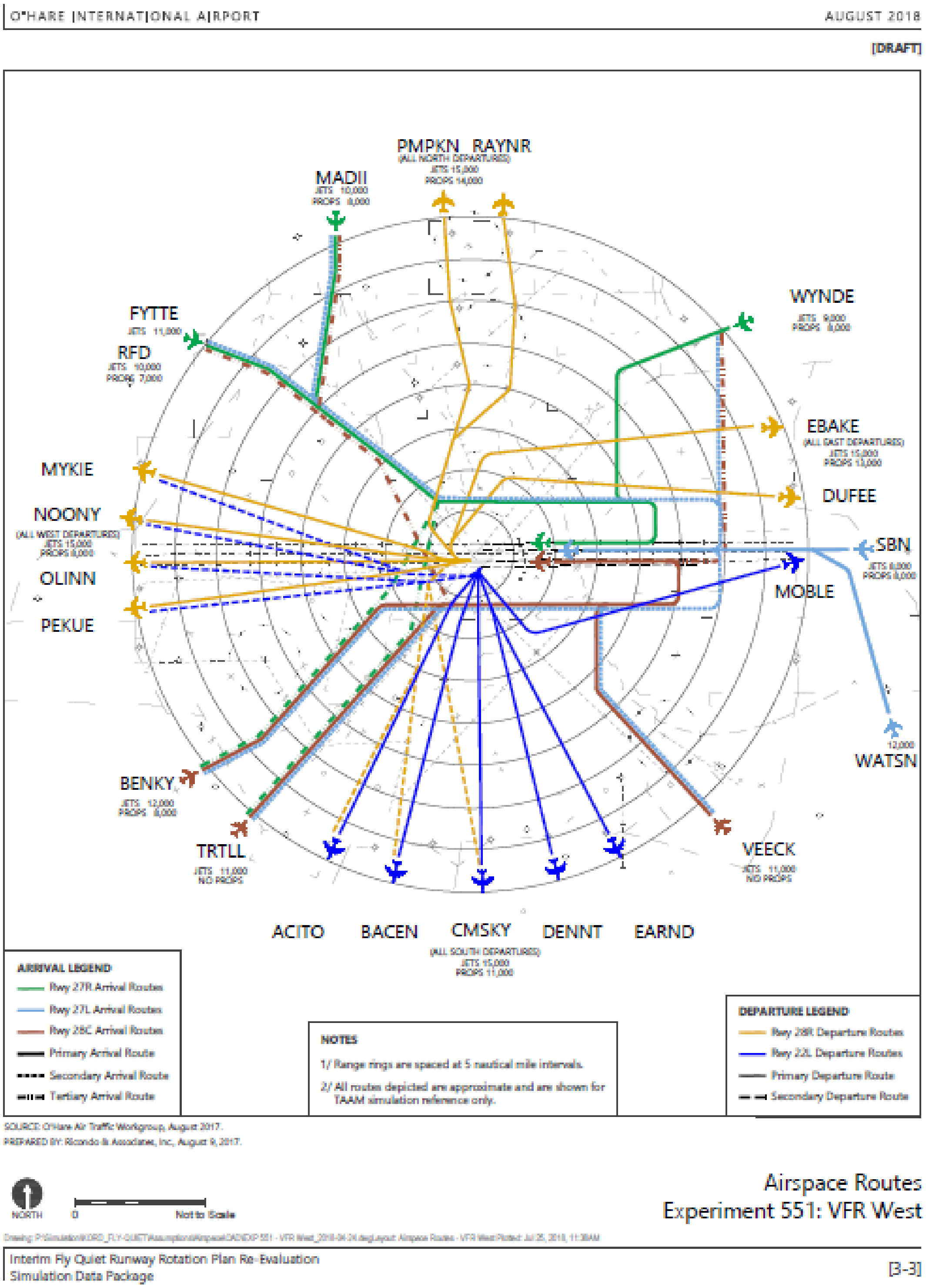


FIGURE A-3
EXPERIMENT 552: IFR WEST TAXIWAY ROUTES

O'HARE INTERNATIONAL AIRPORT AUGUST 2018

[DRAFT]

SOURCES: O'Hare International Airport, Airport Layout Plan, September 2005; Ricondo & Associates, Inc., August 2017.
PREPARED BY: Ricondo & Associates, Inc., August 2017.

NORTH 0 Not to Scale

Taxiway Routes
Experiment 552: IFR West

Interim Fly Quiet Runway Rotation Plan Re-Evaluation
Simulation Data Package

[4-2]

FIGURE A-4
EXPERIMENT 552: IFR WEST AIRSPACE ROUTES

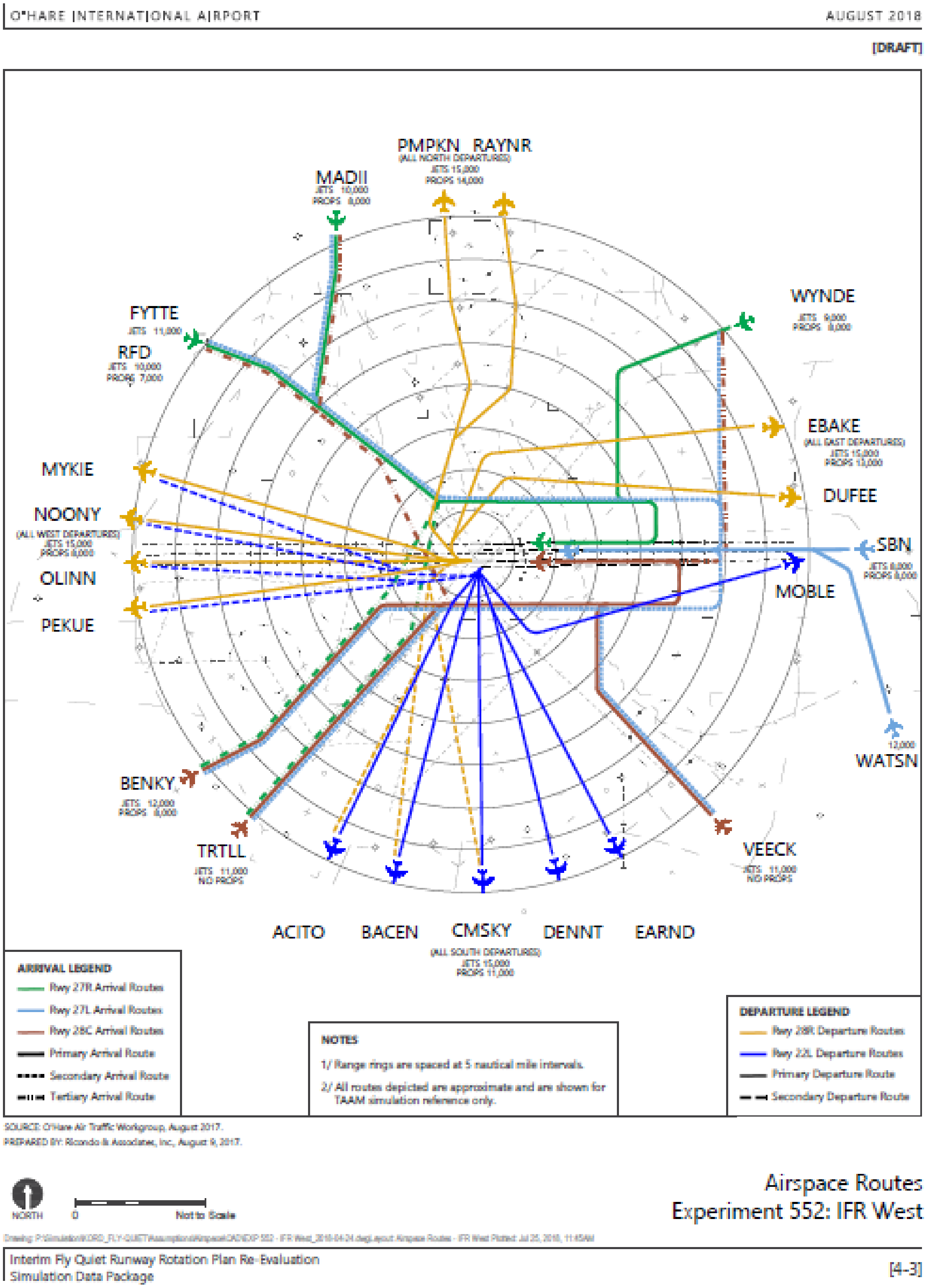
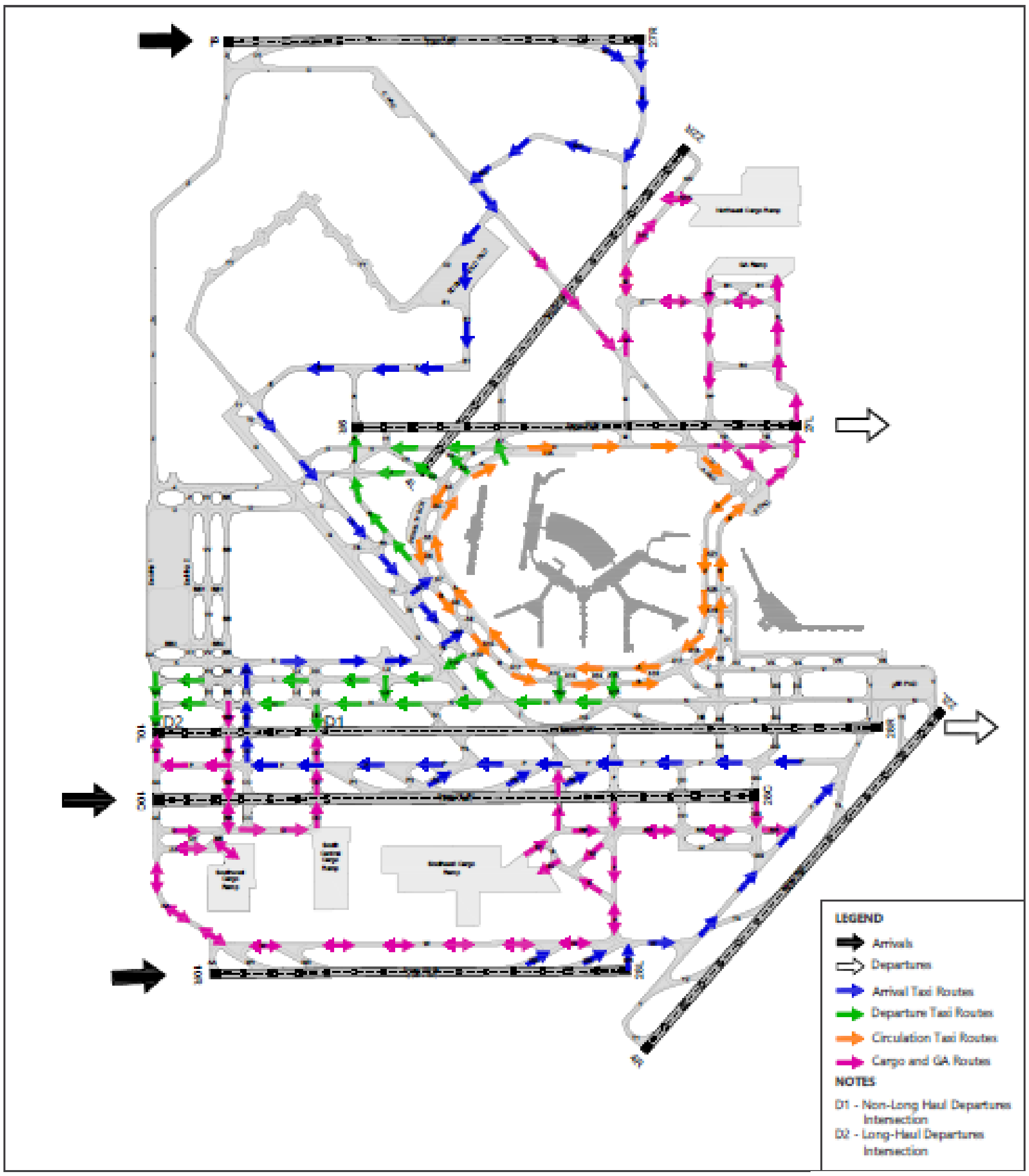


FIGURE A-5
EXPERIMENT 553: VFR EAST TAXIWAY ROUTES

O'HARE INTERNATIONAL AIRPORT AUGUST 2018

[DRAFT]



SOURCES: O'Hare International Airport, Airport Layout Plan, September 2005; Ricondo & Associates, Inc., August 2017.
PREPARED BY: Ricondo & Associates, Inc., August 2017.

