SUBURBAN O'HARE COMMISSION

ORD RUNWAY ROTATION PLAN ANALYSIS AND RECOMMENDATIONS

Final Report

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1. INTRODUCTION

This report summarizes the collaborative effort between JDA and Chicago Department of Aviation to identify a Fly Quiet II Runway Rotation Plan (RRP) for the initial test period of approximately June to November of 2016.

Since the publication of the JDA Preliminary Report on Proposed ORD Runway Headings, Runway Rotation Plan and Status of the JDA FQ 20 Recommendations on February 11, 2016, the O'Hare Noise Compatibility Commission (ONCC) adopted Fly Quiet II Runway Rotation Criteria, Departure Procedure Criteria and Three Fly Quiet Programs on March 11, 2016. As a result of the ONCC action, the Chicago Department of Aviation (CDA) chose to focus only on recommendation of a Fly Quiet II RRP for the May 6, 2016 ONCC meeting.

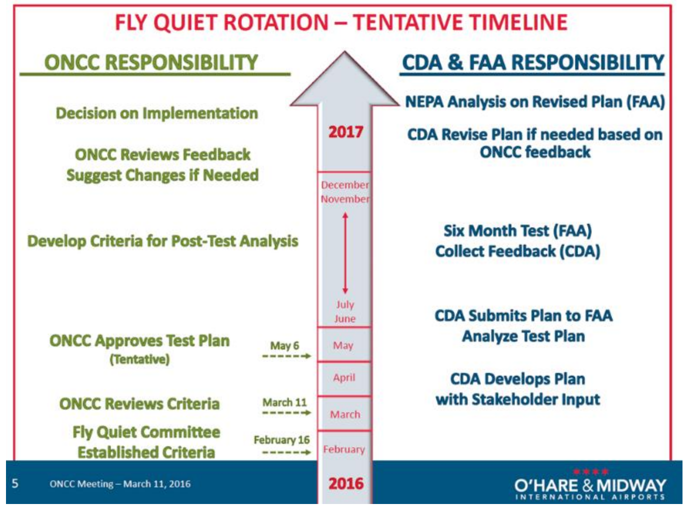

Figure 1: Tentative Timeline FQ II RRP

Through a series of meetings with JDA, SOC, CDA staff, Landrum and Brown and the FAA reviewing several iterations of runway use configurations, runway utilization rates and performance metrics the team was able to reach consensus on a runway rotation plan and performance metrics by which to measure impacts of the rotation plan for the initial test period during the summer and fall of 2016 that could be collectively

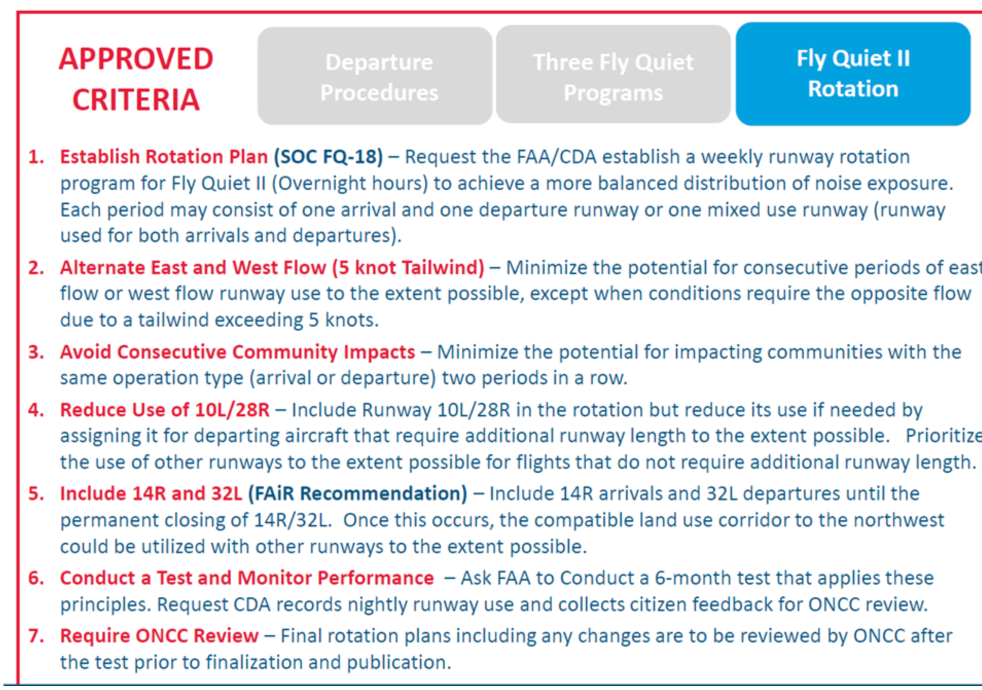

Figure 2: ONCC Approved FQ II RRP Criteria

recommended to the ONCC for adoption at the May 6, 2016 ONCC meeting.

The ONCC adopted seven criteria for the FQ II RRP. Criteria 1 limits the FQ II period to demand windows that can be served with one arrival and one departure runway. It should be noted that this constrains the rotation program to a period that includes 25% of nighttime operations.

Based on the ONCC criteria, JDA in collaboration with CDA reached consensus on ten runway configurations to be used alternately in a 12-week rotation scheme summarized as follows:

- Limited to overnight hours when demand allows for one arrival and one departure runway
- Balances approach for 12 weekly periods
    - 6 Parallel Configurations and 6 Diagonal Configurations
    - 6 West Flow and 6 East Flow
    - Primary and Secondary runway options for East and West flow based on wind conditions for that day
- Reflects stakeholder input
    - ONCC Criteria
    - SOC Supports Plan
    - FAIR – Use of Diagonals
- Includes procedures to limit use of longest runways
- Communication protocols defined for CDA and Airlines

The analysis described in this report will be used to help evaluate the test results for SOC review prior to making a final recommendation to the O'Hare Noise Compatibility Commission after the test period.

The proposed rotation configurations are balanced to the extent possible but the longest runways will always have a weighted balance because of the operational requirements of the night time fleet mix. As explained in detail in Section 3a of this report, the fleet mix at night contains many heavy and large aircraft. This creates a significant demand for runways 9,600' and longer. This demand has to be served by either 10L/28R, 10C/28C or 14R/32L. Additionally, JDA analysis of the flight data provided by CDA and considering the aircraft performance and stage length flown by the current fleet mix at ORD, the airport could expect 4 to 6 flights per night requiring long runways (i.e., greater than 9,600 feet). The modeling allocates 5 flights per night to 10L/28R when no long runway is available.

Sometime in late 2018 or early 2019, Runway 14R/32L will close and 09C/27C and 09R/27L will provide two other options to balance noise. Similar analysis should be performed to balance the impacts to communities.

2. RUNWAY CONFIGURATIONS AND ROTATION PLAN

a. Runway Configurations

Runway Configurations A through J shown in Figure 3 are paired vertically to combine East and West flow options rotated in primary and secondary alternatives throughout a proposed 12-week rotation discussed below. The three parallel configuration pairs (A-F, C-H, and E-J) are used twice in the 12-week rotation and the two crosswind runway configuration pairs (B-G and D-I) are used three times in the twelve week rotation.

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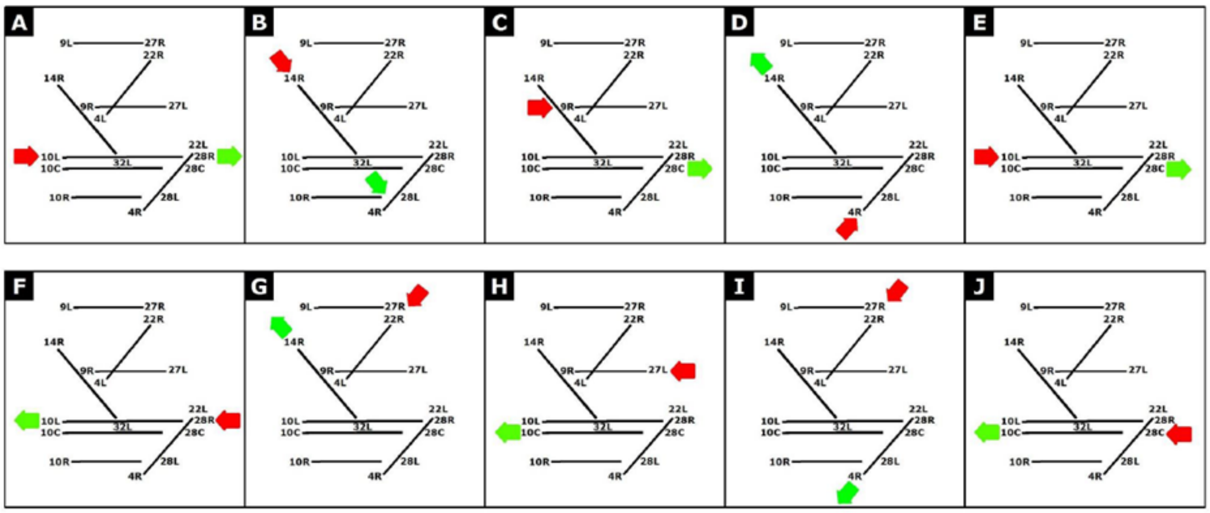

Figure 3: Proposed Runway Configurations to be used in the Runway Rotation Plan.

Assumptions applied to the rotation plan:

1) Use of these runways if voluntary, pilots are encouraged to use designated nighttime preferential runways.
2) Alternative runways may be used to allow for construction, snow removal, runway maintenance, runway inspections and specific aircraft operational needs. Available runways are determined by Chicago Department of Aviation (CDA) Operations and prevailing winds.
3) The proposed plan has not been approved by the Federal Aviation Administration (FAA).
4) Runway 10L/28R, if closed for noise abatement, would be made available for flights that require additional runway length after operator coordination, at a minimum of 2 hours prior to arrival or departure, with Chicago Department of Aviation (CDA) Operations.

b. Rotation Plan

The proposed runway rotation plan is shown in Figures 4 and 5. The goal of the proposed rotation plan is to provide better balance of runway utilization than existing use. ONCC criteria one seeks to achieve a balanced distribution of noise. At the same time ONCC criteria four seeks to reduce the use of 10L/28R through the use of other runways to the extent possible. The test period should be utilized to measure impacts to balance the distribution fairly throughout all of the long runways to help communities reach a consensus regarding what runway loading achieves a balanced distribution.

Analysis of historical wind data indicates that the primary configurations can be used particularly during the summer and fall months when the test period will be occurring.