NORTH 0 Not to Scale

Taxiway Flows
Experiment 553: VFR East

Interim Fly Quiet Runway Rotation Plan Re-Evaluation
Simulation Data Package [5-2]

FIGURE A-6
EXPERIMENT 553: VFR EAST AIRSPACE ROUTES

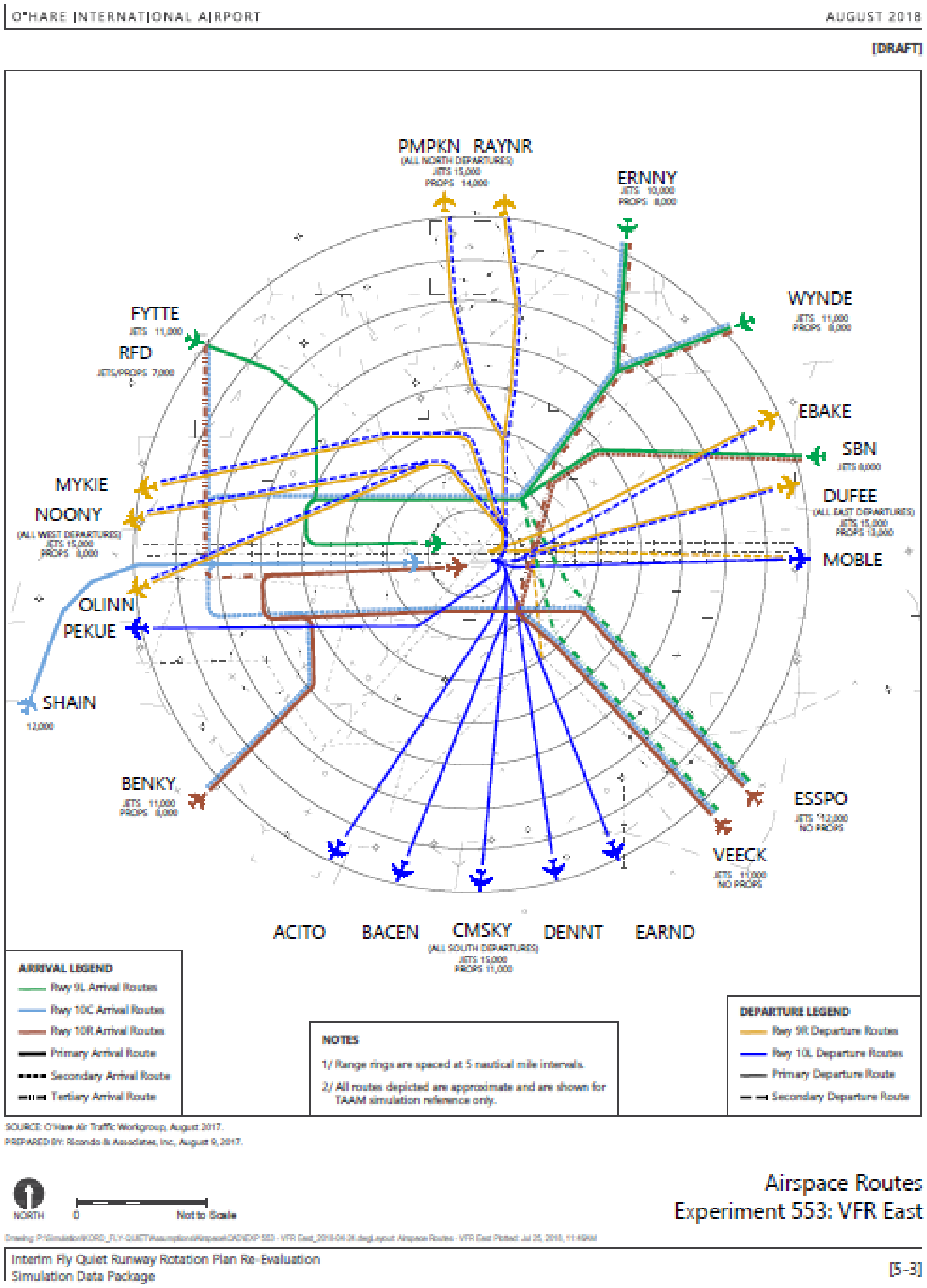
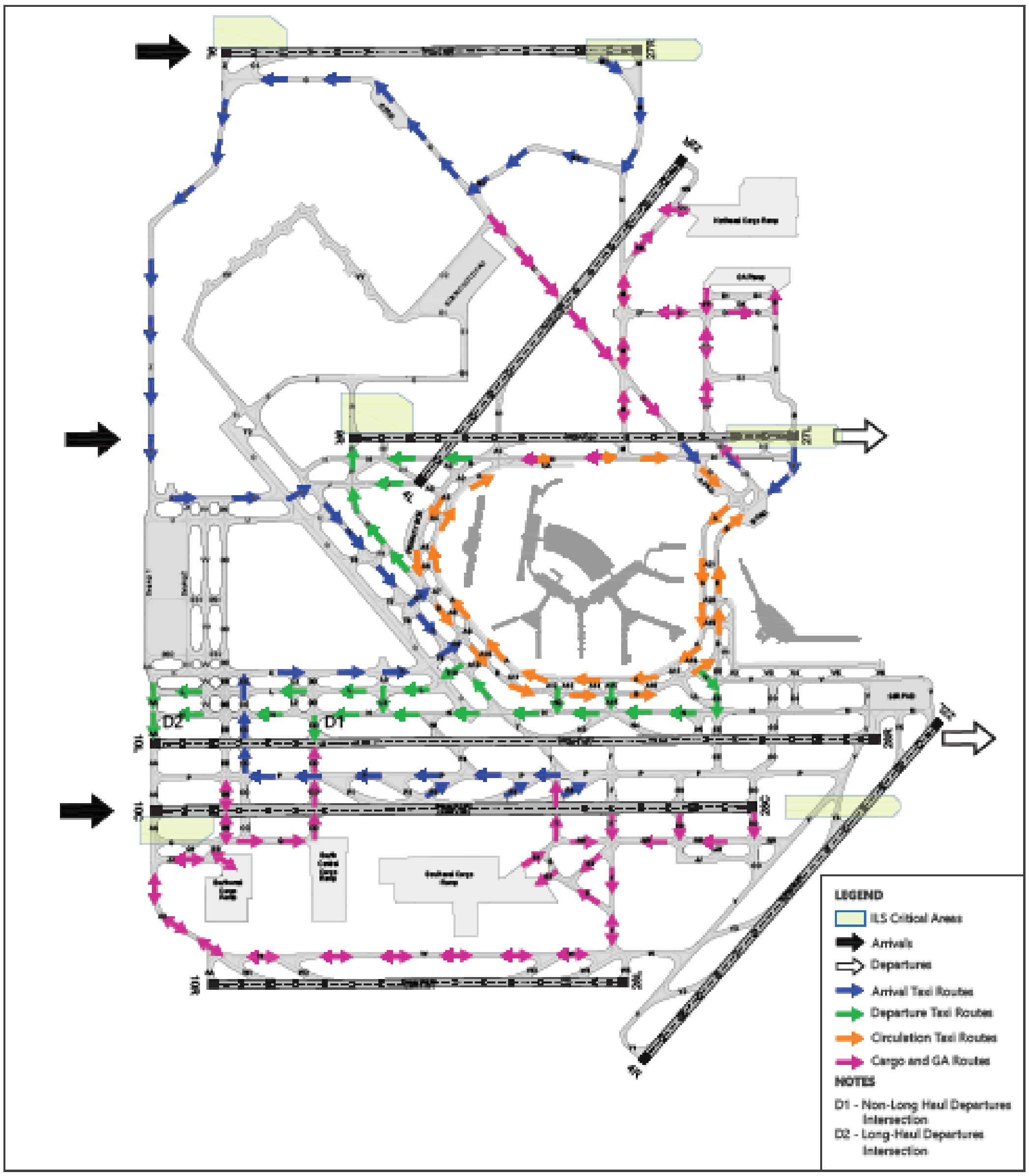


FIGURE A-7
EXPERIMENT 554: IFR EAST TAXIWAY ROUTES

O'HARE INTERNATIONAL AIRPORT AUGUST 2018

[DRAFT]



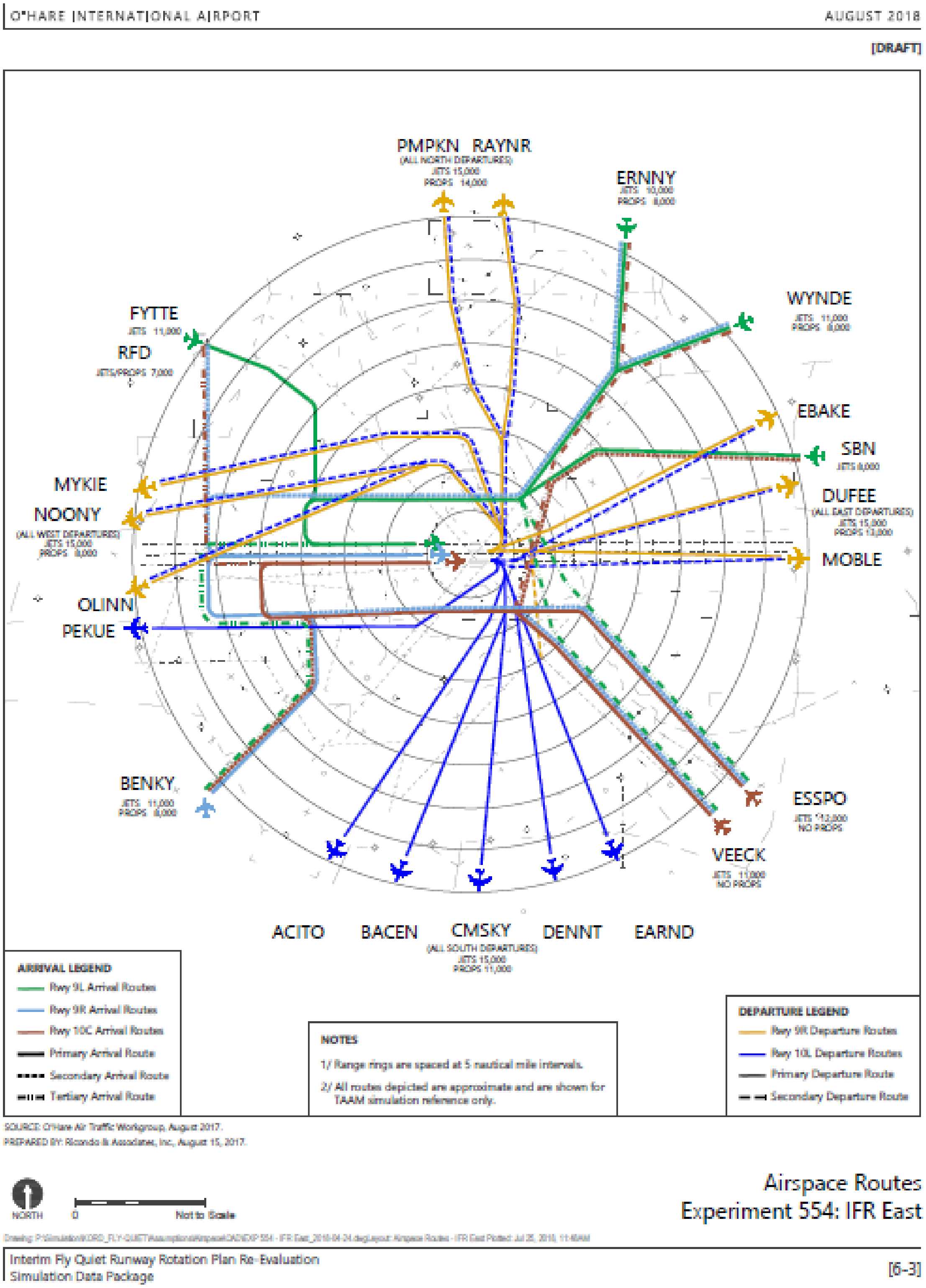
SOURCES: O'Hare International Airport, Airport Layout Plan, September 2005; Ricondo & Associates, Inc., August 2017.
PREPARED BY: Ricondo & Associates, Inc., August 2017.

NORTH 0 Not to Scale

Taxiway Flows
Experiment 554: IFR East

Interim Fly Quiet Runway Rotation Plan Re-Evaluation
Simulation Data Package [6-2]

FIGURE A-8
EXPERIMENT 554: VFR EAST AIRSPACE ROUTES



ATTACHMENT A-4

WEATHER ANALYSIS

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MEMORANDUM

Date: June 26, 2018

To: Ms. Amy Hanson
Environmental Protection Specialist
Federal Aviation Administration – Chicago Airports District Office

From: Kevin M. Markwell

Subject: O'HARE INTERIM FLY QUIET RUNWAY ROTATION PLAN RE-EVALUATION WEATHER ANALYSIS

A weather conditions analysis was performed to determine the weighting of operating configurations at Chicago O'Hare International Airport (O'Hare). This analysis was requested to support decision making processes and technical analysis for the Interim Fly Quiet (IFQ) Runway Rotation Plan Re-Evaluation.

Two weather analyses were performed. The first analysis determined the weighting of airfield operating configurations estimated to occur over a 12-month calendar year (January 1 – December 31). The second analysis determined weighting of operating configurations estimated to occur during a non-consecutive 11-month period representing the IFQ Plan anticipated to occur from November 1, 2019 – May 15, 2020, and September 16, 2020 – January 31, 2021, which reflects accommodation of planned runway reconstruction projects.

Configuration Weighting Over Entire Calendar Year

To establish weightings for the runway configurations modeled as part of the IFQ Re-Evaluation, wind and weather data from the National Centers for Environmental Information (NCEI) were utilized to determine what percentage of the year each runway use configuration could theoretically be used. Ten full years of hourly data, consisting of 87,638 total observations from January 1, 2008, to December 31, 2017, was reviewed to determine the nature, frequency, and duration of weather conditions that influence aircraft operations.

VISUAL AND INSTRUMENT METEOROLOGICAL CONDITIONS

Meteorological conditions such as cloud ceiling height and visibility affect airfield performance, in addition to wind direction and velocity. Low cloud ceiling heights and/or visibility conditions may preclude the use of some runway-operating configurations and the use of visual separation rules, which could potentially result in a loss of airfield capacity, increased travel times, and possible additional spacing between aircraft in the airspace surrounding O'Hare. The conditions for Visual and Instrument Flight Rules (VFR and IFR) operations are as follows:

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- Visual Flight Rules (VFR) includes weather conditions where cloud ceiling height is equal to or greater than 1,000 feet above ground level (AGL) and visibility is 3 statute miles or greater, and
- Instrument Flight Rules (IFR) includes weather conditions where cloud ceiling height is less than 1,000 feet AGL or visibility is less than 3 statute miles.[1]

Table 1 compares the percent of time conditions associated with VFR and IFR occurred over the 10-year period from 2008 to 2017.