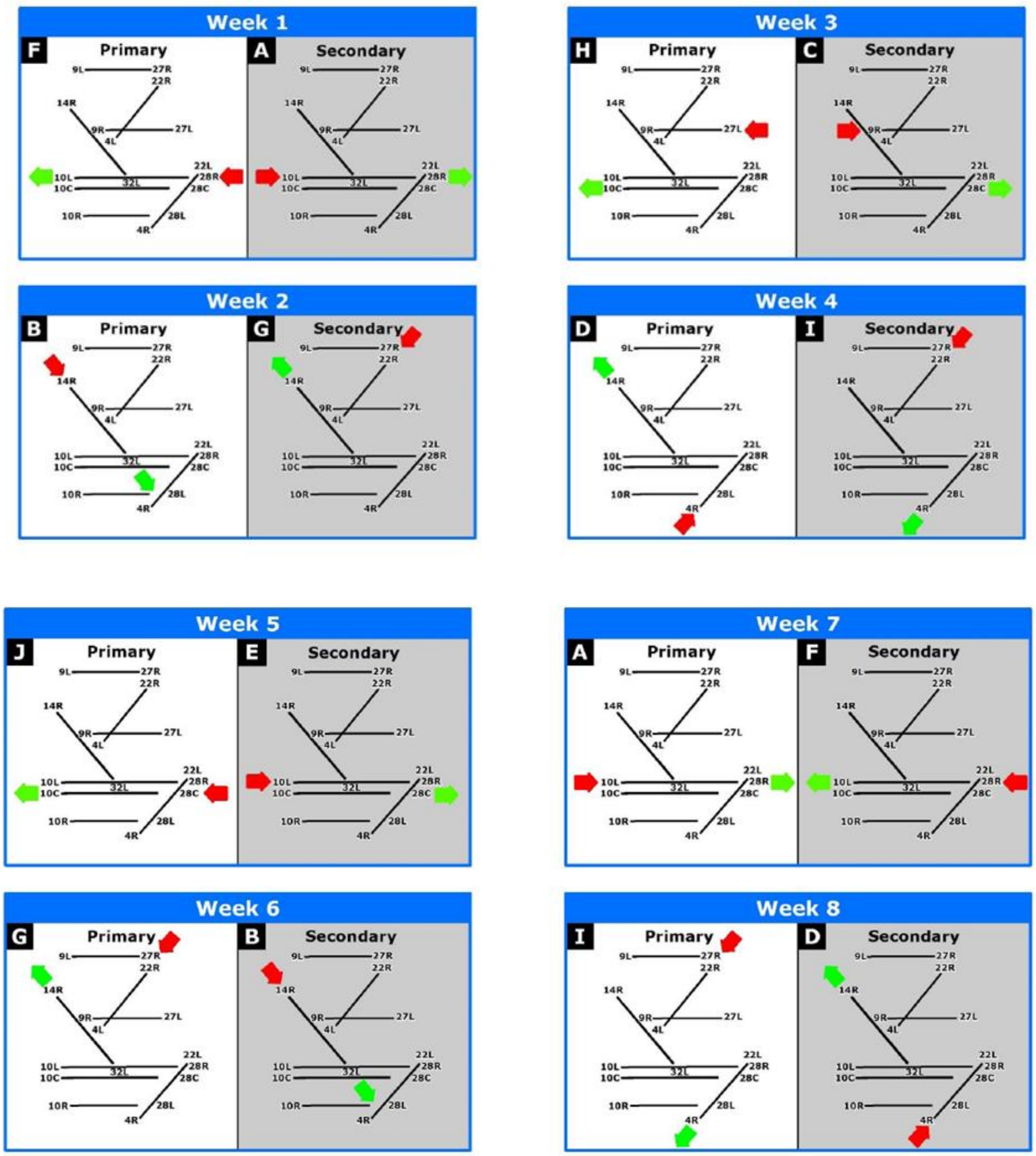

Figure 4: Proposed FQ II Runway Rotation Periods (Weeks 1-8).

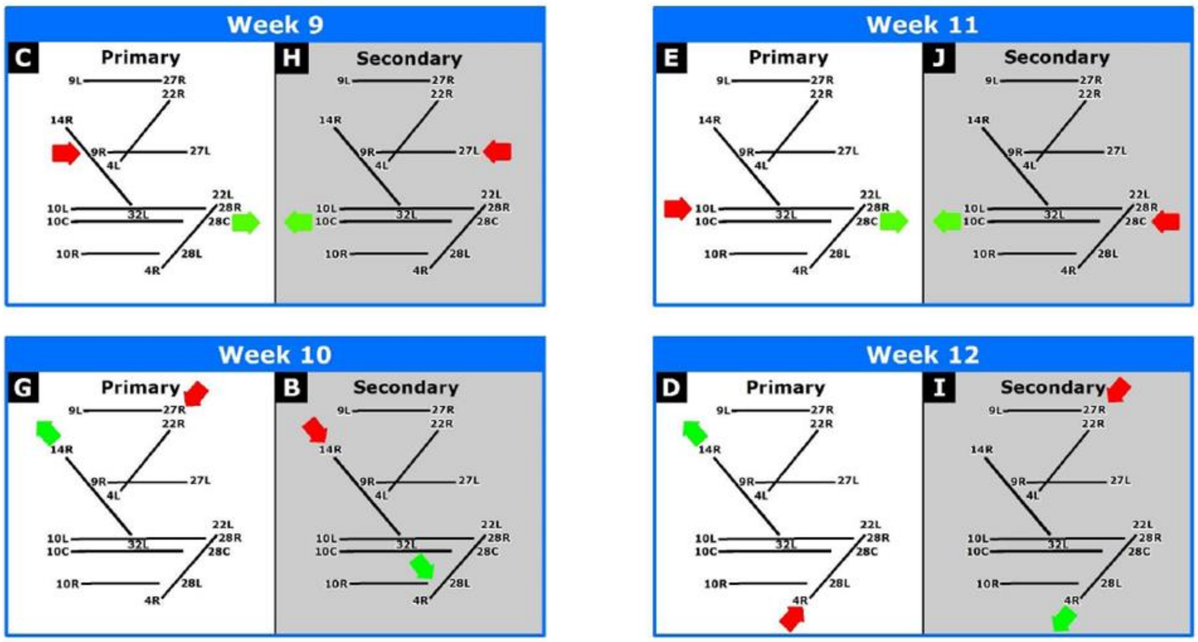

Figure 5: Proposed FQ II Runway Rotation Periods (Weeks 9-12).

Internal air traffic tower procedures vary based on airfield configurations and safety concerns specific to each airport operating environment. The proposed configurations and their use in the 12 week rotation periods should be submitted for approval to the FAA with the option of modifying configurations A through J as necessary to comply with standard operating procedures for use in the runway rotation test period.

3. DATA COLLECTION AND ANALYSIS

a. Flight Data

Detailed flight track data was provided by CDA after a request made by JDA. Data provided by CDA included nearly 6 months of data. Two requests were made during the duration of the project. The first request included 117 days of data from August 1 to November 30, 2015. The data was judged to be representative of the many operations at ORD. The data set included 284,552 flights (day and night operations) with an average of 11.4% nighttime events. The data included information on aircraft type, flight identification, detailed flight track (three dimensional information), time of day of the operation and runway used. Figure 6 illustrates the departure flight track data during 117 days at Chicago O'Hare International Airport during Fly Quiet 2 hours (~23:00 hrs. to 5:00 AM). Figure 7 shows a sample of the FQ II arrival flight track data used in this study. The data was processed using Matlab – an engineering analysis tool and further manipulated to develop input files required in the noise analysis.

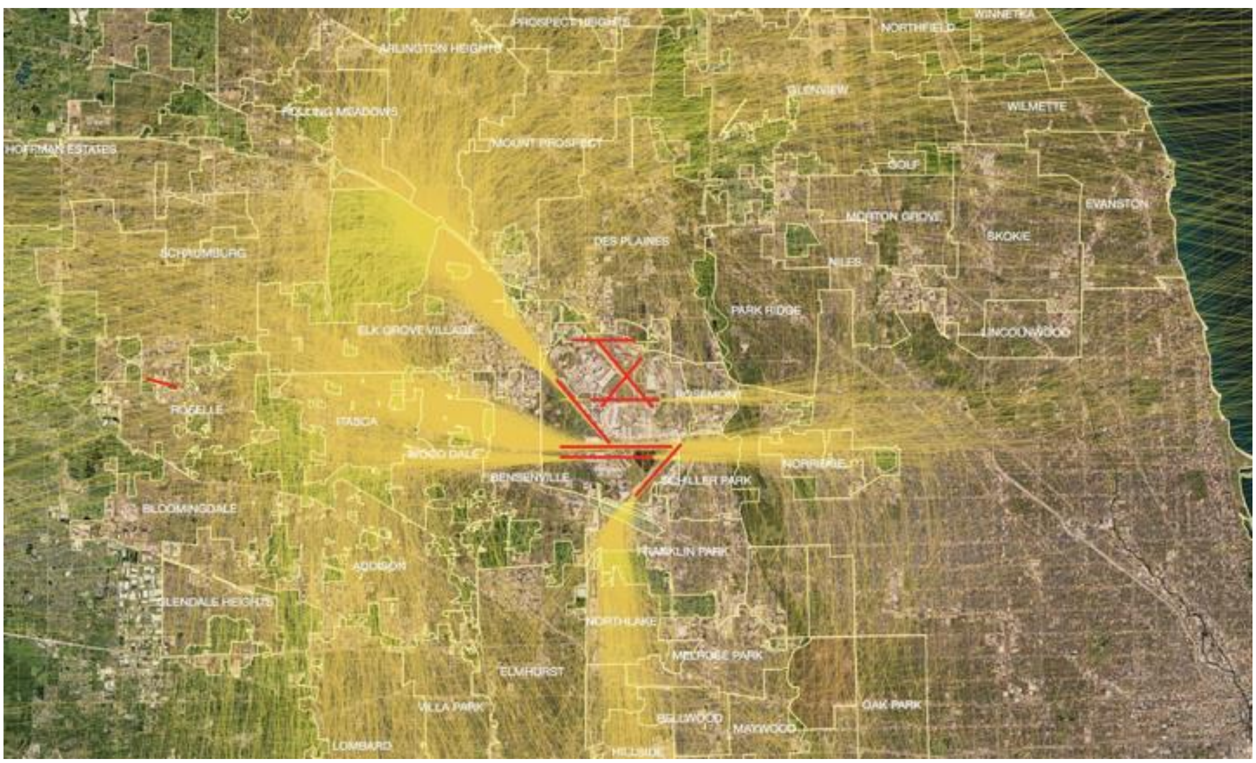

Figure 6: Sample Departure Flight Track Data Provided by CDA. Only Flight Quiet II Operations Period Shown.

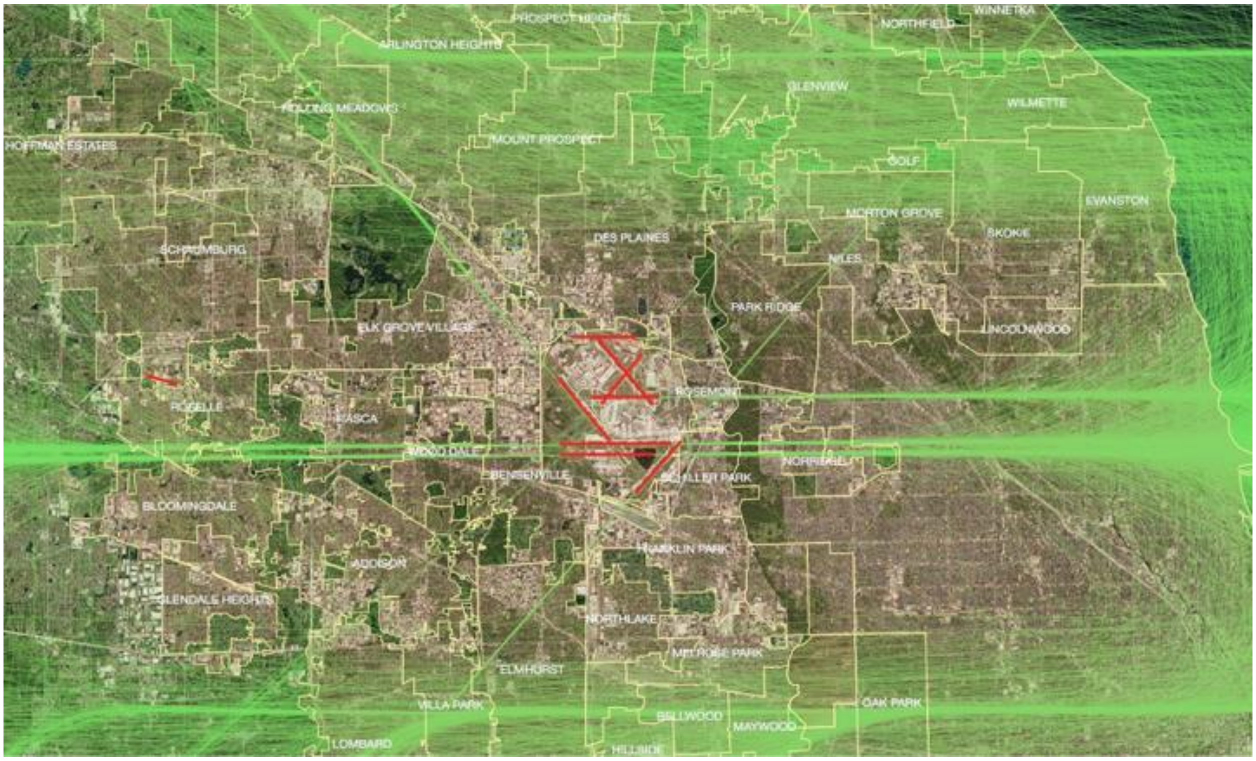

Figure 7: Sample Arrival Flight Track Data Provided by CDA. Only Flight Quiet II Operations Shown.

b. Fly Quiet II Period

The Fly Quiet period is that period of time when runway operations at the airport subside to a level that one arrival runway and one departure runway suffice to provide enough runway capacity to process operations at the airport. Since each day is unique in terms of traffic activity, we defined the Fly Quiet period (called FQ II) as the average day when single runway operations can process the flight demand at the airport. Figure 8 shows the distribution of flight operations at ORD during the nighttime period (10 PM to 7 AM). The graphic shows the average arrivals and departures observed in 117 days of data at the airport. Detailed analysis of the operations shows that the Fly Quiet II period at the airport starts at 22:50 PM and ends at 5:25 AM on average. During this period, an average of 86.7 operations are recorded at the airport. During FQ II there are 51.4 arrivals and 35.3 departures.

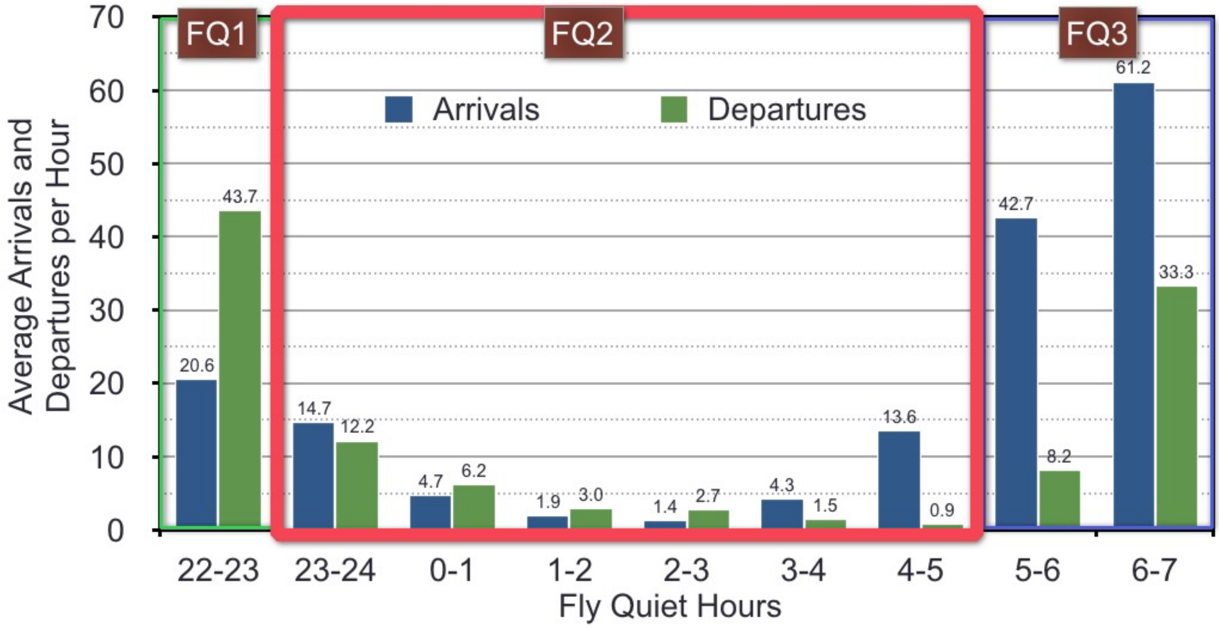

Figure 8: Definitions of Various Fly Quiet Periods at the Airport. Bars Present Average Arrivals and Departures in 117 Days.

c. Fleet Mix

The fleet mix at the airport during the Fly Quiet period is distinct compared to daytime operations. At night, the airport has a lower percent of regional jet operations and a higher percent of heavy aircraft operations. Figure 9 shows the top 24 aircraft types operated at ORD during the FQ II period. Note that narrow body aircraft make the top of the list (Boeing 737-800, 737-900 and Airbus A320). Heavy aircraft like Boeing 747-400, 777-300 and 747-8 also make the top 6 of the list with significant number of operations. In fact, 28.5% of the operations during FQ II hours are heavy aircraft weighting more than 260,000 lb. This is significant because heavy aircraft generate more noise while flying over the community surrounding the airport. To illustrate the point, consider that a single flyover of Boeing 747-400 generates the same acoustic energy as 13 passenger regional jets (Embraer 135). For modeling purposes, we restricted of aircraft defined in the noise model to 87 distinct aircraft types observed in the data sets provided by CDA. Furthermore, these aircraft were mapped to 40 aircraft types in the Integrated Noise Model. The aircraft fleet mix in the study is shown in the Appendix.

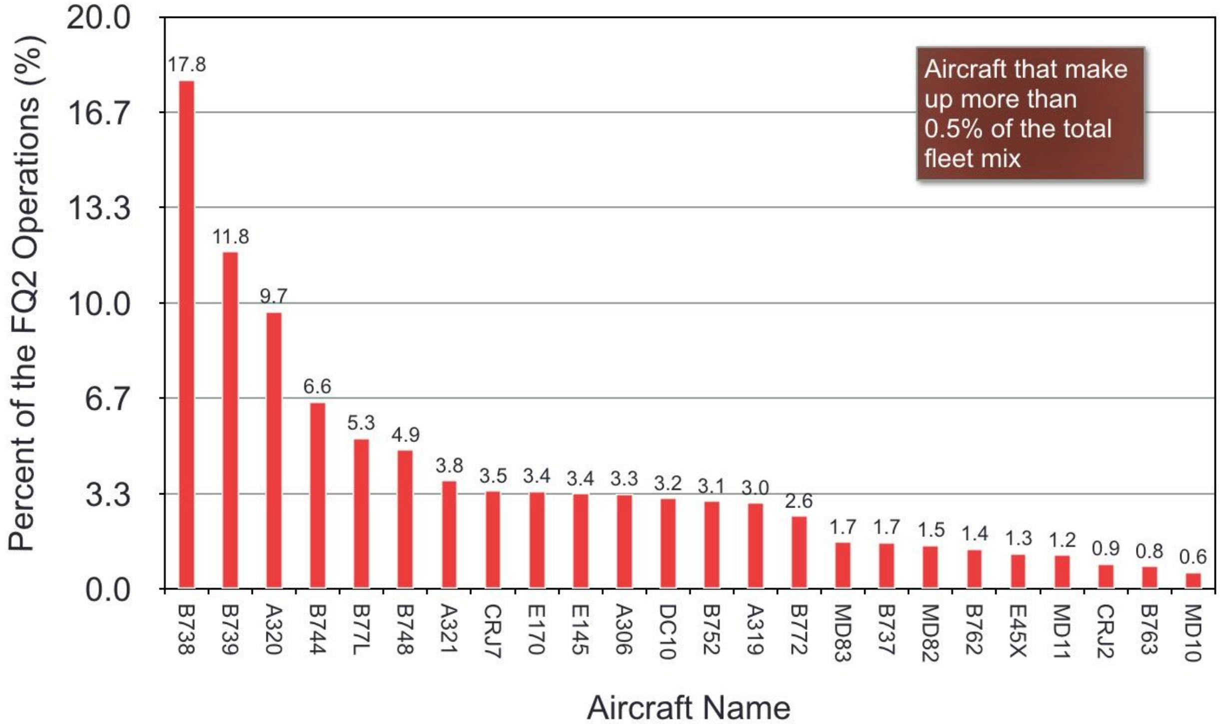

Figure 9: ORD Fleet Mix Operating During the FQ II Period (22:55 hr. to 5:25 hr.).

d. ORD Current Runway Operations in FQ II

Observation of 117 days of data provides useful information to understand how the airport is operated today. Table 1 contains the number of heavy aircraft operations recorded at the airport over 117 days by runway and aircraft type during the FQ II period. Heavy aircraft are defined as those with takeoff weight above 260,000 lb. The cells with brighter colors indicate more operations at the airport. For example, 239 Boeing 747-400 operations used runway 28R. The total number of operations by aircraft is shown in the last column of Table 1. Table 2 shows the number of operations by large aircraft at ORD during the FQ II period. Large aircraft are those whose takeoff weights are above 41,000 lb. and below 260,000 lb. The following observations can be made from the analysis of heavy aircraft operations during the FQ II period:

- The Boeing 747-400, Boeing 747-8, Boeing 777-300 and Boeing 777-200 are the most frequent heavy aircraft operating at ORD during FQ II hours
- Runways 28R and 28C are used 58% of the time by heavy aircraft during FQ hours
- Runway 32L accounted for almost 17% of the FQ heavy operations at ORD (all departures)
- During FQ hours, 94.3% of the heavy aircraft operations at ORD use a 9,600 ft. runway or longer

The most striking fact about these findings is that 94.3% of the heavy aircraft operations use long runways at ORD. The number is intriguing because even for arrivals, long runways are assigned to heavy aircraft with high frequency. It is unknown if these are pilot requests or assigned by ATC for convenience in handing the aircraft after the landing rollout.