Table 1: Percent Occurrence of VFR and IFR Conditions

WEATHER CONDITION	DESCRIPTION	PERCENTAGE OF OCCURRENCE
VFR	Cloud ceiling at least 1,000 feet above ground level AND visibility at least 3 statute miles	92.6%
IFR	Cloud ceiling less than 1,000 feet above ground level OR visibility less than 3 statute miles	7.4%
	TOTAL	**100.0%**

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

EVALUATION OF RUNWAY CONFIGURATION COVERAGES

Pertinent weather observations from the 10-year weather data set that includes wind velocity, wind direction, cloud ceiling height, and visibility were used to identify the percentage of occurrences associated with the runway operating configurations considered for modeling. Consistent with the O'Hare Modernization Environmental Impact Statement (OM EIS) completed in 2005, it was assumed that runways in an orientation that would most efficiently serve a particular weather condition would be available for use provided that:

- the tailwind component associated with the runway's orientation is no greater than 5 knots; and
- the crosswind component associated with the runway's orientation is no greater than 20 knots in VFR conditions and 15 knots under IFR conditions.

[1] Title 14 Code of Federal Regulations (CFR) Part 91.155, *Basic VFR Weather Minimums*.

Three runway operating configurations were considered for modeling:

- West Flow with Runway 22L: This operating configuration consisted of arrivals on Runways 27R, 27L, and 28C with departures on Runways 28R and 22L.
- West Flow without Runway 22L: This operating configuration consisted of arrivals on Runways 27R, 27L, and 28L with departures on Runways 28R and 28C.
- East Flow: This operating configuration consisted of arrivals on Runways 9L, 10C, and 10R with departures on Runways 9R and 10L.

For observations associated with calm conditions, where the wind velocity is less than three knots[2], any of the modeled runway operating configurations can be used. Furthermore, the combination of runway operating configurations and acceptable crosswind and tailwind components allows the potential use of more than one runway operating configuration for some wind velocities and directions exceeding calm conditions. For example, all three runway operating configurations considered for modelling are available for a weather observation with a wind velocity of four knots from a 190-degree heading. For purposes of the analysis, calm and multiple runway operating configuration weather observations are collectively referred to as "unassigned."

Table 2 summarizes the occurrence of calm weather conditions, observations that may utilize only one of the runway operating configurations considered for modeling, and weather observations that can use multiple runway operating configurations under VFR and IFR conditions. Wind and weather conditions that could not be accommodated in East or West Flow operating configurations were grouped into a single "unaccounted" category which totaled 0.7%. This group largely included conditions with severe north or south winds.

For the purpose of weighting, values associated with nonmodeled operating configurations were allocated to the most similar modeled runway operating configuration. VFR observations were assigned to the modeled VFR operating configurations. Likewise, IFR observations were assigned to modeled IFR operating configurations. The percentage of unaccounted operating configurations for both VFR and IFR were allocated to the modeled operating configurations with the worst travel time performance, VFR East Flow and IFR East Flow. **Table 3** depicts the allocation of runway operating configurations after values associated with nonmodeled operating configurations were assigned.

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[2] Federal Aviation Administration, *FAA Order JO 7110.65X, Air Traffic Control*, September 12, 2017.

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Table 2: Percent Occurrence of Weather Conditions

RUNWAY OPERATING CONFIGURATION	PERCENTAGE OF OCCURRENCE		
	VFR	IFR	TOTAL
West Flow with Runway 22L	27.9%	1.1%	29.0%
West Flow without Runway 22L[1/]	0.3%	0.1%	0.4%
East Flow	14.0%	1.9%	16.0%
Calm	7.3%	0.4%	7.7%
Multiple Configurations (East Flow or West Flow with Runway 22L)	37.6%	2.7%	40.3%
Multiple Configurations (East Flow or West Flow without Runway 22L)	5.0%	0.9%	6.0%
Unaccounted	0.4%	0.3%	0.7%
TOTAL[2/]	**92.6%**	**7.4%**	**100.0%**

NOTES:

1/ Preference was given to the West Flow with Runway 22L operating configuration when either West Flow operating configuration was usable.

2/ Totals may not sum due to rounding.

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

Table 3: Allocation of Non-Modeled Runway Configurations

RUNWAY OPERATING CONFIGURATION	PERCENTAGE OF OCCURRENCE		
	VFR	IFR	TOTAL
West Flow with Runway 22L	28.2%	1.2%	29.4%
East Flow	14.5%	2.2%	16.7%
Calm	7.3%	0.4%	7.7%
Multiple Configurations (East Flow or West Flow with Runway 22L)	42.7%	3.6%	46.3%
TOTAL[1/]	**92.6%**	**7.4%**	**100.0%**

NOTE:

1/ Totals may not sum due to rounding.

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

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In the 2005 OM EIS analysis all unassigned weather observations were allocated to the West Flow operating configuration because this configuration was designated by the Air Traffic Workgroup as preferred. However, the commissioning of Runway 10R-28L in October 2015 more closely aligned the throughput capacity of East and West Flows and lessened the preference to utilize West Flow when East or West flow was possible. As a result, two methodologies were developed to assess how unassigned weather observations were allocated:

- Weighted Allocation: Unassigned observations were allocated based on the percent occurrence of the modeled runway operating configurations.
- Chronological Allocation: Unassigned observations were allocated chronologically based on the preceding and/or succeeding runway operating configuration in use.

Weighted Allocation Methodology

Allocation of the unassigned weather observations based on the occurrence of the modeled runway operating configurations required normalization of the two modeled configurations (**Table 4**).

Table 4: Normalization of Modeled Runway Operating Configurations

	VFR		IFR	
RUNWAY OPERATING CONFIGURATION	**OCCURRENCE**	**NORMALIZED**	**OCCURRENCE**	**NORMALIZED**
West Flow with Runway 22L	28.2%	66.1%	1.2%	34.9%
East Flow	14.5%	33.9%	2.2%	65.1%
TOTAL	**42.7%**	**100.0%**	**3.4%**	**100.0%**

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

The normalized occurrence of the modeled runway operating configurations was then used to allocate the unassigned weather observations. **Table 5** depicts the weighting of the modeled runway operating configurations after the use of weighted allocation.

Table 5: Weighting of Modeled Runway Operating Configurations – Weighted Allocation

	PERCENTAGE OF OCCURRENCE		
RUNWAY OPERATING CONFIGURATION	**VFR**	**IFR**	**TOTAL**
West Flow with Runway 22L	61.2%	2.6%	63.8%
East Flow	31.4%	4.8%	36.2%
TOTAL	**92.6%**	**7.4%**	**100.0%**

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

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Chronological Allocation Methodology

Allocation of the unassigned weather observations in chronological order took into consideration the runway operating configuration in use prior to or after the unassigned weather condition. This methodology was intended to account for the preference provided by Air Traffic Control to remain in a runway operating configuration until the weather conditions required a change to a different operating configuration.

The hourly wind and weather data was analyzed and two techniques were used to assign one of the modeled runway operating configurations depending on the time the unassigned weather observation was recorded:

- Typical: Any unassigned weather observation between 05:00 and 00:59 was allocated to the previous hour's assigned runway operating configuration. For instance, if the 10:00 weather observation required the use of East Flow, but the 11:00 weather observation was unassigned, East Flow was allocated.
- Low Demand: Any unassigned weather observation between 01:00 and 04:59 was allocated to the first modeled runway operating configuration in use after 05:00 which was assumed to be anticipated. For example, if the weather observations from 02:00 to 04:00 were unassigned, then the 02:00 to 04:00 weather observations will be allocated to the configuration in use at 05:00. This technique was developed to replicate the preference to change configurations during periods of low traffic rather than during a busy period.

Table 6 depicts the weighting of the modeled runway operating configurations after the use of chronological allocation.

Table 6: Weighting of Modeled Runway Operating Configurations – Chronological Allocation

	PERCENTAGE OF OCCURRENCE		
RUNWAY OPERATING CONFIGURATION	VFR	IFR	TOTAL
West Flow with Runway 22L	55.6%	2.9%	58.5%
East Flow	37.0%	4.5%	41.5%
TOTAL	**92.6%**	**7.4%**	**100.0%**

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

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COMPARISON TO HITSTORICAL RUNWAY CONFIGURATION USAGE

To assess the validity of the two methods of allocating unassigned weather observations, each method was compared to historical runway operating configuration utilization reported in the FAA's Aviation System Performance Metrics (ASPM) database (**Table 7**). The data comparison was limited to the 2016 and 2017 calendar years to account for the commissioning of Runway 10R-28L in October 2015 and the historical configuration usage was normalized to include only the modeled runway operating configurations.

Table 7: Comparison of 2016 and 2017 Runway Operating Configuration Utilization

RUNWAY OPERATING CONFIGURATION	2016 AND 2017 OPERATING CONFIGURATION USAGE		
	ASPM	WEIGHTED	CHRONOLOGICAL
West Flow	**62.1%**	**65.6%**	**59.3%**
VFR	58.3%	63.2%	56.6%
IFR	3.8%	2.4%	2.8%
East Flow	**37.9%**	**34.4%**	**40.7%**
VFR	33.3%	29.6%	36.2%
IFR	4.6%	4.8%	4.4%

SOURCES: Federal Aviation Administration, Aviation System Performance Metrics (ASPM), June 2018 (data); National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

RECOMMENDED METHOD FOR WEIGHTING OF CONFIGURATIONS

The City of Chicago Department of Aviation (CDA) and the FAA agreed during the August 2017 IFQ Air Traffic Workgroup meetings that the chronological method be used for the allocation of unassigned weather observations. **Table 8** shows the calendar year weightings for the modeled runway operating configurations using the chronological weighting assumptions previously described.

Table 8: Calendar Year Weighting for Modeled Configurations

TAAM EXPERIMENT NUMBERS	RUNWAY CONFIGURATION	ESTIMATED PERCENTAGE OF OCCURRENCE
551	VFR West	55.6%
552	IFR West	2.9%
553	VFR East	37.0%
554	IFR East	4.5%
	TOTAL	**100.0%**

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

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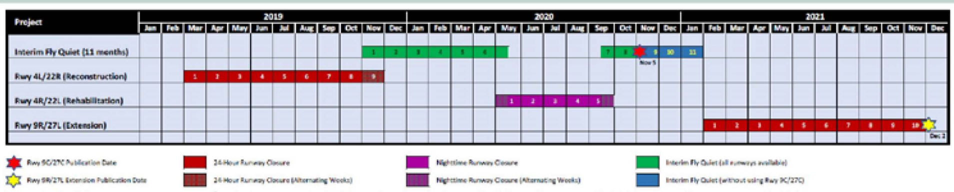
Configuration Weighting to Accommodate Proposed Runway Reconstruction Construction Schedules

As part of ongoing capital improvement program efforts at O'Hare, the CDA notified the FAA that it intends to perform reconstruction of Runway 4L-22R and a rehabilitation of Runway 4R-22L prior to the commissioning of Runway 9C-27C. Therefore, the IFQ modeling period must be adjusted for the construction schedule. The CDA, FAA, and representatives of airlines operating at O'Hare agreed to a schedule (**Exhibit 1**) that includes 11 months of runway rotation for IFQ modeling purposes between November 1, 2019, and January 31, 2021, and accommodates planned runway reconstruction and rehabilitation.

Exhibit 1: Interim Fly Quiet Modeling and Runway Rehabilitation Schedule



SOURCES: Chicago Department of Aviation, March 2018; Federal Aviation Administration, March 2018; Ricondo, Inc., March 2018.

As detailed in Exhibit 1, the IFQ modeling period will consist of two intervals over a 15-month span. The two intervals are:

- November 1, 2019 – May 15, 2020, represents the period starting November 1, 2019, when the runway rotation plan is anticipated to begin following substantial completion of the reconstruction of Runway 4L-22R, and May 15, 2020, when the runway rotation plan is anticipated to be interrupted due to planned rehabilitation of Runway 4R-22L.
- September 16, 2020 – January 31, 2021, represents the period starting September 16, 2020, when the runway rotation plan is anticipated to resume following the rehabilitation of Runway 4R-22L, and January 31, 2021, when Runway 9R-27L is expected to close to construct the runway extension. This would reflect the end of a period of 11 non-consecutive months of largely uninterrupted runway rotation for IFQ modeling purposes. Although Runway 9C-27C is anticipated to be commissioned in November of 2020, it will not be included in the runway rotation plan.

Because the periods when the full runway rotation plan is anticipated to be in effect are not evenly distributed throughout the calendar year, an additional analysis was conducted using the chronological runway assignments to determine the occurrence of the modeled runway operating configurations outside

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Ms. Amy Hanson – Federal Aviation Administration
June 26, 2018
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the planned runway closures. The methodology for calculating the IFQ configuration weighting consisted of two steps:

- The chronological runway configuration assignments were parsed into monthly or half-month increments that correspond to the dates the runway rotation plan is anticipated to be in effect
- The chronological runway configuration assignments were summed based on the number of times the month or half-month increment will occur during the dates the runway rotation plan is anticipated to be in effect

Table 9 details the occurrence of the month or half-month increments within the IFQ modeling period and the corresponding allocation of chronological runway operating assignments.

Table 9: Occurrence of Modeled Configurations During IFQ

		OBSERVATIONS				PERCENT OCCURENCE			
TIME PERIOD	TIME PERIOD OCCURRENCE DURING IFQ	VFR WEST	IFR WEST	VFR EAST	IFR EAST	VFR WEST	IFR WEST	VFR EAST	IFR EAST
January	2	5,393	674	969	399	72.5%	9.1%	13.0%	5.4%
February	1	4,486	302	1,420	583	66.1%	4.4%	20.9%	8.6%
March	1	3,273	159	3,465	538	44.0%	2.1%	46.6%	7.2%
April	1	2,940	121	3,639	499	40.8%	1.7%	50.5%	6.9%
May 1st – 15th	1	1,617	48	1,650	286	44.9%	1.3%	45.8%	7.9%
September 16th – 30th	1	1,496	27	2,012	64	41.6%	0.8%	55.9%	1.8%
October	1	4,426	158	2,663	191	59.5%	2.1%	35.8%	2.6%
November	2	4,798	199	1,979	221	66.7%	2.8%	27.5%	3.1%
December	2	4,874	575	1,395	591	65.6%	7.7%	18.8%	7.9%
	Total	*48,368*	*3,711*	*23,535*	*4,583*	*60.3%*	*4.6%*	*29.4%*	*5.7%*

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

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Table 10 shows the weightings for the modeled runway operating configurations within the IFQ modeling period.