Table 1: Heavy Aircraft Operations at ORD during FQ II Period Hours.

		Operations by Aircraft and by Runway at ORD										
Runway Length (ft)	10801	13000	9686	8075	7967	10801	13000	9686	10005	7500	7967	
Heavy Aircraft	10C	10L	14R	22L	27L	28C	28R	32L	32R	4R	9R	Grand Total
A306	32	19	4	21		100	44	52		4		276
A30B	4	14	2			6	17	12				55
A332		1					2	2				5
A333		1		1				2				4
A343		3		1			10	5	1			20
A346		3					3	2				8
B744	37	73	12	5	4	153	239	89		1		613
B748	20	70	8	4		98	167	105	1			473
B74F							6	1				7
B762	10	15		20	3	32	19	35			1	135
B763	2	9	1	9	2	8	22	18			3	74
B764		1	1		1		2	1				6
B772	20	29	4	1	26	51	94	10			1	236
B773		1					1					2
B77L	31	57	6	4	2	130	190	61		1		482
B77W	2	6		2		6	19	31	1			67
B788		1				1	10	5				17
DC10	39	23	3	10		89	50	65		1	1	281
MD10	5	5		1		17	12	13				53
MD11	8	14	2	1		38	35	10				108
Grand Total	**210**	**345**	**43**	**80**	**38**	**729**	**942**	**519**	**3**	**7**	**6**	**2922**
Percent Use by Heavies (%)	7.2	11.8	1.5	2.7	1.3	24.9	32.2	17.8	0.1	0.2	0.2	100.0

Table 2: Large Aircraft Operations at ORD during FQ II Period Hours.

	Runway				Operations by Aircraft and by Runway at ORD										
Runway Length (ft)	10801	13000	9686	8075	7500	7967	7500	10801	13000	9686	7967	7500	8075	7967	
Aircraft Group	10C	10L	14R	22L	22R	27L	27R	28C	28R	32L	32R	4L	4R	9R	Grand Total
A319	18	23	8	12		37		79	69	45	3	1		3	298
A320	77	115	32	46	2	136		226	258	147	1	1	6	10	1057
A321	28	41	14	9		44		96	108	47	1		3	1	392
B712						3		1	3	1					8
B734	2	6		2		1		2	13						26
B737	7	13	8	15	1	14		21	36	28	2	1	2	5	153
B738	133	174	51	92	3	248	2	487	442	197	4		10	19	1862
B739	97	116	32	33		133		279	288	102	2	1	7	11	1101
B752	28	27	3	6		12		96	52	56	1		1	2	284
B753								1	4	2					7
CRJ2	7	9	1	13		6		17	25	28	2				108
CRJ7	24	19	8	45	1	27		61	71	138	3	1		13	411
CRJ9			1			4		1	2	1					9
E135	3			5		5		2	5	10		1			31
E145	32	22	10	41		38		99	74	111	5			10	442
E170	18	28	10	41		38		88	76	171	7		1	8	486
E190		3				5			3	4					15
E45X	3	12	3	19		13		18	28	46	2		1	8	153
FA7X									1						1
GALX				1											1
GL5T		1													1
GLEX								1							1
GLF4	1	2				1		2	2	2					10
GLF5	1					1		1			1				4
MD82	7	5	3	18		10		41	37	28		1	1	2	153
MD83	10	8	8	24		11		17	46	34				2	160
MD88		1		1		2		5	3						12
MD90	1	3	2	1		3		6	6						22
Grand Total	**497**	**628**	**194**	**424**	**7**	**792**	**2**	**1647**	**1652**	**1198**	**34**	**7**	**32**	**94**	7208
Percent Use by Large (%)	6.9	8.7	2.7	5.9	0.1	11.0	0.0	22.8	22.9	16.6	0.5	0.1	0.4	1.3	100

The runway use of shorter runways improves for large aircraft (see Table 2) but not by much. According to the data provided, 81% of the time the airport's three longest runways (10L/28R, 10C/28C and 14R/32L) are used by large aircraft operating at the airport. In other words, during the FQ II period, most of the aircraft operations at ORD are using long runways in significant numbers. This fact affects any runway rotation plan because it implies that long runways always need to be available for long range flights irrespective of the runways planned in the rotation plan.

Managing the preference of a long runway versus the requirement for a longer runway is difficult. In order to estimate the percent of heavy aircraft runway operations requiring a long runway at ORD, we conducted an analysis of takeoff roll distance using the CDA flight track data. Figure 10 shows cumulative takeoff roll distributions for heavy jets using ORD today. The plot shows that 28% of the Boeing 747-8 use more than 10,000 feet of runway while departing the airport from runway 28R. In the figure we estimate takeoff roll distance to the point where the aircraft crosses an imaginary 35 feet obstacle at the opposite end of the runway. The analysis should be considered a first-order analysis due to the inherent precision of the sensor used to collect the data. However, the information shows that under any runway rotation plan, some aircraft will request the longest runways at ORD. To verify the findings shown in Figure 10, we also studied the average stage lengths flown by aircraft operating at ORD during the FQ II period. A plot showing the great circle distance and the frequency of flights is shown in Figure 11. The figure shows significant number of flights with great circle distances above 3,000 nm. For example, the data shows that 32% of the heavy aircraft fly routes longer than 3,000 nm from ORD.

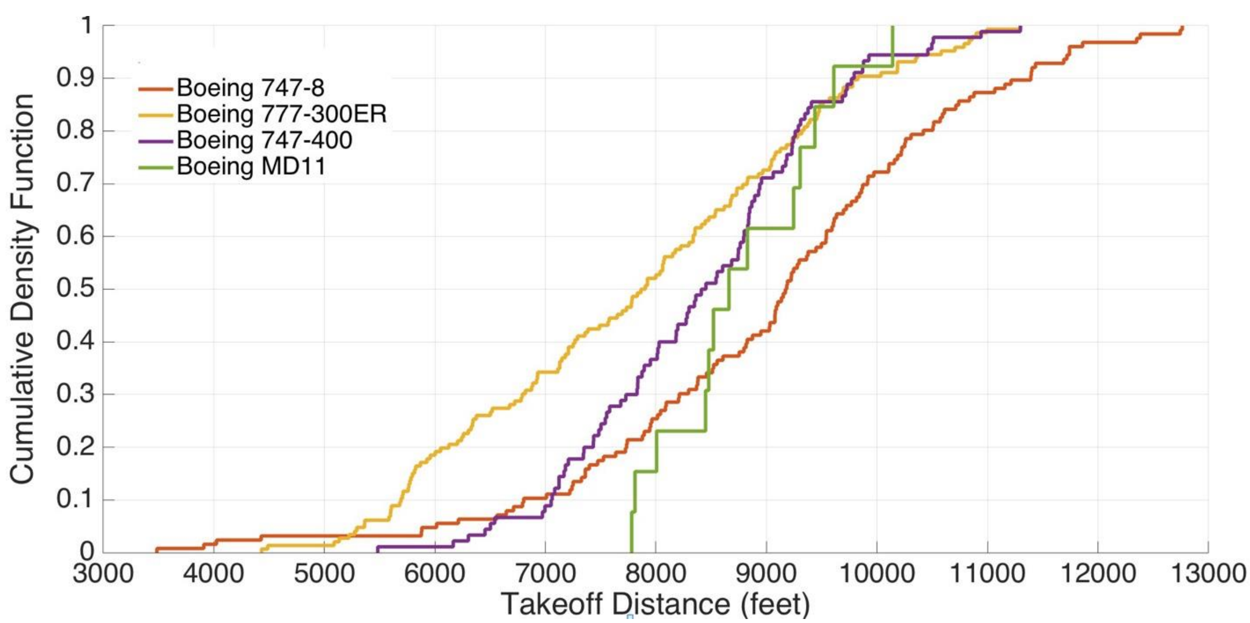

Figure 10: Estimated Takeoff Roll Distance for selected Heavy Aircraft Operating at ORD using CDA Data. Runway 28R Data.

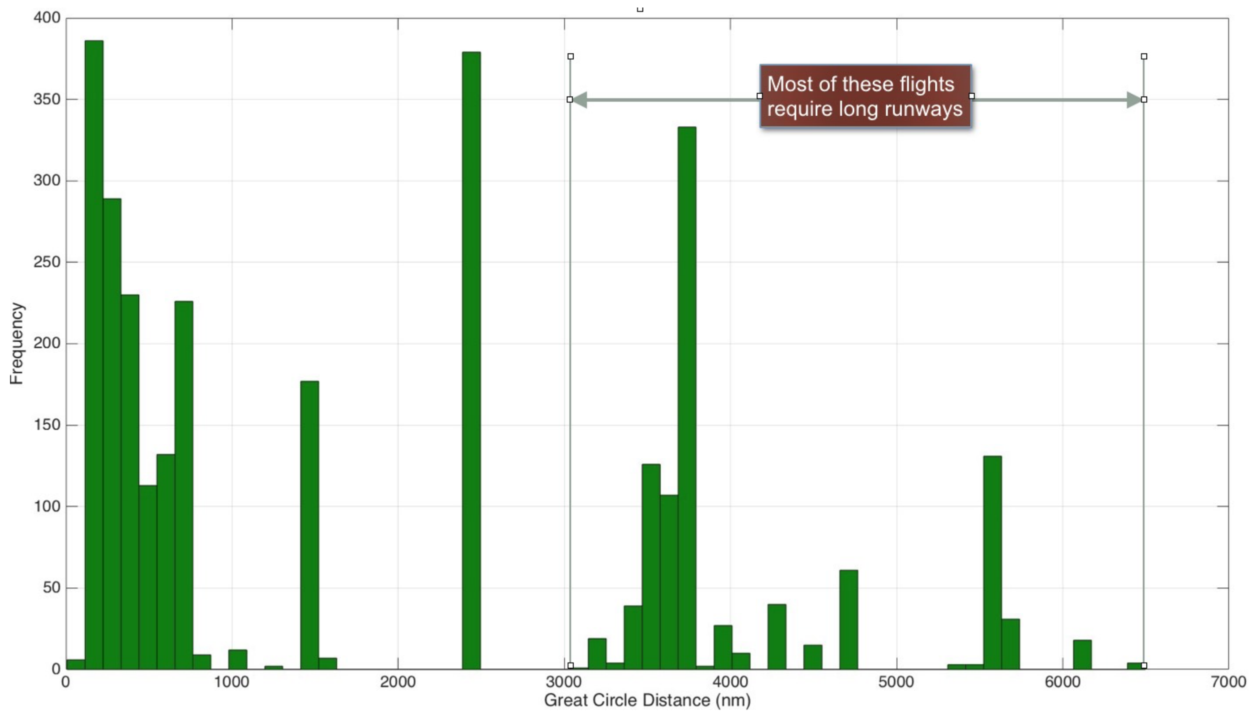

Figure 11: Great Circle Distance for Flights Operating at ORD International Airport.