Table 10: IFQ Weighting for Modeled Configurations

TAAM EXPERIMENT NUMBER	RUNWAY CONFIGURATION	IFW WEIGHTING
551	VFR WEST	60.3%
552	IFR WEST	4.6%
553	VFR EAST	29.4%
554	IFR EAST	5.7%
	TOTAL	**100.0%**

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

Table 11 compares the calendar year (Table 8) and IFQ weighting (Table 10).

Table 11: Comparison of Calendar Year and Interim Fly Quiet Weighting of Modeled Configurations

TAAM EXPERIMENT NUMBER	RUNWAY CONFIGURATION	CALENDAR YEAR WEIGHTING	IFQ WEIGHTING	DIFFERENCE
551	VFR West	55.6%	60.3%	+4.7%
552	IFR West	2.9%	4.6%	+1.7%
553	VFR East	37.0%	29.4%	-7.6%
554	IFR East	4.5%	5.7%	+1.2%
	TOTAL	**100.0%**	**100.0%**	

SOURCES: National Centers for Environmental Information, January 1, 2008 through December 31, 2017 (data); Ricondo, Inc., June 2018 (analysis).

cc:
11-01-0735 0601-12
Aaron Frame – Chicago Department of Aviation
Joshua Jones – Ricondo
Jeffrey Jackson – Landrum & Brown

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ATTACHMENT A-5

METHODOLOGY FOR NIGHTTIME OPERATIONS FOR THE PROPOSED INTERIM FLY QUIET

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O'HARE MODERNIZATION PROGRAM EIS RE-EVALUATION FOR THE INTERIM USE OF THE FLY QUIET RUNWAY ROTATION PLAN

Methodology for Nighttime Operations for the Proposed Interim Action

DRAFT

October 30, 2018
Prepared by Landrum & Brown

CHICAGO DEPARTMENT OF AVIATION

Table of Contents

1. Introduction

This document summarizes the methodology and assumptions used to develop runway assignments and associated taxi time for each Proposed Action Fly Quiet operation in support of the O'Hare Modernization Program Environmental Impact Statement Re-Evaluation for the Interim Use of the Fly Quiet Runway Rotation Plan.

2. Background

Based on the recommendation of the O'Hare Noise Compatibility Commission (ONCC), the Chicago Department of Aviation (CDA) is submitting a proposal for an Interim Fly Quiet Runway Rotation Plan (IFQ) to the Federal Aviation Administration (FAA) for environmental review. The requested implementation period is the months between November 2019 through the end of January 2021 without construction on Runway 4L/22R and Runway 4R/22L. The CDA conducted three Fly Quiet Runway Rotation Tests, each of which was approved by the FAA. The purpose of the tests was to collect data on specific Fly Quiet runway configurations to provide near-term noise relief and reduce noise impacts to the highest impacted communities surrounding Chicago O'Hare International Airport (O'Hare).

1. Test 1 was conducted from the night of July 6, 2016, through the morning of December 25, 2016, and its purpose was to test the possibility of a weekly runway rotation and the capabilities of the different configurations.
2. Test 2 was administered from the night of April 30, 2017, through the morning of July 23, 2017, and its purpose was to test the capabilities of the different configurations in response to FAA comments on Test 1, as well as test new configurations that were not included in Test 1.
3. Test 3 was in place from the night of July 23, 2017, through the morning of October 15, 2017, and its purpose was to test a condition that could be in place during the period of time between Runway 15/33 decommissioning until Runway 9C/27C commissioning.

3. IFQ Operations

The FAA considers nighttime hours as 10:00:00 p.m. - 6:59:59 a.m. It is the CDA's goal for the Fly Quiet Program to occur during the entire nine-hour nighttime period of 10:00 p.m. to 7:00 a.m., however due to operational demand by the airlines and traveling public, Fly Quiet is typically limited to a period less than nine hours. Fly Quiet Mode, the period of time in Fly Quiet, starts each night on or after 10:00 p.m., once demand allows for two departure runways and one arrival runway and allows for the preferential flight tracks as outlined in the CDA's Fly Quiet Manual. Demand for the majority of the night allows for one arrival runway and one departure runway. Once demand increases in the morning where additional runways are needed and preferential flight tracks can no longer be utilized, Fly Quiet Mode stops.

Ideally, all operations occur on the designated runways for each IFQ configuration while in Fly Quiet Mode. Some operations occur on other runways due to aircraft performance requirements, pilot preference, or a designated runway is closed due to general maintenance or a runway safety inspection. Each runway at O'Hare is required to be closed throughout the night for approximately one hour in order to perform a proper runway safety inspection for FAR Part 139. During this time, a configuration will stop and typically resumes after the safety inspection is complete. In addition, there are typically periods of time immediately after Fly Quiet starts and immediately before Fly Quiet stops that the designated runways are not utilized or only partially utilized for many reasons.[1]

3.1 Runway Assignments

The process of assigning runways to operations in IFQ consisted of three key steps:

- Step 1: **Collect Test Data**
- Step 2: **Annualize IFQ Configurations**
- Step 3: **Apply Configurations to Schedule**

3.1.1 Collect Sample Data

This step involved collecting all operational flight data for each IFQ configuration that occurred in all tests. For each IFQ configuration, the sample data was averaged for each condition for only the nights that specific condition occurred. Average data for each condition will be compiled for the following data:

1. Fly Quiet Start Time
2. Fly Quiet Stop Time
3. Operations by aircraft type and runway assignment

Since the duration of nightly runway safety inspections is specific to each runway, the above data will encompass the period of time for each runway closures associated with safety inspections. This data also reflected special runway requests. Special runway requests typically occur for wide-body aircraft that request a specific longer runway rather than the runway designated for Fly Quiet.

The CDA collected test data for all IFQ configurations using their Airport Noise Management System (ANMS). The CDA conducted the following three Fly Quiet Runway Rotation Tests:

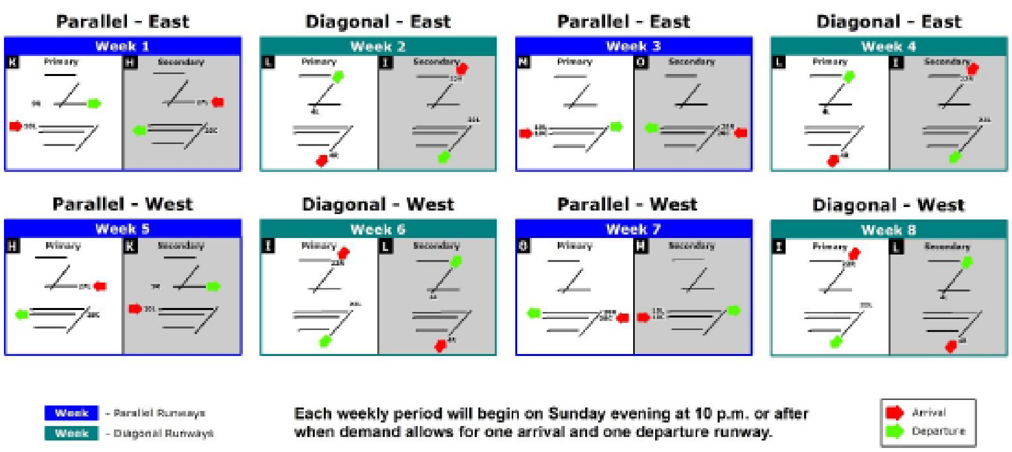
Test 1: July 6, 2016 to December 25, 2016 (25 Weeks)
Test 2: April 30, 2017 to July 23, 2017 (12 Weeks)
Test 3: July 23, 2017 to October 15, 2017 (12 Weeks)

[1] On any given night, Test configurations may not have been allowed due to occurrences including, but not limited to, runway safety closures, thunderstorms, snow removal, FAA flight checks, construction, rubber removal, runway requests, and similar.

Data collected during these three tests was utilized to develop annualized conditions for use on the Proposed Interim Fly Quiet in **Figure 1**. The seven relevant conditions studied are:

a. Configuration H: This configuration is a West Flow configuration and utilizes runway 28C for departures and 27L for arrivals. This configuration occurred in Test 1, 2, and 3.
b. Configuration I: This configuration is a West Flow configuration and utilizes runway 22L for departures and 22R for arrivals. This configuration occurred in Test 1, 2, and 3.
c. Configuration K: This configuration is an East Flow configuration and utilizes runway 9R for departures and 10L for arrivals. This configuration occurred in Test 2 and 3.
d. Configuration L: This configuration is an East Flow configuration and utilizes runway 4L for departures and 4R for arrivals. This configuration occurred in Test 2 and 3.
e. Configuration M: This configuration is an East Flow configuration and utilizes runway 10L for departures and 10C for arrivals. This configuration occurred in Test 2 and 3.
f. Configuration O: This configuration is a West Flow configuration and utilizes runway 28R for departures and 28C for arrivals. This configuration occurred in Test 2 and 3.
g. Non Fly Quiet Condition: This is the period of nighttime operations that are not operating in any current or proposed Fly Quiet condition. These operations operate in a similar manner as typical daytime operations. Non Fly Quiet samples will be obtained from the nights when Fly Quiet was not occurring and for the periods of time during the night when Fly Quiet was not occurring.
h.

Figure 1: Proposed Interim Fly Quiet



3.1.2 Annualize IFQ Configurations

This step involved annualizing each IFQ configuration based on the flight schedule and annual conditions since tests did not occur in every month of the year. Historical wind conditions were analyzed from Total Airspace and Airport Modeller (TAAM) annualization and were applied to each IFQ configuration: Annualization for each IFQ configuration was placed in an IFQ Operations Model along with the original nighttime flight schedule.

3.1.3 Apply IFQ Configurations to Schedule

Based on the 48-week period of IFQ, a weekly IFQ schedule was developed based on the Proposed Action. Each new week began on Sunday evening when demand allows for one designated arrival runway and one designated departure runway. The proposed IFQ consists of an eight week rotation starting with four weeks of east flow alternating weeks between parallel and diagonal operations and finishing with four weeks of west flow alternating weeks between parallel and diagonal operations. The schedule was carried out until construction or maintenance dictated the closure of a runway, which caused the stop of IFQ. Once maintenance and construction ended, IFQ began again on the following Sunday with the beginning of the IFQ schedule. A total of 48 weeks was included in the Proposed Action. The percentage of occurrences by each IFQ configuration was applied to the operations dataset in the IFQ Operations Model for Fly Quiet. All operations for daytime and nighttime not in Fly Quiet Mode remains the same as No Action.

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Figure 2: IFQ Weekly Schedule

2019								CONFIG	WEEK
MONTH	Su	Mo	Tu	We	Th	Fr	Sa		
November	27	28	29	30	31	01	02		
	03	04	05	06	07	08	09	K	1
	10	11	12	13	14	15	16	L	2
	17	18	19	20	21	22	23	M	3
	24	25	26	27	28	29	30	L	4
December	01	02	03	04	05	06	07	H	5
	08	09	10	11	12	13	14	I	6
	15	16	17	18	19	20	21	O	7
	22	23	24	25	26	27	28	I	8
January	29	30	31	01	02	03	04	K	9

2020								CONFIG	WEEK
MONTH	Su	Mo	Tu	We	Th	Fr	Sa		
January	29	30	31	01	02	03	04	*included in 2019*	
	05	06	07	08	09	10	11	L	10
	12	13	14	15	16	17	18	M	11
	19	20	21	22	23	24	25	L	12
February	26	27	28	29	30	31	01	H	13
	02	03	04	05	06	07	08	I	14
	09	10	11	12	13	14	15	O	15
	16	17	18	19	20	21	22	I	16
	23	24	25	26	27	28	29	K	17
March	01	02	03	04	05	06	07	L	18
	08	09	10	11	12	13	14	M	19
	15	16	17	18	19	20	21	L	20
	22	23	24	25	26	27	28	H	21
April	29	30	31	01	02	03	04	I	22
	05	06	07	08	09	10	11	O	23
	12	13	14	15	16	17	18	I	24
	19	20	21	22	23	24	25	K	25
May	26	27	28	29	30	01	02	L	26
	03	04	05	06	07	08	09	M	27
	10	11	12	13	14	15	16	L	28
	17	18	19	20	21	22	23		
	24	25	26	27	28	29	30		
June	31	01	02	03	04	05	06		
	07	08	09	10	11	12	13		
	14	15	16	17	18	19	20		
	21	22	23	24	25	26	27		
July	28	29	30	01	02	03	04		
	05	06	07	08	09	10	11		
	12	13	14	15	16	17	18	Runway 4R/22L Rehabilitation	
	19	20	21	22	23	24	25		
August	26	27	28	29	30	31	01		
	02	03	04	05	06	07	08		
	09	10	11	12	13	14	15		
	16	17	18	19	20	21	22		
	23	24	25	26	27	28	29		
September	30	31	01	02	03	04	05		
	06	07	08	09	10	11	12		
	13	14	15	16	17	18	19	K	29
	20	21	22	23	24	25	26	L	30
October	27	28	29	30	01	02	03	M	31
	04	05	06	07	08	09	10	L	32
	11	12	13	14	15	16	17	H	33
	18	19	20	21	22	23	24	I	34
	25	26	27	28	29	30	31	O	35
November	01	02	03	04	05	06	07	I	36
	08	09	10	11	12	13	14	K	37
	15	16	17	18	19	20	21	L	38
	22	23	24	25	26	27	28	M	39
December	29	30	01	02	03	04	05	L	40
	06	07	08	09	10	11	12	H	41
	13	14	15	16	17	18	19	I	42
	20	21	22	23	24	25	26	O	43
January	27	28	29	30	31	01	02	I	44

2021								CONFIG	WEEK
MONTH	Su	Mo	Tu	We	Th	Fr	Sa		
January	27	28	29	30	31	01	02	*included in 2020*	
	03	04	05	06	07	08	09	K	45
	10	11	12	13	14	15	16	L	46
	17	18	19	20	21	22	23	M	47
	24	25	26	27	28	29	30	L	48

3.1.4 Proposed IFQ Results

Table 1 depicts the Fly Quiet Mode Start and Stop times that were based on the data collected in the tests and was used for IFQ development purposes:

Table 1: Configuration Start and Stop Time

Fly Quiet Mode		
Configuration	Start Time	Stop Time
K	22:28 p.m.	5:45 a.m.
L	22:46 p.m.	5:44 a.m.
M	22:28 p.m.	5:45 a.m.
H	22:28 p.m.	5:45 a.m.
I	22:38 p.m.	5:44 a.m.
O	22:28 p.m.	5:45 a.m.

Based on the Schedule in **Figure 2**, the occurrences and weighting for each configuration for the IFQ period is depicted in **Table 2**.

Table 2: Configuration Weighting

IFQ CONFIGURATIONS			
Flow	Configuration	Occurrences	Weighting
East Flow	K	7	15%
East Flow	L	14	29%
East Flow	M	7	15%
West Flow	H	5	10%
West Flow	I	10	21%
West Flow	O	5	10%
Total		**48**	**100%**

Based on the test data for each configuration and the above occurrences and weighting, the runway utilization was developed. The nighttime runway utilization No Action and Proposed Action are depicted in Table 3.

Table 3: Nighttime Runway Utilization for No Action and Proposed Action

Runway	Arrivals		Departures	
	No Action	Proposed Action	No Action	Proposed Action
9L	6.3%	6.3%	--	--
9R	1.1%	0.3%	22.2%	16.3%
10L	18.0%	7.1%	14.1%	15.7%
10C	9.4%	16.1%	--	1.2%
10R	0.6%	0.6%	--	--
27L	41.4%	22.3%	--	--
27R	9.2%	9.2%	--	--
28C	8.2%	19.8%	--	5.6%
28R	5.7%	2.6%	48.9%	37.9%
22L	--	--	14.8%	20.2%
22R	--	10.6%	--	--
4L	--	--	--	3.0%
4R	--	5.0%	--	--
Total	**100%**	**100%**	**100%**	**100%**

Note: Does not include intersection departure data.

3.2 Taxi-Time Assignments

The process of determining taxi time assignments for each of the operations in this dataset consisted of three key steps:

- Step 1: **Measure taxi distances** between gates and runways
- Step 2: **Convert taxi distances to taxi times** and create a database of the unimpeded taxi time between each gate and runway
- Step 3: **Determine the taxi time assignment** for each aircraft operation in the dataset. Refine taxi time assignment for departures by adding corresponding push-back time based on the aircraft type.

3.2.1 Measure Taxi Distances

This step involved calculation of taxi distances between gates at the terminal and the north and south cargo ramps for operations during Fly Quiet.

To simplify the calculation process, each taxi distance was split into two segments:

1. The *distance from each gate to the nearest hand-off point*. A hand-off point is the transfer point between the non-movement (under ramp control) and movement (under ATC ground control) areas on the airfield. See **Figure 3** for a depiction of the hand-off points that were used in this analysis.
2. The *distance from each hand-off point to every runway exit (for arrivals) and runway end or intersection (for departures)*. In order to measure taxi-in distances, FAA-approved taxi flows (see **Figures 4-6**) were used to map the route an arrival would take from each runway exit to each hand-off point. Similarly, these taxi flows were also used to determine the taxi-out routes taken by departures from each hand-off point to each runway's departure end.

The total taxi distance for each operation in the nighttime dataset (between the operation's gate assignment and runway assignment) was the sum of the two segments listed above. ESRI ArcGIS (a geographic information system software used to create and analyze geographic data) was used to map and measure all the taxi distances.

In order to reflect real-world operation, the movement of aircraft within the B-C channel was assumed to be south-to-north in east flow configuration and north-to-south in west flow configuration. Thus, in east flow, all arrivals enter the B-C channel from the south (hand-off point BC2) and all departures exit the channel from the north (hand-off point BC1). In west flow, all arrivals enter the B-C channel from the north (hand-off point BC1) and all departures exit the channel from the south (hand-off point BC2).

Figure 3: Hand-Off Points used in Nighttime Taxi Time Analysis

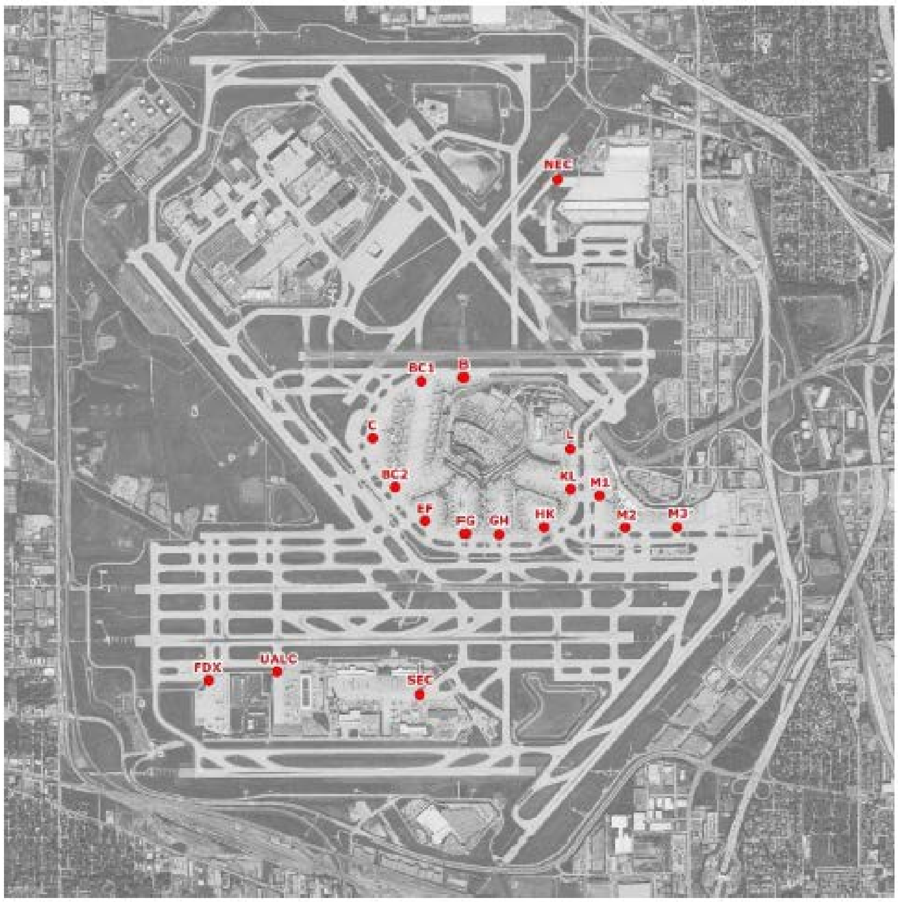

Figure 4: Taxiway Routes – VFR West Flow

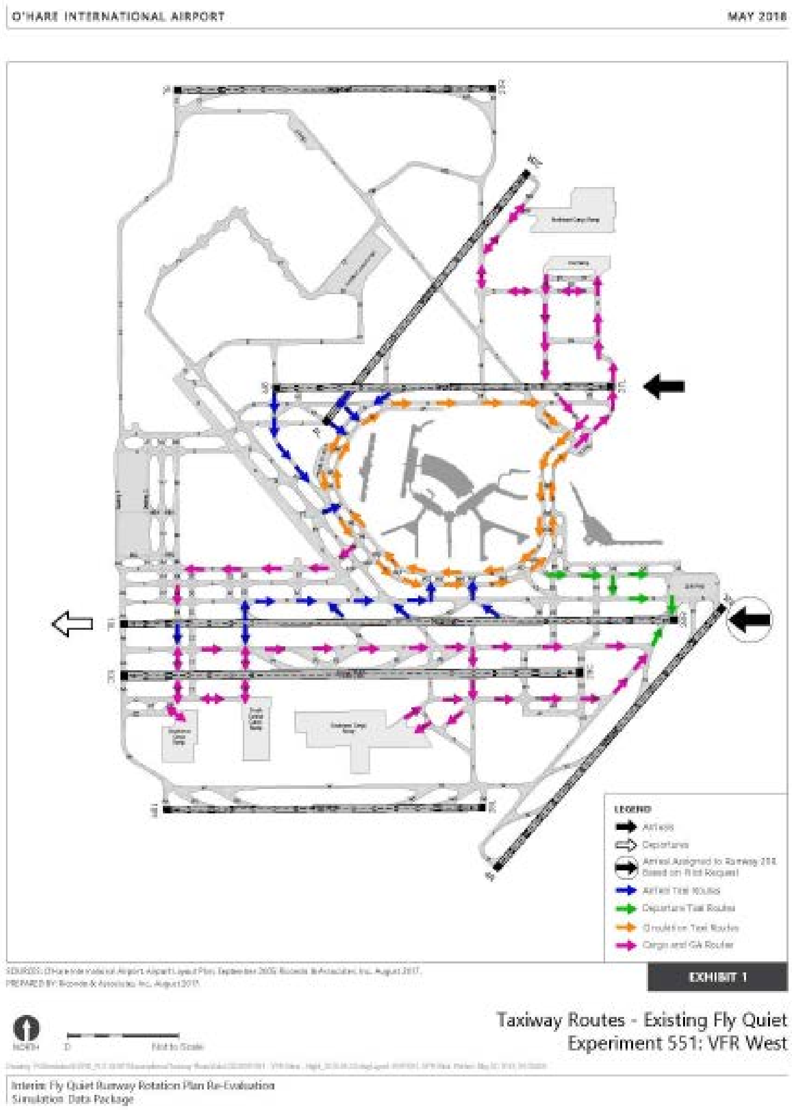

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Figure 5: Taxiway Routes – VFR East Flow

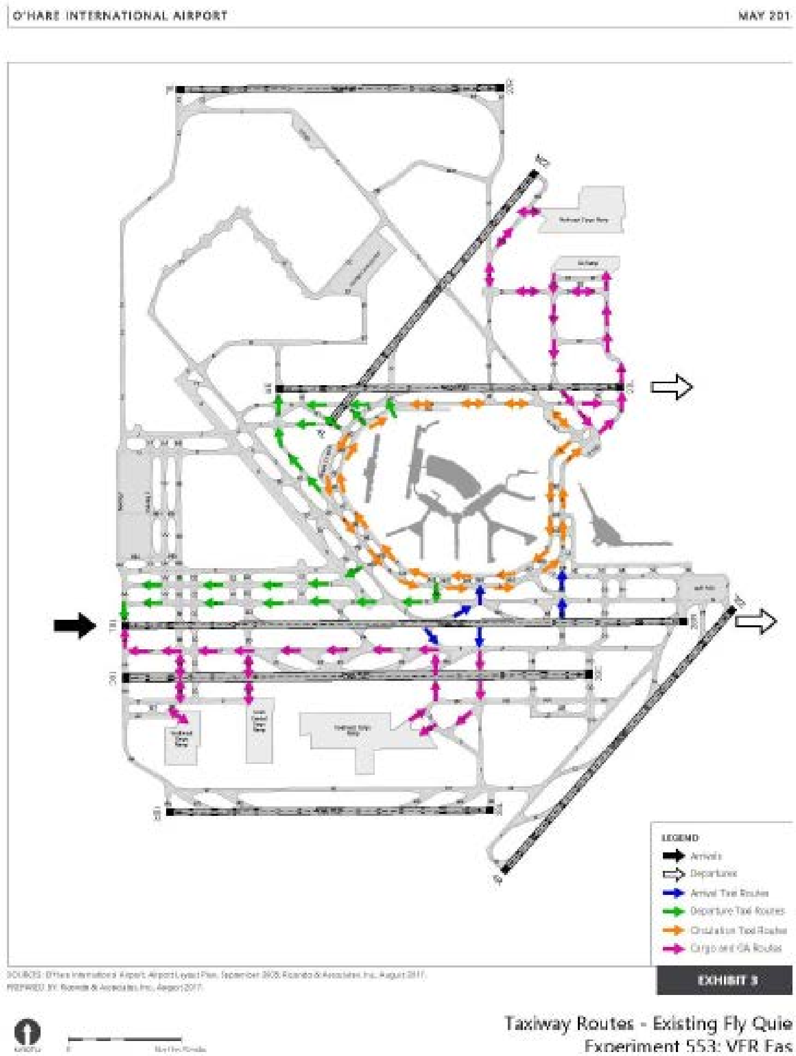

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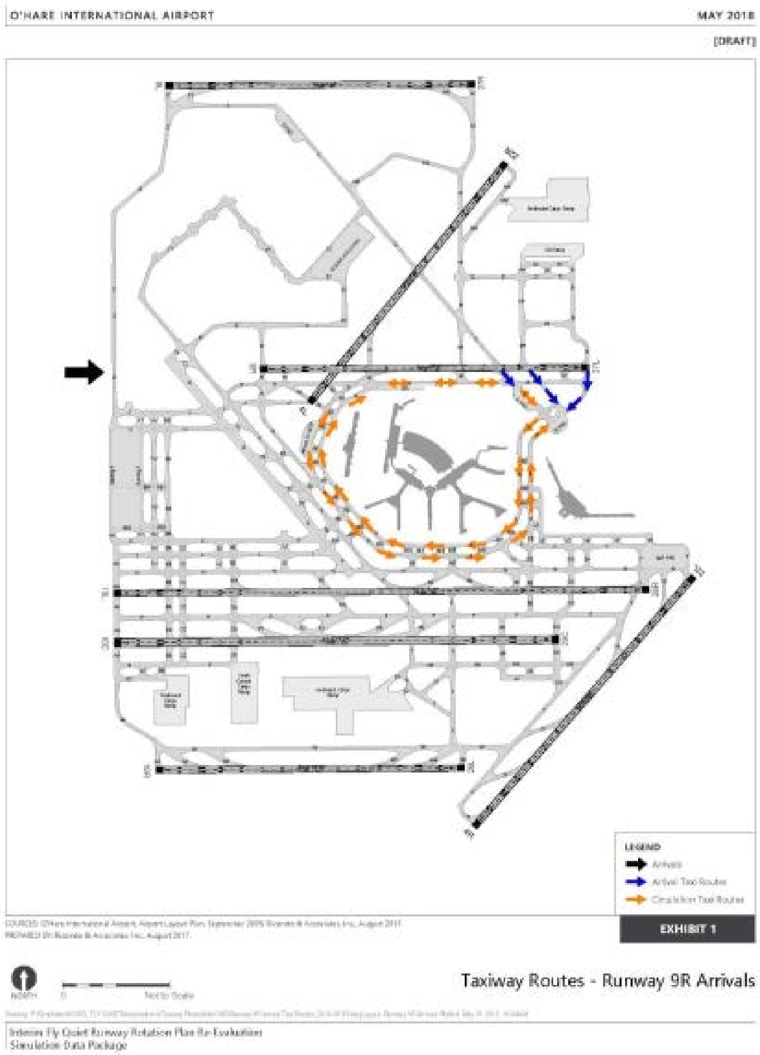
Figure 6: Taxiway Routes – Runway 9R Arrivals