e. Flight Track Data Analysis

The flight tracks provided by CDA were studied in detail to understand the traffic patterns in and out of the airport and in the terminal area. The goal was to understand the traffic flow patterns so that we could re-create expected traffic conditions associated with any proposed runway rotation plan. Figure 12 shows an example of the flight tracks associated with runway 32L. Given that runway 32L is used 17% during FQ II hours today, the traffic patterns shown in Figure 12 were duplicated in the rotation plan. For most of the 13 runway ends required in the CDA proposed runway rotation plan, there were enough tracks to prescribe future traffic patterns. Figure 13 illustrates the departure patterns from runway 28R at ORD. Note that in both figures, it is clear that large heading dispersions are observed at the airport.

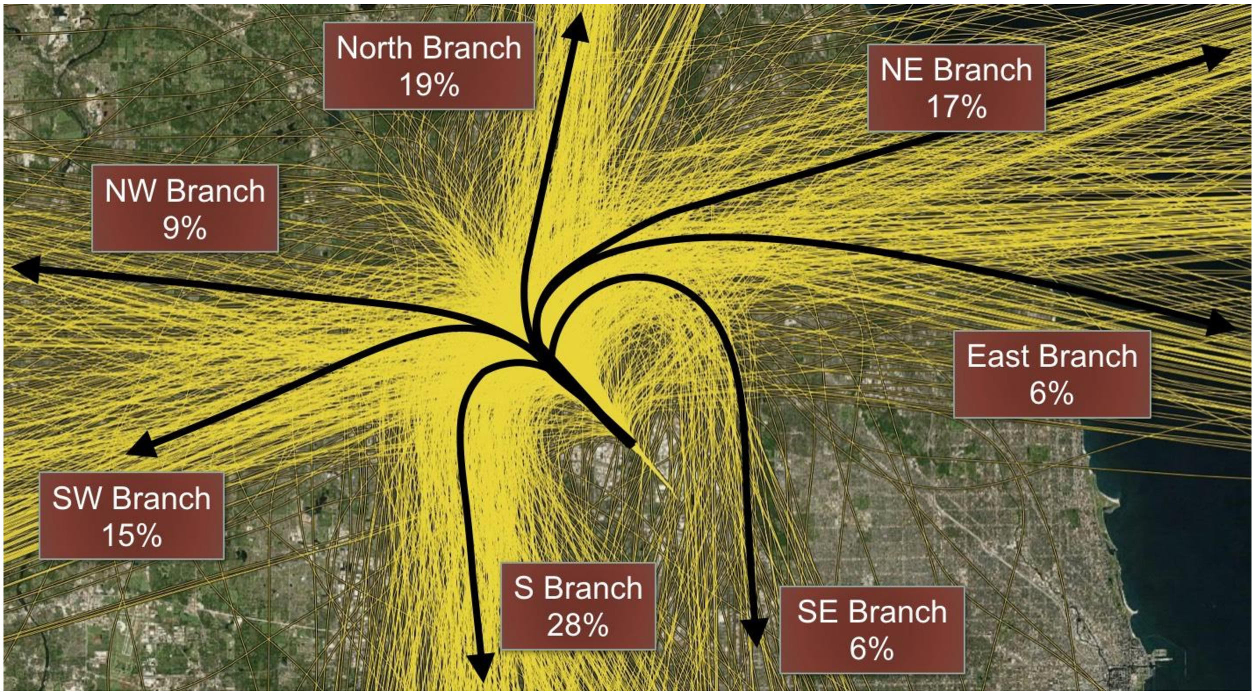

Figure 12: Example of Departure Traffic Flows Associated with Runway 32L. 1756 Flight Tracks Shown.

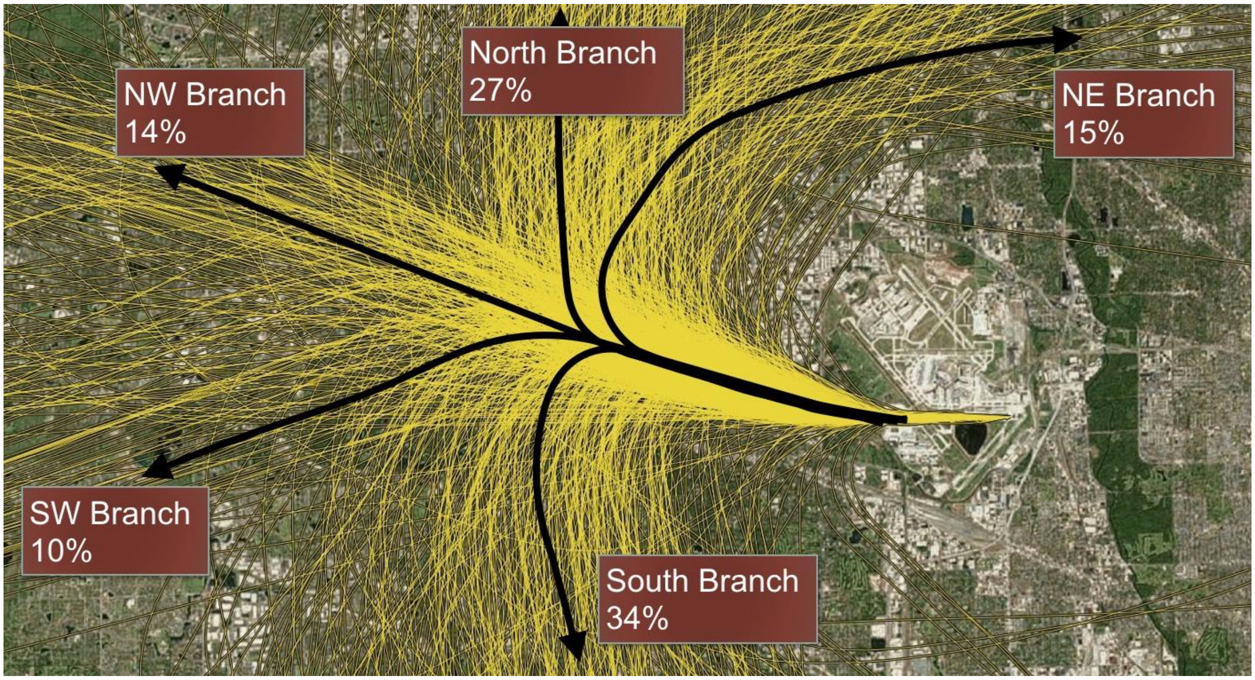

Figure 13: Example of Departure Traffic Flows Associated with Runway 28R. 1036 Flight Tracks Shown.

4. NOISE ANALYSIS METHODOLOGY

The Federal Aviation Administration (FAA) Integrated Noise Model (INM) version 7.0d was used to model each of the weekly runway plan scenarios in the proposed Runway Rotation Plan (RRP). Using individual weekly runway rotations, a composite 12 week INM scenario was produced to establish objective comparisons between the baseline and the proposed runway rotation plan. Figure 14 illustrates the method used to construct an INM model. Another important factor in the study is the aircraft fleet mix operating at the airport and more specifically, operating from each runway. These conditions were carefully studied in the data provided and appropriate flight operation files were prepared in INM to reflect the most recent ORD operating conditions.

The construction of INM cases was carried out using observed flight tracks at ORD during the FQ II period. The JDA team started with 10,250 FQ II tracks recorded in 117 days of data. A track "geometric reduction" exercise was carried out using mathematical algorithms that preserve the quality of the tracks during aircraft turning maneuvers. After the reduction and simplification of the tracks, we employed 5,289 flights tracks across all 13 runway ends to model noise impacts to the communities around ORD (see Figure 15). We produced a baseline set of flights during FQ II hours using the reduced set of tracks and observed runway use patterns at the airport.

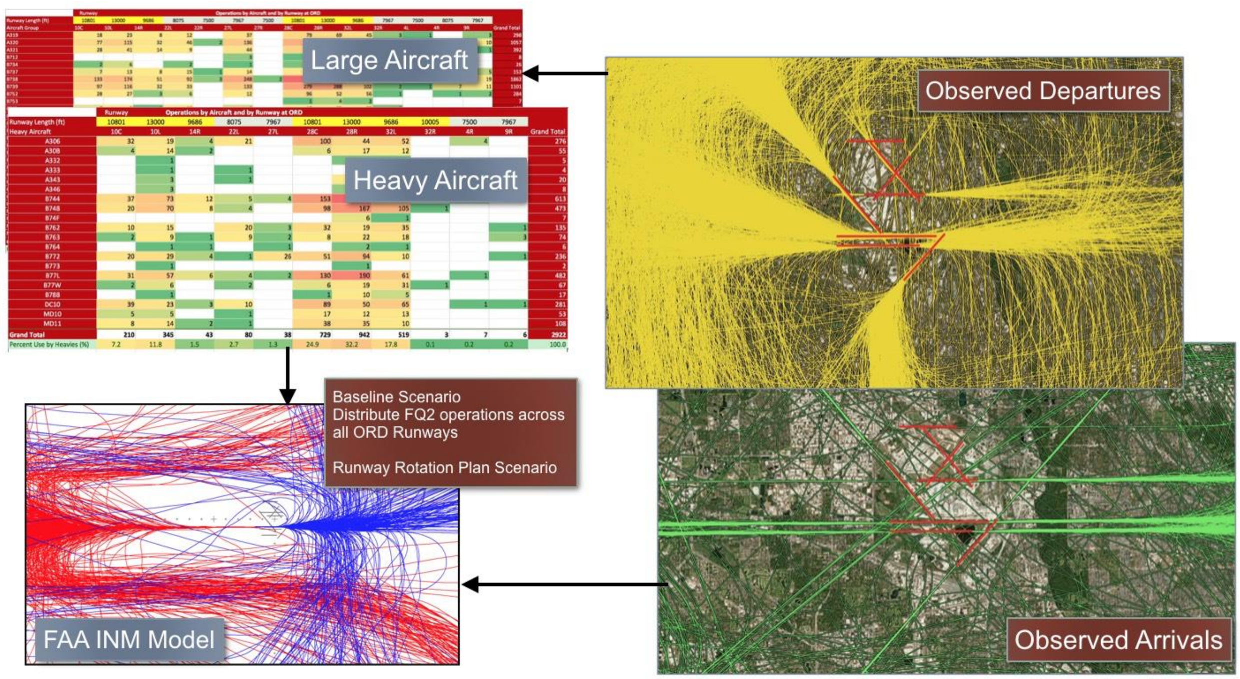

Figure 14: Integrated Noise Model Construction Procedure.