For clarity, an example taxi distance measurement is provided here. Consider a departure operation from Gate H8 to Runway 22L. **Figure 7** shows the taxi route the aircraft will take from Gate H8 to its corresponding hand-off point "GH". This distance was measured to be 680 feet (or 0.11 nautical miles). **Figure 8** illustrates the taxi route that the aircraft will follow from "GH" to the departure end of Runway 22L. This distance was measured to be 7,285 feet (or 1.2 nautical miles). Thus, the total taxi distance for a departure from Gate H8 to Runway 22L is approximately 1.31 nautical miles. A similar process was followed to estimate the taxi distances between all gates and runways (exits and departure ends) in the nighttime operations dataset.

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Figure 7: Taxi Routes between Gates in the G-H channel and "GH" Hand-Off Point

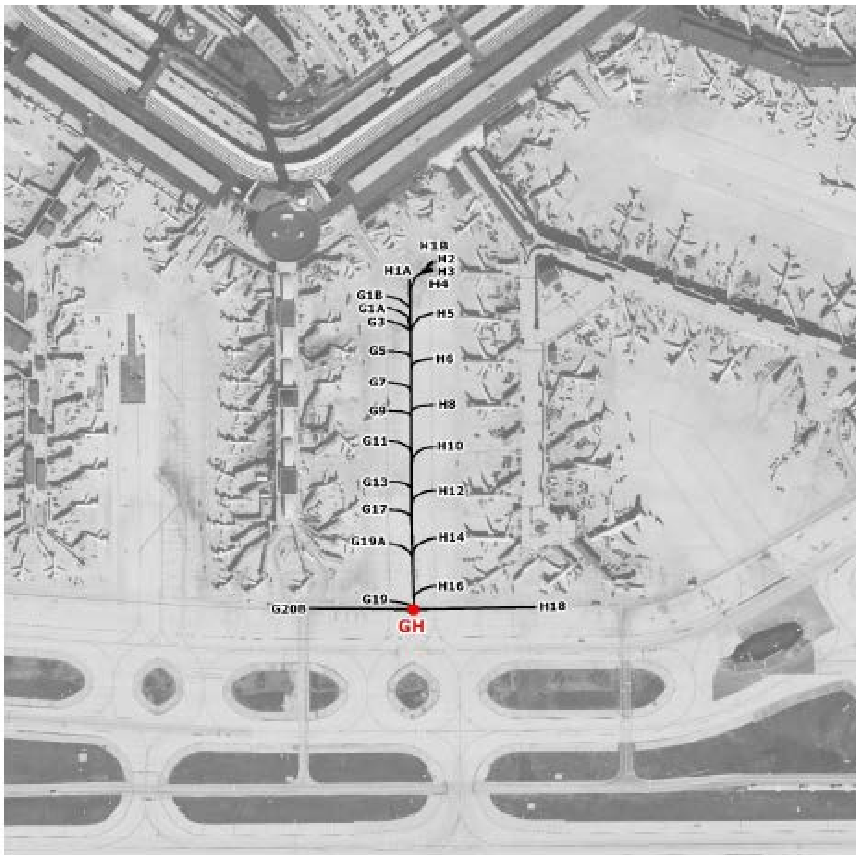

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Figure 8: Taxi Out Route from "GH" Hand-Off Point to Runway 22L

3.2.2 Convert Taxi Distances to Taxi Times

Once all the taxi distances were measured, the next step involved estimation of the corresponding taxi times for arrivals and departures. This process was carried out using the traditional speed formula (see Equation (1)).

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \tag{1}$$

When solved for time, Equation (1) becomes:

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}} \tag{2}$$

Consistent with the parameters used in the TAAM simulations, the taxi speed within the non-movement area (that is, between each gate and its corresponding hand-off point) was assumed to be 7 knots, while the taxi speed in the movement areas (between each hand-off point and runway exits/departure ends) was assumed to be 15 knots. Application of Equation (2), to the taxi distances developed in Step 1 yielded unimpeded taxi time estimates for each taxi distance.

As a sample calculation, consider again the example of the departure operation from Gate H8 to Runway 22L. Using Equation (2), the taxi time from Gate H8 to the hand-off point "GH" (based on a taxi speed of 7 knots) was calculated to be 0.96 minutes, while the taxi time from the hand-off point "GH" to Runway 22L (using a taxi speed of 15 knots) was calculated to be 4.80 minutes. Therefore, the total taxi out time assignment for this departure was estimated to be approximately 5.76 minutes.

All the taxi times were consolidated into two databases (henceforth, referred to as taxi time tables): one for departures and one for arrivals.

Figure 9 was developed with each gate name as a row and each runway departure end as a column. Using the calculations outlined previously, each cell in the table was populated with the corresponding taxi out time estimate between the gate and runway end associated with the cell. **Figure** 9 provides a snapshot of this table. Note that the departure taxi time table only reflects estimates for the unimpeded taxi out time and does not include push-back times.. Push-back times are a function of the aircraft type and not of the taxi route between gates and departure runways. Therefore, push-back times are accounted for in the final step of this analysis.

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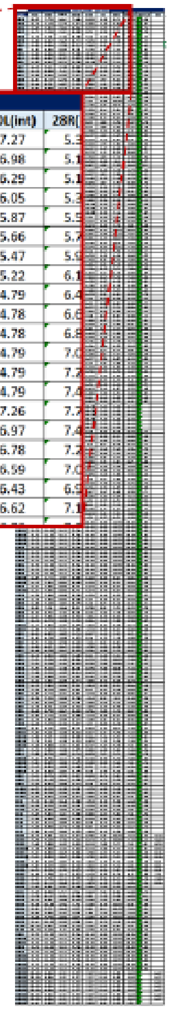
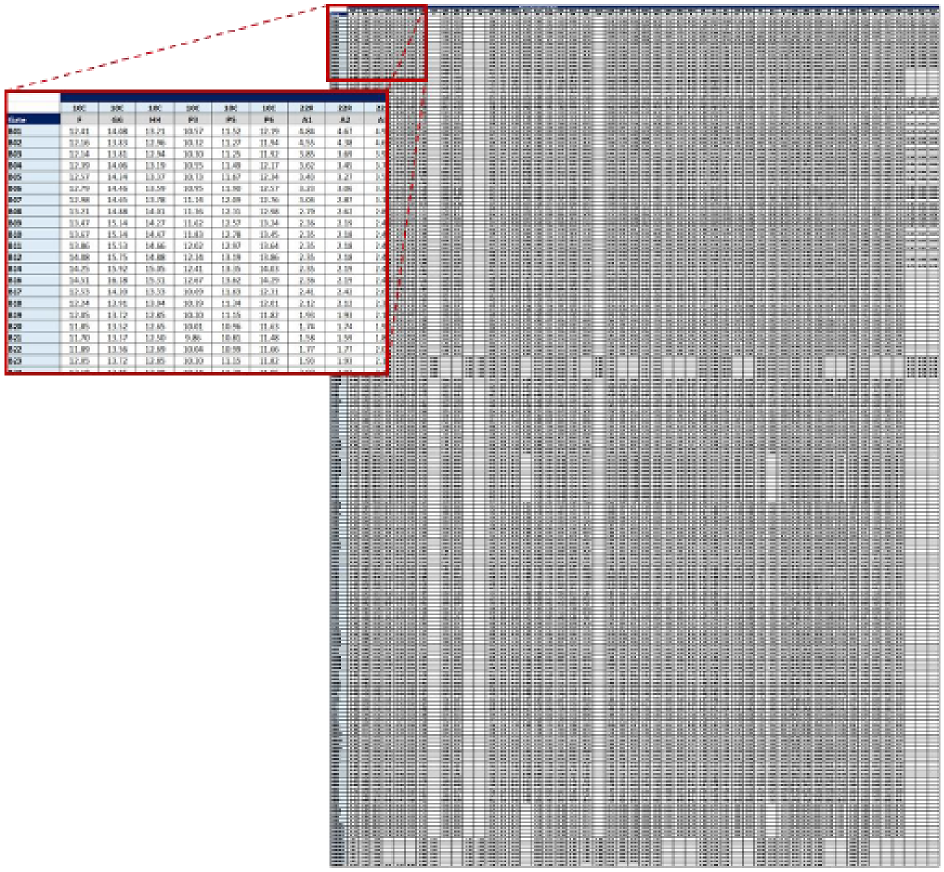
Figure 9: Snapshot of Departure Taxi Time Table (times shown are in minutes)



	Departure Runways								
Gate	9R	10L	28C	28R	22L	4L	10C	10L(int)	28R(
B01	6.51	9.15	6.64	7.68	8.34	5.70	9.93	7.27	5.3
B02	6.22	8.86	6.39	7.43	8.09	5.41	9.64	6.98	5.1
B03	5.52	8.17	6.37	7.41	8.07	4.72	8.94	6.29	5.1
B04	5.29	7.93	6.61	7.66	8.32	4.48	8.71	6.05	5.3
B05	5.10	7.75	6.79	7.84	8.50	4.30	8.52	5.87	5.5
B06	4.89	7.54	7.02	8.06	8.72	4.09	8.31	5.66	5.7
B07	4.71	7.35	7.21	8.25	8.91	3.90	8.13	5.47	5.9
B08	4.46	7.10	7.43	8.48	9.13	3.65	7.88	5.22	6.1
B09	4.03	6.67	7.69	8.74	9.39	3.22	7.45	4.79	6.4
B10	4.02	6.66	7.90	8.94	9.60	3.21	7.44	4.78	6.6
B11	4.02	6.66	8.09	9.13	9.79	3.21	7.44	4.78	6.8
B12	4.02	6.66	8.31	9.35	10.01	3.22	7.44	4.79	7.0
B14	4.02	6.67	8.47	9.52	10.18	3.22	7.44	4.79	7.2
B16	4.03	6.67	8.74	9.78	10.44	3.22	7.44	4.79	7.4
B17	3.49	9.14	7.40	8.05	8.71	2.64	9.92	7.26	7.7
B18	3.19	8.85	7.11	7.76	8.42	2.35	9.63	6.97	7.4
B19	3.00	8.66	6.92	7.57	8.23	2.16	9.44	6.78	7.2
B20	2.81	8.47	6.73	7.38	8.03	1.97	9.24	6.59	7.0
B21	2.66	8.31	6.57	7.22	7.88	1.81	9.09	6.43	6.9
B22	2.84	8.50	6.76	7.41	8.07	2.00	9.28	6.62	7.1

Figure 10 was developed with each gate name as a row and each runway exit as a column. Using the calculations outlined previously, each cell in the table was populated with the corresponding taxi in time estimate between the runway exit and gate associated with the cell. **Figure 10** provides a snapshot of this table.

Figure 10: Snapshot of Arrival Taxi Time Table (times shown are in minutes)



	10C	10C	10C	10C	10C	10C	22R	22R
Gate	F	G6	H4	P3	P5	P6	A1	A2
B01	12.41	14.08	13.21	10.57	11.52	12.39	4.80	4.61
B02	12.16	13.83	12.96	10.12	11.27	11.94	4.55	4.38
B03	12.14	13.81	12.94	10.10	11.25	11.92	3.85	3.68
B04	12.39	14.06	13.19	10.35	11.48	12.17	3.62	3.45
B05	12.57	14.14	13.37	10.13	11.67	12.34	3.40	3.27
B06	12.79	14.46	13.59	10.75	11.90	12.57	3.23	3.06
B07	12.98	14.65	13.78	11.18	12.08	12.76	3.06	2.87
B08	13.21	14.88	14.01	11.16	12.31	12.98	2.79	2.62
B09	13.47	15.14	14.27	11.42	12.57	13.24	2.36	2.19
B10	13.67	15.34	14.47	11.83	12.78	13.45	2.35	2.18
B11	13.86	15.53	14.66	12.02	12.97	13.64	2.35	2.18
B12	14.08	15.75	14.88	12.18	13.19	13.86	2.35	2.18
B14	14.25	15.92	15.05	12.41	13.35	14.03	2.35	2.18
B16	14.51	16.18	15.31	12.67	13.62	14.29	2.36	2.19
B17	12.53	14.10	13.33	10.49	11.63	12.31	2.41	2.41
B18	12.24	13.91	13.04	10.19	11.34	12.01	2.12	2.13
B19	12.05	13.72	12.85	10.10	11.15	11.82	1.90	1.93
B20	11.85	13.12	12.65	10.01	10.96	11.63	1.78	1.74
B21	11.70	13.17	12.50	9.86	10.81	11.48	1.58	1.58
B22	11.89	13.56	12.69	10.04	10.99	11.66	1.77	1.71
B23	12.05	13.72	12.85	10.10	11.15	11.82	1.90	1.93

3.2.3 Determine the Taxi Time Assignment

For each operation in the nighttime dataset, a suitable taxi time was assigned based on the taxi time tables generated in Step 2. This assignment model was developed with separate considerations for departures and arrivals as described below.