Figure 15: 5,289 Tracks Used to Model ORD Noise Impacts during FQ II Hours. Source of Data: CDA. Analysis by JDA.

5. RUNWAY ROTATION PLAN NOISE IMPACTS

a. ORD Baseline FQ II LAEQN Heat Map Analysis

Noise studies can rely on multiple metrics to estimate impacts of flight operations to the community. There is no perfect single value noise metric that can provide a clear estimate of a complex perception issue. For this study we decided to use the Night Equivalent Sound Level (LAEQN) to estimate noise impacts due to flights around the airport. **This study does not quantify the DNL metric because we only focus on partial nighttime flight events**. The Fly Quiet Program II normally starts when the airport is able to service the flight demand with one runway for arrivals and one for departures. Analysis of the flight operations at ORD suggests the FQ II period starts at 10:50 PM and ends at 5:25 AM.

To understand the impacts of any new procedure at an airport, it is necessary to develop a baseline case. Using the 117 days of FQ II data we developed a baseline LAEQN values for Census tract blocks using the runway loadings observed at the airport between August and November 2015. It is important to understand that conditions present during the baseline data timeframe will differ from the actual test period both in seasons and available runway mix. 09R/27L was closed during part of the baseline timeframe and runway 10L/28R will be closed during the proposed test period. Figure 16 shows a summary of runway utilization under the baseline conditions. The bars show the percent of time a runway is used at ORD for both arrivals and departures. Runway 32L handles 17.2% of the total FQ II operations (all departures). The airport saw little or no activity on runways 04R and 04L during the period of the data collected. Runway 04R was used 0.38% of the time whereas runway 04L was used 0.07% of the time.

The proposed runway rotation plan is expected to use runways 4R and 22R more frequently. For example, runway 22R is assigned as the primary landing runway for 3 out of 12 weeks of a typical cycle of the rotation plan. Since a single arrival runway is used during the FQ II period, this implies runway 22R could receive 25% of the landing traffic at ORD during FQ II over a 12-week period (weather permitting). Note that according to Figure 16 runway 22R was used 0.1% during the period of the data collection. Under the proposed rotation plan, runway 22R could be assigned 14.8% of the operations at the airport during the FQ II period. This is illustrated in Figure 17. The same figure serves to illustrate the expected used of runway 14R. This runway is expected to see a nearly three and a half times the traffic observed today. The runway loadings for the proposed runway rotation plan shown in Figure 17 attempts to better balance East flow operations. For example, runway 10L use could increase by 50%.

Figure 18 shows the baseline Census tract level heat map (in LAEQN) for the airport during FQ II hours using the runway use distribution of 117 days and the runway utilization shown in Figure 16. It is evident that the airport was operated mostly in West flow mode during the period of analysis. The LAEQN values show little influence of few operations on runways 04R and 22R.

This will be one of the main differences between the baseline and the proposed runway rotation plan.

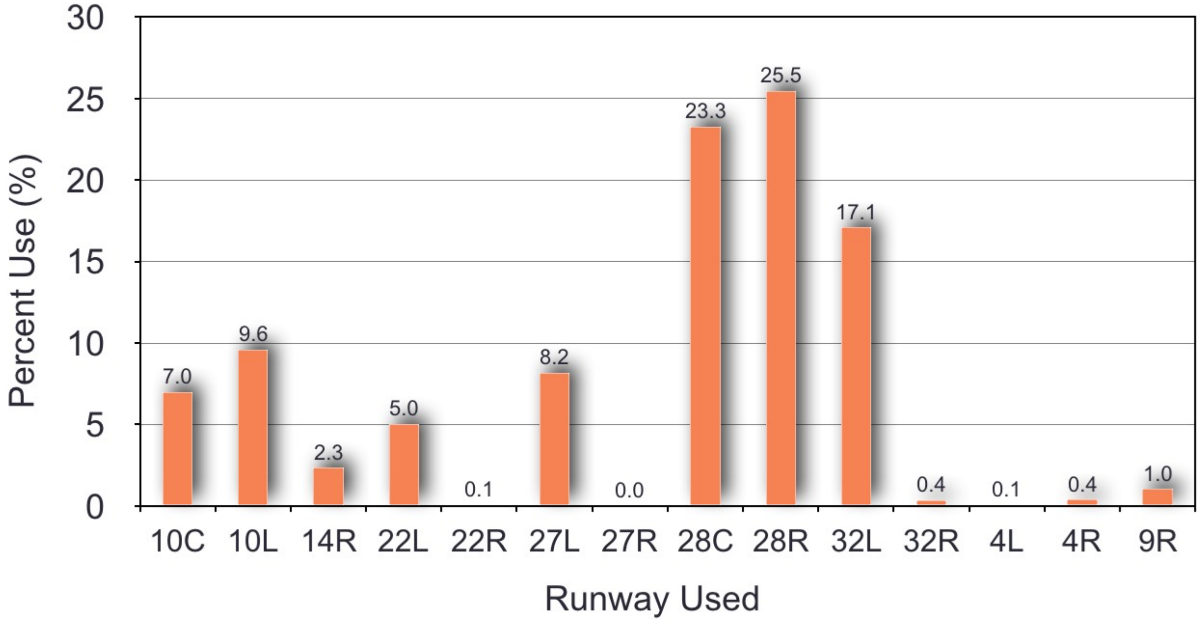

Figure 16: ORD Baseline Case FQ II Runway Use. 117 Days of Data (August-November, 2015). Some Runway Maintenance Occurred During that Period of Time. The Airport Is Seldom at Steady-State so a True Baseline is Difficult to Estimate.

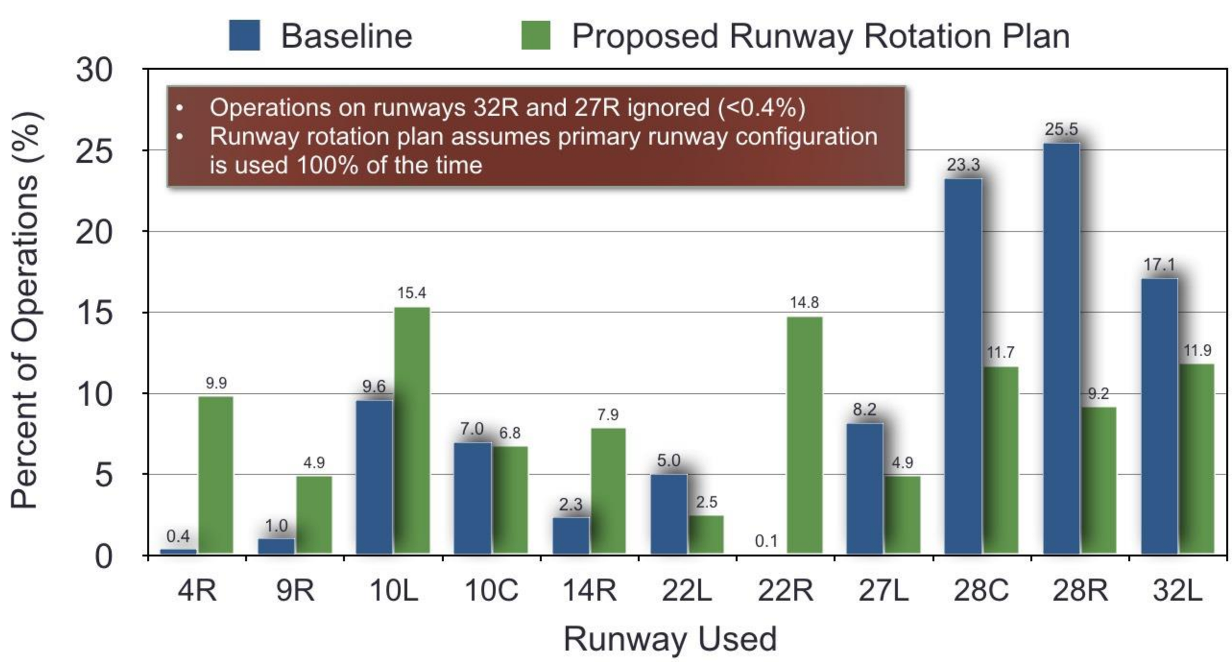

Figure 17: ORD Baseline vs. Proposed Runway Rotation Plan. 117 Days of Data (August-November, 2015). Some Runway Maintenance Occurred During that Period of Time. Runway Rotation Plan Statistics Assume 100% of the Primary Configurations Used during a Twelve Week Rotation Period.

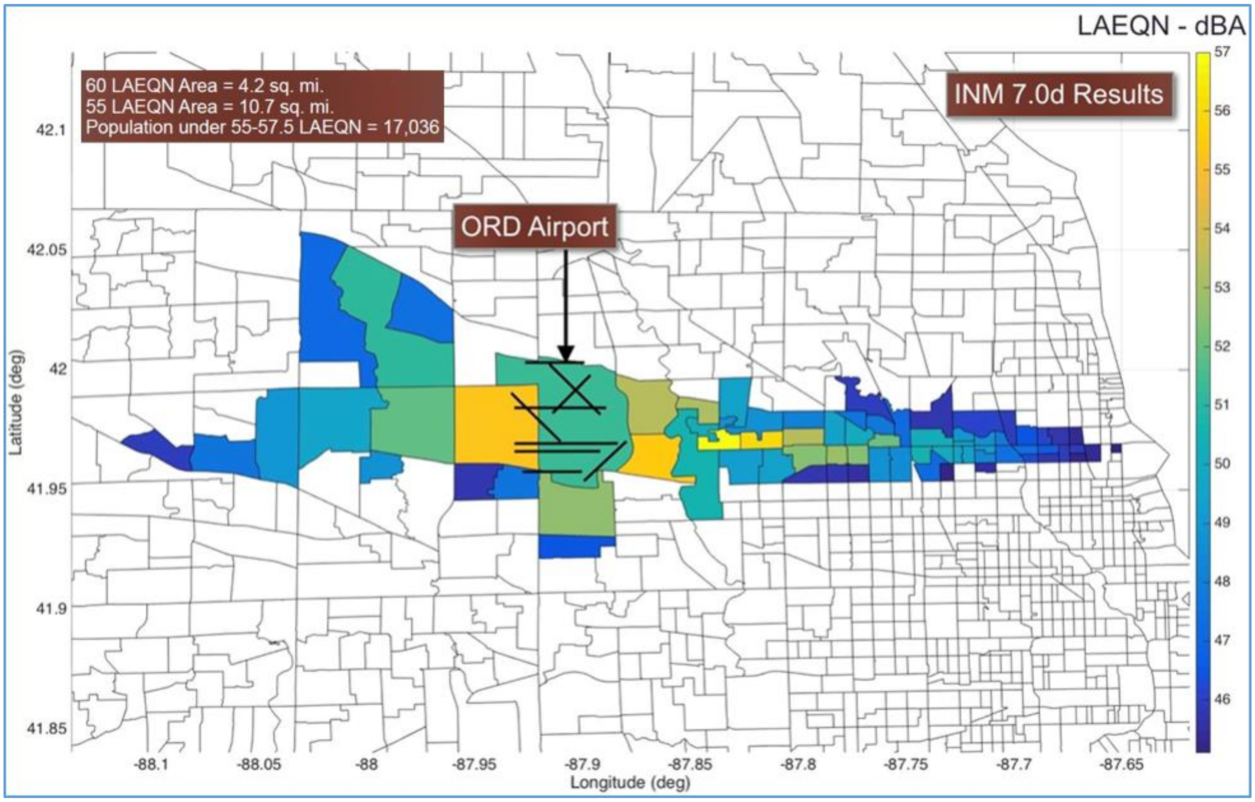

Figure 18: ORD Baseline Case FQ II Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Flight Patterns derived using 117 Days of Data (August-November, 2015). Noise Results Using INM 7.0d.

b. Runway Rotation Plan FQ II LAEQN Heat Maps for Runway Configurations A-J

In order to assess the noise impacts of a proposed runway rotation plan, we developed Census Tract level LAEQN value heat map for the proposed CDA 12-week rotation plan. This analysis combines 10 different runway configurations proposed by CDA (see configurations A-J in Figure 3) to generate a composite picture of ORD operations. In the analysis of the runway rotation plan we made the following assumptions: a) the primary runway configuration proposed in the runway rotation plan is used in each week of the plan; b) the fleet mix is the same as that of the baseline case (see Appendix A); and c) the runway configurations are weighted differently according to the CDA proposed runway rotation plan. For example, in the 12-week period, runway D and G (see Figures 4 and 5) are used twice. Other configurations are used once.

Using the FAA INM 7.0d model we generated Census tract level heat maps using the night equivalent sound level (LAEQN) noise metric for each runway configuration. Figure 19 shows the LAEQN heat map for runway configuration A of the proposed runway rotation. In configuration A, both arrivals and departures use the same runway (10L). The plot shows the LAEQN levels predicted by the model down to 45 dBA (ambient range).

Figure 20 shows the LAEQN heat maps for runway configuration B of the proposed runway rotation plan. In configuration B both arrivals and departures use the same runway (14R). Because runway 14R is 9,600 feet long, we estimate that a small number of heavy aircraft flying long-haul routes (> 4,000 nm) will request to use runway 10R during the FQ II period. This has been considered in our analysis. The LAEQN map shows this a small branch North of Norridge.

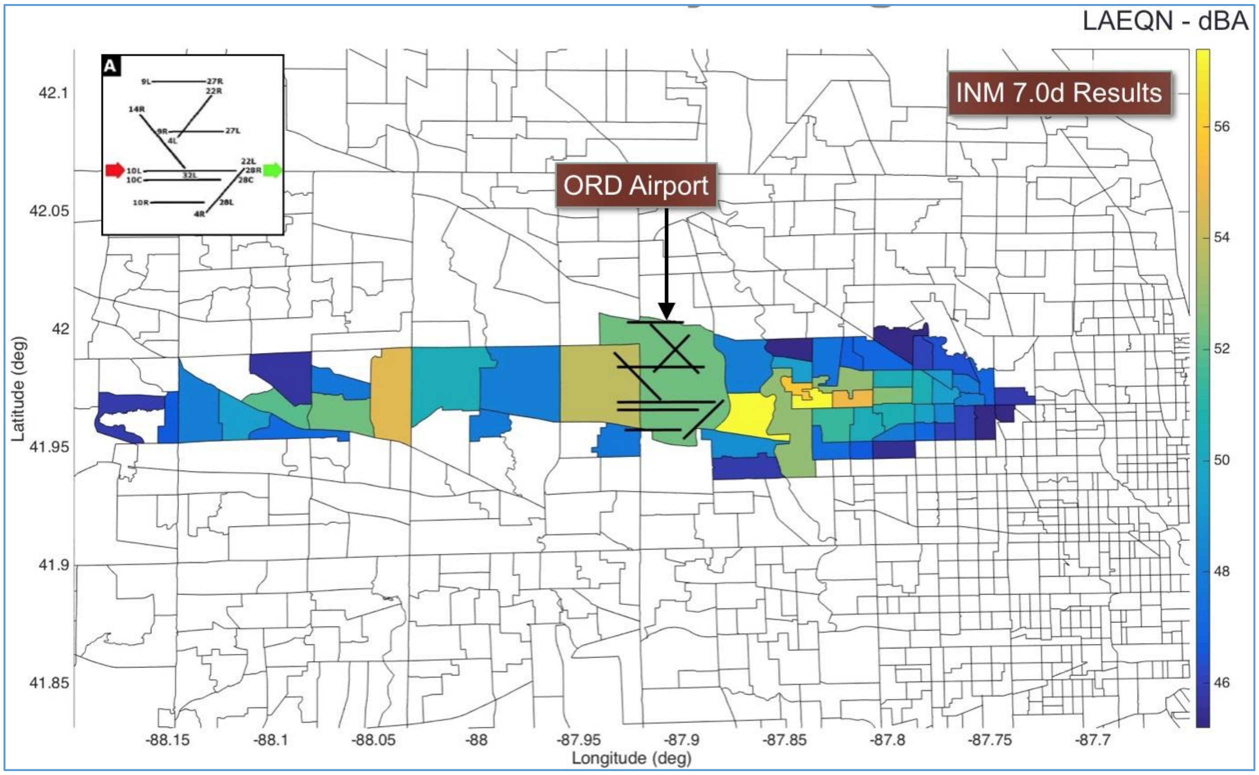

Figure 19: Runway Configuration A Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 10L Used in Mixed Operations.

Figure 21 shows the LAEQN heat map for runway configuration C of the proposed runway rotation plan. In configuration C runway 9R is used for arrivals and runway 10C for departures. Because runway 10C is 10,800 feet long, we assumed the runway can support long-haul routes.

Figures 22 through 28 show the LAEQN heat maps for runway configurations D through J, respectively. Each map shows the noise footprint of the operations. The maps also serve to illustrate that under the runway rotation program, significant noise mitigation will be experienced for many communities around ORD airport.

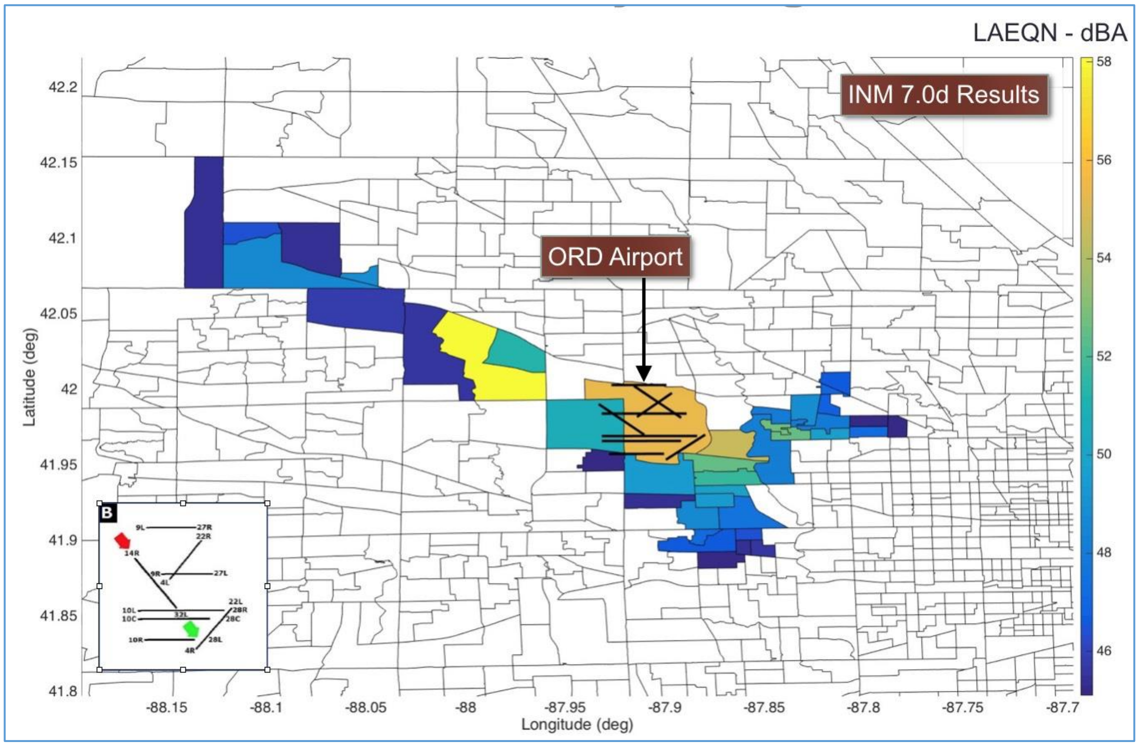

Figure 20: Runway Configuration B Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 14R Used in Mixed Operations. Runway 10L Used for Long Range Flights with Route Lengths Greater than 3,000 nm.