Departures: Every departure in the nighttime dataset included a runway assignment and a gate assignment. Using both these values, the assignment model first found the corresponding taxi time in the Departure Taxi Time Table. Returning to the example of a departure operation from Gate H8 to Runway

22L, using the table the total unimpeded taxi out time assignment for this departure was estimated to be approximately 5.76 minutes. Next, the model determined a reasonable push-back time for each departure. Push-back times are typically specific to the aircraft type. In order to maintain consistency with other related simulation and modeling analyses, push-back times that were inputs in the TAAM simulations were used in this analysis. Based on each departure's aircraft type, the corresponding push-back time (as specified in TAAM) was identified. For example, a Boeing 737-800 aircraft has a modeled push-back time in TAAM of 2.4 minutes. Finally, summation of the departure taxi out time and the push-back time was used as the taxi out time assignment. For instance, a departing B737-800 aircraft from Gate H8 to Runway 22L has an unimpeded taxi out time assignment of 8.16 minutes.

Arrivals: Every arrival in the nighttime dataset included a runway assignment and a gate assignment. In order to use the Arrival Taxi Time Table to find the corresponding taxi in time for arrivals, a runway exit needed to be specified. Using the FAA's Runway Exit Interactive Design Model (REDIM), an exit use analysis was carried out for each aircraft type on each runway (see **Section 3.2.4** for a detailed report on the exit use study). The results of the analysis presented exit use percentages for each arrival runway (in the nighttime operations dataset) by type of aircraft (REDIM-adjusted). Next, for each arrival in the nighttime dataset, a random number between 0% and 100% was generated. Comparison of this random number to the cumulative exit use percentages for each aircraft type (for the runway assignment specified in the database), a suitable runway exit for that particular arrival was determined. Consider, for example, a B737-800 arrival on Runway 28C taxiing to Gate K16. A random number of 89% was generated. The exit use study indicated that 12% of B737-800 aircraft landing on Runway 28C use exit T, 86% use exit P1, and 2% use exit DD. Thus, comparing the random number of 89% with the exit use results, P1 is estimated to be the most likely used exit for this arrival. Finally, using the runway exit and the gate assignment information, the assignment model determined the corresponding taxi in time in the Arrival Taxi Time Table. Returning the B737-800 example, using the table the total unimpeded taxi in time assignment for this arrival was estimated to be approximately 7.79 minutes.

3.2.4 Runway Exit Use Analysis

The runway exit analysis was conducted using the Runway Exit Design Interactive Model (REDIM). REDIM is an FAA supported runway exit analysis tool developed by Virginia Tech University to assist with design and planning projects for Airports. The program uses a series of mathematical equations and models to analyze the dynamics of aircraft landings given a detailed set of program input.

Three main sets of inputs are required to run the analysis in REDIM and include: fleet mix, airport inputs, and runway inputs.

3.2.4.1 Fleet Mix

The fleet mix was generated from the aircraft types included in the nighttime dataset provided in the flight schedule and was condensed in this analysis due to aircraft type limitations in REDIM program. REDIM does not contain all aircraft manufacturers and models so similar performing aircraft were substituted within the program. These fleets are called the REDIM adjusted fleets and were used for the remainder of the runway exit analysis.

Given the location of passenger terminals and cargo facilities relative to certain runways, different fleet mixes were used for exits to the north and south of Runways 10C, 28C, 10L, and 28R. For example, in the case of Runways 10C and 28C, only cargo arrivals to south of the airfield (South East cargo ramp, United cargo ramp, and FEDEX cargo ramp) were assumed to exit to the south of the runway while all other operations exit to the north. As a result, different fleet mixes were used to analyze the north-bound exits and south-bound exits for these runways.

The fleets used by runway ends are depicted in **Table 4.** For example, 49% of departures on Runway 10C heading south are represented by the A300-600.

Table 4: ORD IFQ REDIM Adjusted Fleets

#	Adjusted Aircraft for REDIM	RWY 9L, 27R, 9R, 27L, 10R, 22R, and 4R	RWY 10C (North)	RWY 10C (South)	RWY 28C (North)	RWY 28C (South)	RWY 10L and 28R (North)	RWY 10L and 28R (South)
1	A300-600	2%	-	49%	2%	-	-	28%
2	A320-200	22%	23%	-	23%	-	24%	-
3	B737-800	26%	27%	-	26%	-	29%	-
4	B747-400	2%	2%	-	2%	-	2%	-
5	B757-200	5%	5%	17%	5%	20%	4%	18%
6	B767-300	2%	1%	17%	1%	20%	1%	18%
7	B777-200	5%	5%	-	4%	20%	4%	9%
8	CRJ200	11%	12%	-	12%	-	12%	-
9	EMB145	17%	18%	-	18%	-	18%	-
10	MD-83	1%	1%	-	1%	-	1%	-
11	MD-87	2%	2%	-	2%	-	2%	-
12	C208	1%	1%	-	1%	-	1%	-
13	C550	1%	1%	-	1%	-	1%	-
14	BE400	1%	1%	-	1%	-	1%	-
15	MD-11	1%	-	17%	1%	-	-	9%
16	DC10	1%	1%	-	-	40%	-	18%

Total	100%	100%	100%	100%	100%	100%	100%

Notes: 1. Adjustments to the future fleet mix were made to satisfy aircraft fleet parameters within REDIM. If an aircraft type was not available in REDIM

2. Fleet percentages were derived from the flight schedule.

3.2.4.2 Airport Inputs

Amongst many standard inputs used in the program, airport specific data was needed to conduct the analysis. The airport specific data are considered fixed inputs and are applied to each runway end analysis in REDIM. The airport specific input for ORD included the following fixed inputs shown in **Table 5.** These values are consistent with parameters used in the TAAM simulations.

Table 5: ORD REDIM Airport Inputs

Input	Data
Wind Speed	0 knots
Airport Elevation	680 feet
Airport Temperature	59 °F
Surface Condition	100% dry conditions on runways

3.2.4.3 Runway Inputs

Amongst many standard inputs used many inputs are runway specific and vary by runway end. The inputs used for each runway end are shown in **Table 6.** These values were obtained from publicly available information about the ORD airfield.

Table 6: ORD REDIM Runway Inputs

Input	RWY 9L	RWY 27R	RWY 9R	RWY 27L	RWY 22R	RWY 10L	RWY 28R	RWY 10C	RWY 28C	RWY 10R	RWY 4R
Runway Orientation	90°	270°	90°	270°	219°	90°	270°	90°	270°	90°	42°
Runway Length	7,500'	7,500'	7,967'	7,967'	7,500'	13,000'	13,000'	10,801'	10,801'	7,500'	8,075'
Runway Width	150'	150'	150'	150'	150'	150'	150'	200'	200'	150'	150'
Runway Gradient	+.05%	-.05%	+.10%	-.10%	-.10%	+.20%	-.20%	+.18%	-.18%	+.29%	+.09%

3.2.4.4 Results of the Runway Exit Analysis

Using the fleet mix and input parameters described in the previous section, REDIM was used to model and evaluate runway exit use at ORD. **Tables 7 through 21** summarize the results of the analysis. Figures 10 through 24 present the exits analyzed for each of the runways. These tables present the exit use percentages for each arrival runway (in the nighttime operations dataset) by type of aircraft (REDIM-adjusted). For example, the runway exit analysis data in Table 4 explains that 26% of the arrivals on RWY 9L are associated with B737-800 and all of which would be expected to use runway exit M1 instead of runway exit M. Note that all exit percentages are rounded to the nearest tenth of a percent. These results have been reviewed by the FAA and include exit use updates that were made based on FAA comments.

Figure 11: ORD Runway 9L Exits

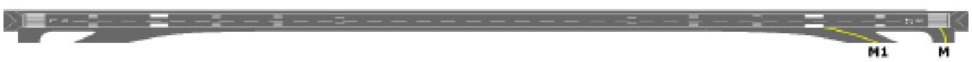


Table 7: ORD Runway 9L Runway Exit Analysis

Fleet	% of Fleet	% Exit Use	
		M1	M
C208	1%	1.0%	0.0%
BE400	1%	1.0%	0.0%
C550	1%	1.0%	0.0%
CRJ-200	11%	11.0%	0.0%
EMB145	17%	17.0%	0.0%
A300-600	2%	2.0%	0.0%
A320-200	22%	22.0%	0.0%
B737-800	26%	26.0%	0.0%
B757-200	5%	5.0%	0.0%
MD-83	1%	0.8%	0.2%
MD-87	2%	1.8%	0.2%
B747-400	2%	0.2%	1.3%
B767-300	2%	2.0%	0.0%
B777-200	5%	5.0%	0.0%
Dc-10-30	1%	0.8%	0.2%

MD-11	1%	1.0%	0.0%
Total	**100%**	**98%**	**2%**

Note: Fleet percentages were derived from the flight schedule.

Figure 12: ORD Runway 27R Exits

Table 8: ORD Runway 27R Runway Exit Analysis

Fleet	% of Fleet	% Exit Use	
		C1	Z
C208	1%	1.0%	0.0%
BE400	1%	1.0%	0.0%
C550	1%	1.0%	0.0%
CRJ-200	11%	11.0%	0.0%
EMB145	17%	17.0%	0.0%
A300-600	2%	2.0%	0.0%
A320-200	22%	22.0%	0.0%
B737-800	26%	26.0%	0.0%
B757-200	5%	5.0%	0.0%
MD-83	1%	0.8%	0.2%
MD-87	2%	1.8%	0.2%
B747-400	2%	0.2%	1.3%
B767-300	2%	2.0%	0.0%
B777-200	5%	5.0%	0.0%
Dc-10-30	1%	0.8%	0.2%
MD-11	1%	1.0%	0.0%
Total	**100%**	**98%**	**2%**

Note: Fleet percentages were derived from the flight schedule.

Figure 13: ORD Runway 9R Exits

Table 9: ORD Runway 9R Runway Exit Analysis

Fleet	% of Fleet	% Exit Use				
		A1	M	C	H3	PP
C208	1%	1.0%	0.0%	1.0%	0.0%	0.0%
BE400	1%	0.0%	1.0%	0.0%	0.0%	0.0%
C550	1%	0.0%	1.0%	0.0%	0.0%	0.0%
CRJ-200	11%	0.0%	0.0%	11.0%	0.0%	0.0%
EMB145	17%	0.0%	0.0%	17.0%	0.0%	0.0%
A300-600	2%	0.0%	0.0%	1.9%	0.1%	0.0%
A320-200	22%	0.0%	0.5%	21.4%	0.1%	0.0%
B737-800	26%	0.0%	0.0%	16.7%	9.3%	0.0%
B757-200	5%	0.0%	0.0%	5.0%	0.0%	0.0%
MD-83	1%	0.0%	0.0%	0.3%	0.7%	0.0%
MD-87	2%	0.0%	0.0%	0.8%	1.2%	0.0%
B747-400	2%	0.0%	0.0%	0.0%	1.3%	0.7%
B767-300	2%	0.0%	0.0%	1.6%	0.4%	0.0%
B777-200	5%	0.0%	0.0%	3.3%	1.7%	0.0%
Dc-10-30	1%	0.0%	0.0%	0.2%	0.8%	0.0%
MD-11	1%	0.0%	0.0%	0.8%	0.2%	0.0%
Total	100%	1%	2%	80%	16%	1%

Note: Fleet percentages were derived from the flight schedule.

Figure 14: ORD Runway 27L Exits

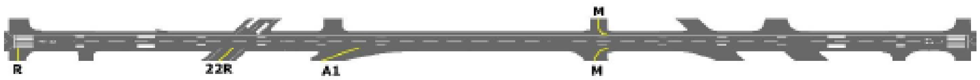


Table 10: ORD Runway 27L Runway Exit Analysis

Fleet	% of Fleet	% Exit Use			
		M	A1	22R	R
C208	1%	1.0%	0.0%	0.0%	0.0%
BE400	1%	0.4%	0.6%	0.0%	0.0%
C550	1%	0.9%	0.1%	0.0%	0.0%
CRJ-200	11%	0.0%	8.5%	2.5%	0.0%
EMB145	17%	0.0%	16.3%	0.7%	0.0%
A300-600	2%	0.0%	0.3%	1.7%	0.0%
A320-200	22%	0.0%	3.7%	18.3%	0.0%
B737-800	26%	0.0%	10.7%	10.7%	4.6%
B757-200	5%	0.0%	2.9%	2.1%	0.0%
MD-83	1%	0.0%	0.0%	0.4%	0.6%
MD-87	2%	0.0%	0.1%	1.1%	0.8%
B747-400	2%	0.0%	0.0%	0.0%	1.8%
B767-300	2%	0.0%	0.0%	1.9%	0.1%
B777-200	5%	0.0%	0.0%	4.1%	0.9%
Dc-10-30	1%	0.0%	0.0%	0.3%	0.7%
MD-11	1%	0.0%	0.0%	0.9%	0.1%
Total	**100%**	**2%**	**43%**	**45%**	**10%**

Note: Fleet percentages were derived from the flight schedule.

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Figure 15: ORD Runway 10R Exits

Table 11: ORD Runway 10R Runway Exit Analysis

Fleet	% of Fleet	% Exit Use		
		W3	W4	W5
C208	1%	1.0%	0.0%	0.0%
BE400	1%	1.0%	0.0%	0.0%
C550	1%	1.0%	0.0%	0.0%
CRJ-200	11%	11.0%	0.0%	0.0%
EMB145	17%	17.0%	0.0%	0.0%
A300-600	2%	1.7%	0.3%	0.0%
A320-200	22%	5.5%	16.5%	0.0%
B737-800	26%	12.1%	13.9%	0.0%
B757-200	5%	0.0%	5.0%	0.0%
MD-83	1%	0.2%	0.6%	0.2%
MD-87	2%	0.7%	1.1%	0.2%
B747-400	2%	0.0%	0.3%	1.4%
B767-300	2%	1.2%	0.8%	0.0%
B777-200	5%	0.0%	5.0%	0.0%
Dc-10-30	1%	0.0%	0.9%	0.1%
MD-11	1%	0.6%	0.4%	0.0%
Total	**100%**	**53%**	**45%**	**2%**

Note: Fleet percentages were derived from the flight schedule.

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Figure 16: ORD Runway 22R Exits

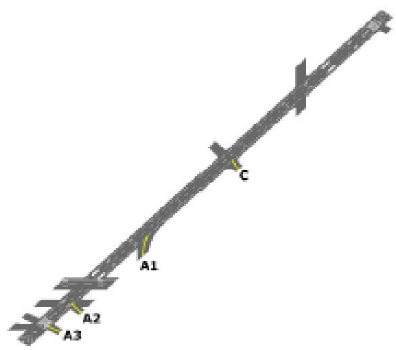

Table 12: ORD Runway 22R Runway Exit Analysis

Fleet	% of Fleet	% Exit Use			
		C	A1	A2	A3
C208	1%	1.0%	0.0%	0.0%	0.0%
BE400	1%	1.0%	0.0%	0.0%	0.0%
C550	1%	1.0%	0.0%	0.0%	0.0%
CRJ-200	11%	0.0%	10.6%	0.4%	0.0%
EMB145	17%	0.0%	17.0%	0.0%	0.0%
A300-600	2%	0.0%	1.0%	1.0%	0.0%
A320-200	22%	0.0%	12.8%	9.2%	0.0%
B737-800	26%	0.0%	26.0%	0.0%	0.0%
B757-200	5%	0.0%	4.4%	0.6%	0.0%
MD-83	1%	0.0%	0.0%	0.9%	0.1%
MD-87	2%	0.0%	0.3%	1.7%	0.1%
B747-400	2%	0.0%	0.0%	0.6%	0.8%
B767-300	2%	0.0%	0.3%	1.7%	0.0%
B777-200	5%	0.0%	0.4%	4.6%	0.0%
Dc-10-30	1%	0.0%	0.0%	0.9%	0.1%
MD-11	1%	0.0%	0.1%	0.9%	0.0%

Total	100%	3%	73%	22%	1%

Note: Fleet percentages were derived from the flight schedule.

Figure 17: ORD Runway 4R Exits

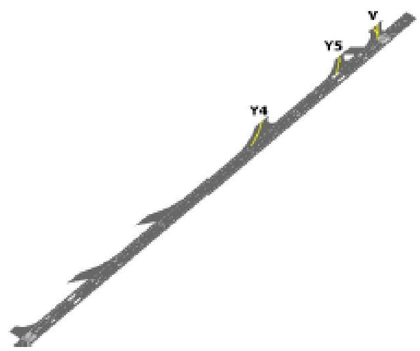

Table 13: ORD Runway 4R Runway Exit Analysis

Fleet	% of Fleet	% Exit Use		
		Y4	Y5	V
C208	1%	1.0%	0.0%	0.0%
BE400	1%	1.0%	0.0%	0.0%
C550	1%	1.0%	0.0%	0.0%
CRJ-200	11%	9.6%	1.4%	0.0%
EMB145	17%	16.7%	0.3%	0.0%
A300-600	2%	0.4%	1.6%	0.0%
A320-200	22%	6.0%	16.0%	0.0%
B737-800	26%	0.0%	26.0%	0.0%
B757-200	5%	3.4%	1.6%	0.0%
MD-83	1%	0.0%	0.9%	0.1%
MD-87	2%	0.1%	1.9%	0.1%
B747-400	2%	0.0%	0.8%	1.0%

B767-300	2%	0.0%	2.0%	0.0%
B777-200	5%	0.0%	5.0%	0.0%
Dc-10-30	1%	0.0%	0.9%	0.1%
MD-11	1%	0.0%	1.0%	0.0%
Total	**100%**	**39%**	**59%**	**1%**

Note: Fleet percentages were derived from the flight schedule.

Figure 18: ORD Runway 10C North Exits

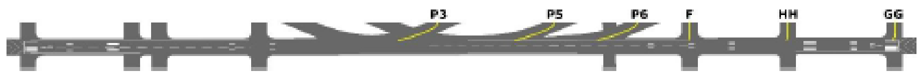

Table 14: ORD Runway 10C North Runway Exit Analysis

Fleet	% of Fleet	% Exit Use					
		P3	P5	P6	F	HH	GG
C208	1%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BE-400	1%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
C-550	1%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CRJ-200	12%	0.0%	12.0%	0.0%	0.0%	0.0%	0.0%
EMB145	18%	1.2%	16.8%	0.0%	0.0%	0.0%	0.0%
A320-200	23%	0.0%	21.3%	1.7%	0.0%	0.0%	0.0%
B737-800	27%	0.0%	13.4%	13.6%	0.0%	0.0%	0.0%
B757-200	5%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
MD-83	1%	0.0%	0.1%	0.6%	0.2%	0.0%	0.0%
MD-87	2%	0.0%	0.5%	1.3%	0.3%	0.0%	0.0%
B747-400	2%	0.0%	0.0%	0.4%	1.4%	0.1%	0.1%
B767-300	1%	0.0%	0.7%	0.3%	0.0%	0.0%	0.0%
B777-200	5%	0.0%	2.3%	2.7%	0.0%	0.0%	0.0%

DC-10-30	1%	0.0%	0.1%	0.8%	0.1%	0.0%	0.0%
Total	**100%**	**4%**	**72%**	**22%**	**2%**	**0%**	**0%**

Note: Fleet percentages were derived from the flight schedule.

Figure 19: ORD Runway 10C South Exits

Table 15: ORD Runway 10C South Runway Exit Analysis

Fleet	% of Fleet	% Exit Use			
		T	F	HH	GG
A300-600	49%	49.0%	0.0%	0.0%	0.0%
B757-200	17%	17.0%	0.0%	0.0%	0.0%
B767-300	17%	17.0%	0.0%	0.0%	0.0%
MD-11	17%	17.0%	0.0%	0.0%	0.0%
Total	**100%**	**100%**	**0%**	**0%**	**0%**

Note: Fleet percentages were derived from the flight schedule.

Figure 20: ORD Runway 28C North Exits

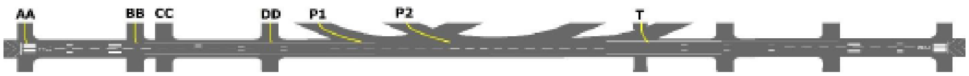

Table 16: ORD Runway 28C North Runway Exit Analysis

Fleet	% of Fleet	% Exit Use						
		T	P2	P1	DD	CC	BB	AA
C208	1%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BE400	1%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
C550	1%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CRJ-200	12%	0.0%	12.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EMB145	18%	0.0%	18.0%	0.0%	0.0%	0.0%	0.0%	0.0%
A300-600	2%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%
A320-200	23%	0.0%	23.0%	0.0%	0.0%	0.0%	0.0%	0.0%
B737-800	26%	0.0%	3.0%	22.3%	0.7%	0.0%	0.0%	0.0%
B757-200	5%	0.0%	4.5%	0.5%	0.0%	0.0%	0.0%	0.0%
MD-83	1%	0.0%	0.0%	0.5%	0.4%	0.1%	0.0%	0.0%
MD-87	2%	0.0%	0.2%	1.1%	0.6%	0.0%	0.0%	0.0%
B747-400	2%	0.0%	0.0%	0.0%	1.3%	0.7%	0.0%	0.0%
B767-300	1%	0.0%	0.2%	0.8%	0.0%	0.0%	0.0%	0.0%
B777-200	4%	0.0%	0.4%	3.4%	0.2%	0.0%	0.0%	0.0%
MD-11	1%	0.0%	0.2%	0.7%	0.0%	0.0%	0.0%	0.0%
Total	100%	1%	66%	29%	3%	1%	0%	0%

Note: Fleet percentages were derived from the flight schedule.

Figure 21: ORD Runway 28C South Exits

Table 17: ORD Runway 28C South Runway Exit Analysis

Fleet	% of Fleet	% Exit Use			
		DD	CC	BB	AA
B757-200	20%	20.0%	0.0%	0.0%	0.0%
B767-300	20%	20.0%	0.0%	0.0%	0.0%
B777-200	20%	20.0%	0.0%	0.0%	0.0%
DC-10-30	40%	40.0%	0.0%	0.0%	0.0%
Total	100%	100%	0%	0%	0%

Note: Fleet percentages were derived from the flight schedule.

Figure 22: ORD Runway 10L North Exits

Table 18: ORD Runway 10L North Runway Exit Analysis

Fleet	% of Fleet	% Exit Use				
		N3	N5	EE	GG	Y
C208	1%	1.0%	0.0%	0.0%	0.0%	0.0%
BE400	1%	1.0%	0.0%	0.0%	0.0%	0.0%
C550	1%	1.0%	0.0%	0.0%	0.0%	0.0%
CRJ-200	12%	12.0%	0.0%	0.0%	0.0%	0.0%
EMB145	18%	18.0%	0.0%	0.0%	0.0%	0.0%

A320-200	24%	24.0%	0.0%	0.0%	0.0%	0.0%
B737-800	29%	29.0%	0.0%	0.0%	0.0%	0.0%
B757-200	4%	4.0%	0.0%	0.0%	0.0%	0.0%
MD-83	1%	0.9%	0.1%	0.1%	0.1%	0.1%
MD-87	2%	1.9%	0.1%	0.1%	0.1%	0.1%
B747-400	2%	1.1%	0.9%	0.0%	0.0%	0.0%
B767-300	1%	1.0%	0.0%	0.0%	0.0%	0.0%
B777-200	4%	4.0%	0.0%	0.0%	0.0%	0.0%
Total	**100%**	**99%**	**1%**	**0%**	**0%**	**0%**

Note: Fleet percentages were derived from the flight schedule.

Figure 23: ORD Runway 10L South Exits

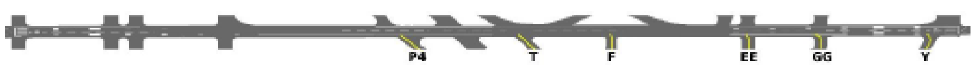

Table 19: ORD Runway 10L South Runway Exit Analysis

Fleet	% of Fleet	% Exit Use					
		P4	T	F	EE	GG	Y
A300-600	28%	3.4%	24.6%	0.0%	0.0%	0.0%	0.0%
B757-200	18%	9.6%	8.4%	0.0%	0.0%	0.0%	0.0%
B767-300	18%	0.0%	18.0%	0.0%	0.0%	0.0%	0.0%
B777-200	9%	0.0%	9.0%	0.0%	0.0%	0.0%	0.0%
DC-10-30	18%	0.0%	15.7%	2.3%	0.0%	0.0%	0.0%
MD-11	9%	0.0%	9.0%	0.0%	0.0%	0.0%	0.0%
Total	**100%**	**13%**	**85%**	**2%**	**0%**	**0%**	**0%**

Note: Fleet percentages were derived from the flight schedule.

Figure 24: ORD Runway 28R North Exits

Table 20: ORD Runway 28R North Runway Exit Analysis

Fleet	% of Fleet	% Exit Use						
		N4	T	N1	DD	CC	BB	AA
C208	1%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BE-400	1%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
C550	1%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CRJ-200	12%	0.0%	12.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EMB145	18%	0.0%	18.0%	0.0%	0.0%	0.0%	0.0%	0.0%
A320-200	24%	0.0%	22.1%	1.9%	0.0%	0.0%	0.0%	0.0%
B737-800	29%	0.0%	14.6%	14.4%	0.0%	0.0%	0.0%	0.0%
B757-200	4%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MD-83	1%	0.0%	0.1%	0.8%	0.0%	0.1%	0.1%	0.1%
MD-87	2%	0.0%	0.4%	1.5%	0.0%	0.1%	0.1%	0.1%
B747-400	2%	0.0%	0.0%	1.2%	0.0%	0.8%	0.0%	0.0%
B767-300	1%	0.0%	0.7%	0.3%	0.0%	0.0%	0.0%	0.0%
B777-200	4%	0.0%	1.8%	2.2%	0.0%	0.0%	0.0%	0.0%
Total	100%	3%	74%	22%	0%	1%	0%	0%

Note: Fleet percentages were derived from the flight schedule.

Figure 25: ORD Runway 28R South Exits

Table 21: ORD Runway 28R South Runway Exit Analysis

Fleet	% of Fleet	% Exit Use					
		F	P4	DD	CC	BB	AA
A300-600	28%	0.0%	28.0%	0.0%	0.0%	0.0%	0.0%
B757-200	18%	0.0%	18.0%	0.0%	0.0%	0.0%	0.0%
B767-300	18%	0.0%	18.0%	0.0%	0.0%	0.0%	0.0%
B777-200	9%	0.0%	9.0%	0.0%	0.0%	0.0%	0.0%
DC-10-30	18%	0.0%	15.3%	2.4%	0.0%	0.0%	0.0%
MD-11	9%	0.0%	9.0%	0.0%	0.0%	0.0%	0.0%
Total	**100%**	**0%**	**97%**	**2%**	**0%**	**0%**	**0%**

Note: Fleet percentages were derived from the flight schedule.