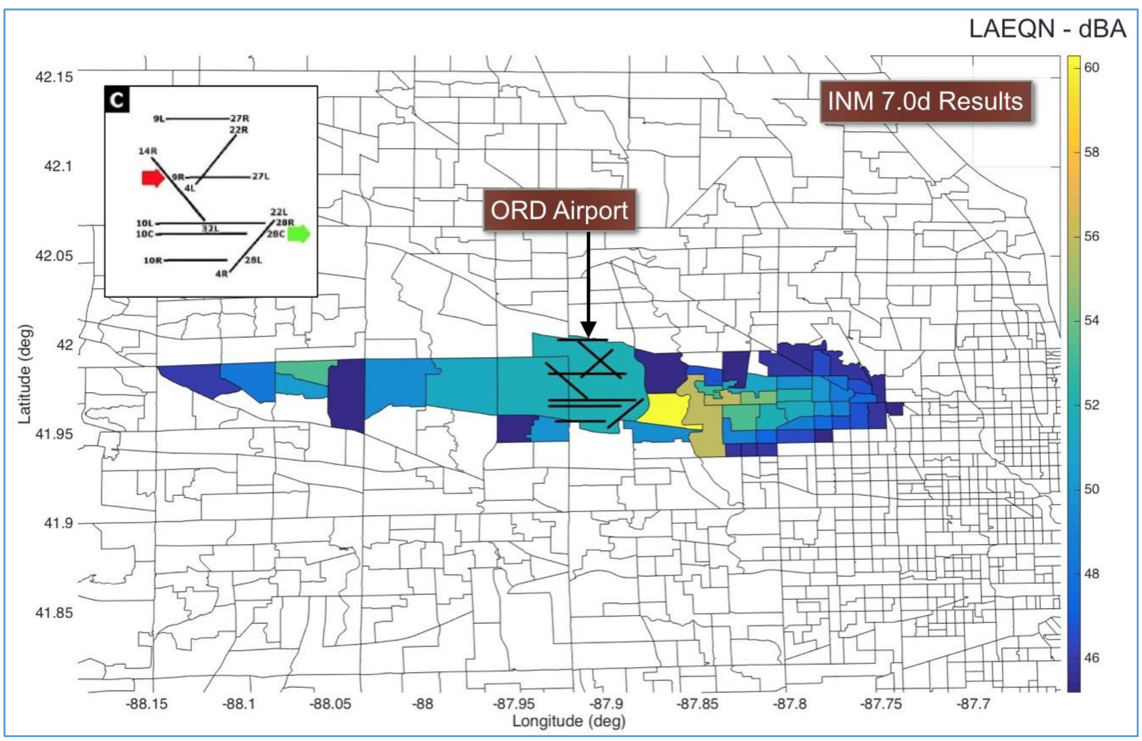

Figure 21: Runway Configuration C Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 9R Used for Arrivals and Runway 10C for Departures.

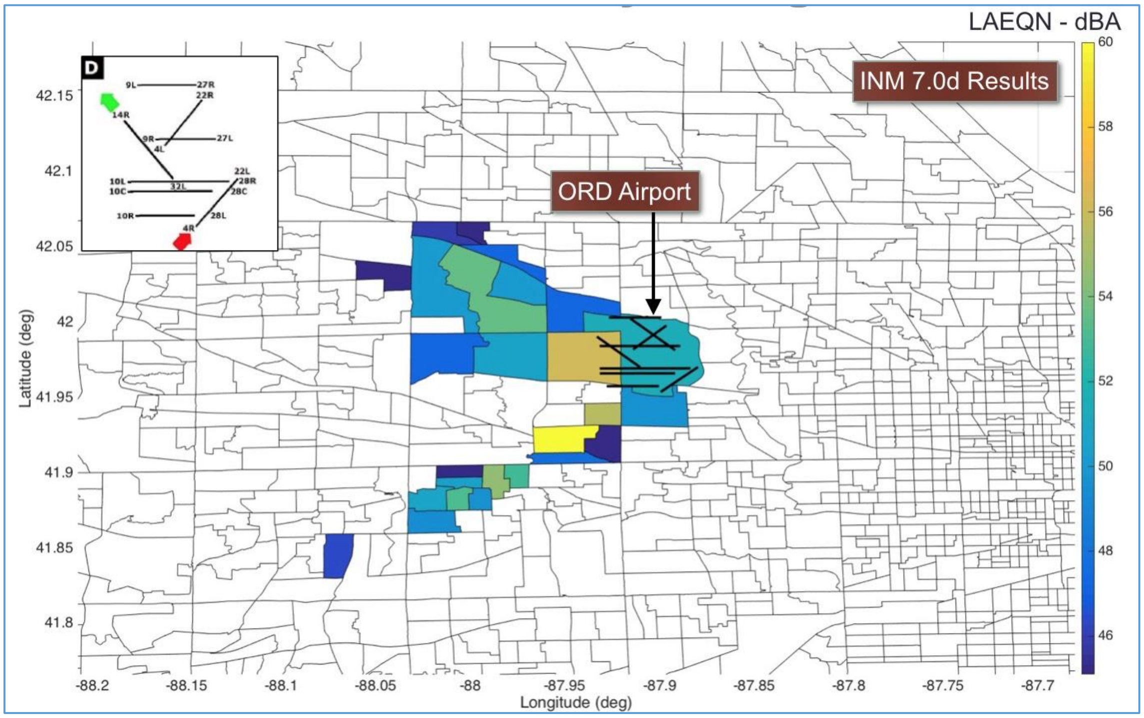

Figure 22: Runway Configuration D Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 4R Used for Arrivals and Runway 32L Used for Departures. Runway 10L Used for Very Long Range Flights with Route Lengths Greater than 4,000 nm.

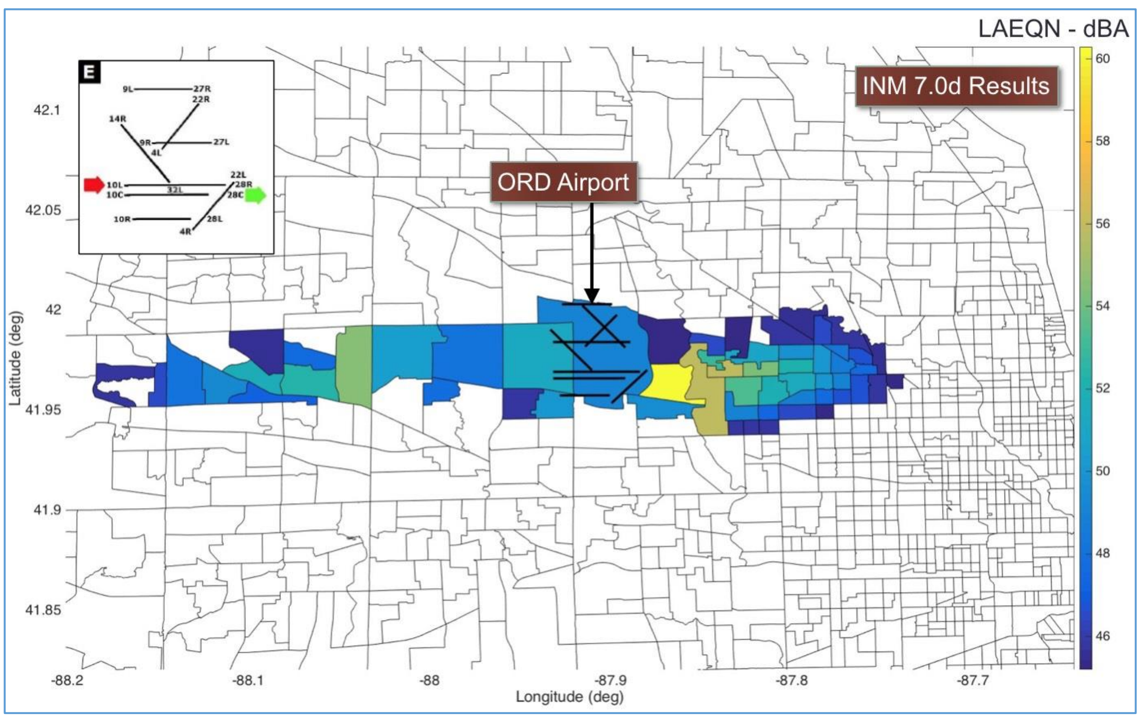

Figure 23: Runway Configuration E Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 10L Used for Arrivals and Runway 10C Used for Departures.

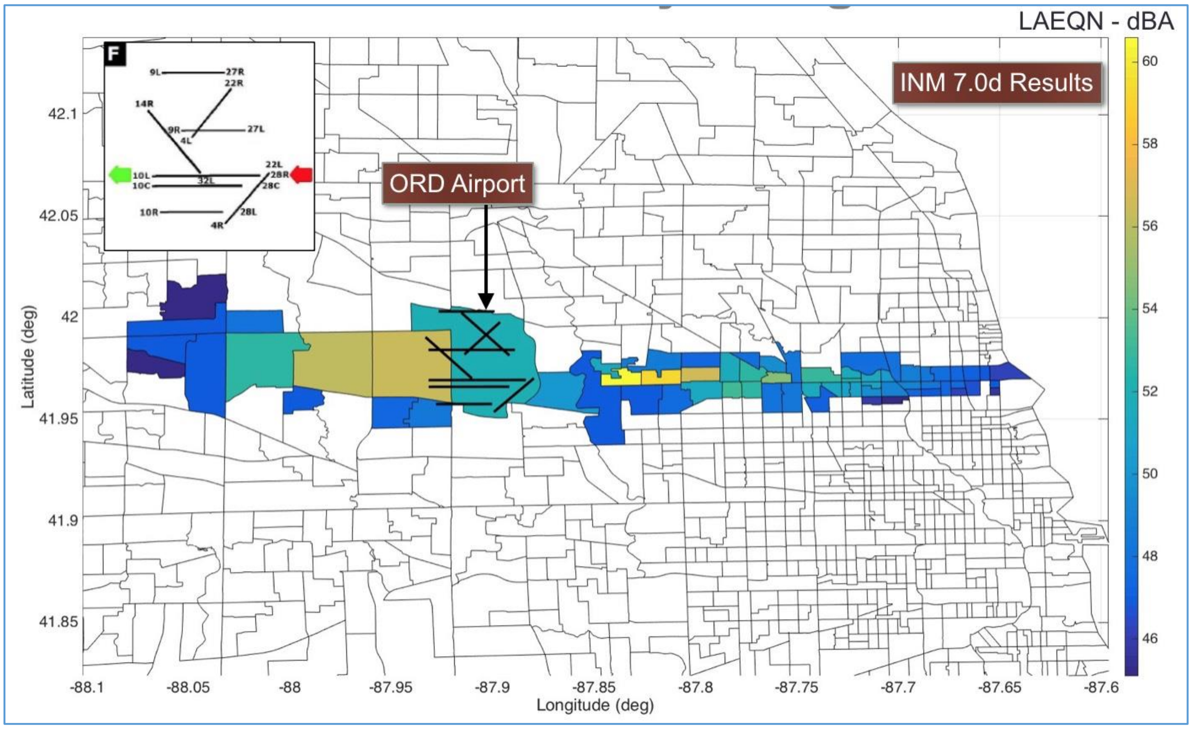

Figure 24: Runway Configuration F Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 28R Used for Arrivals and Departures.

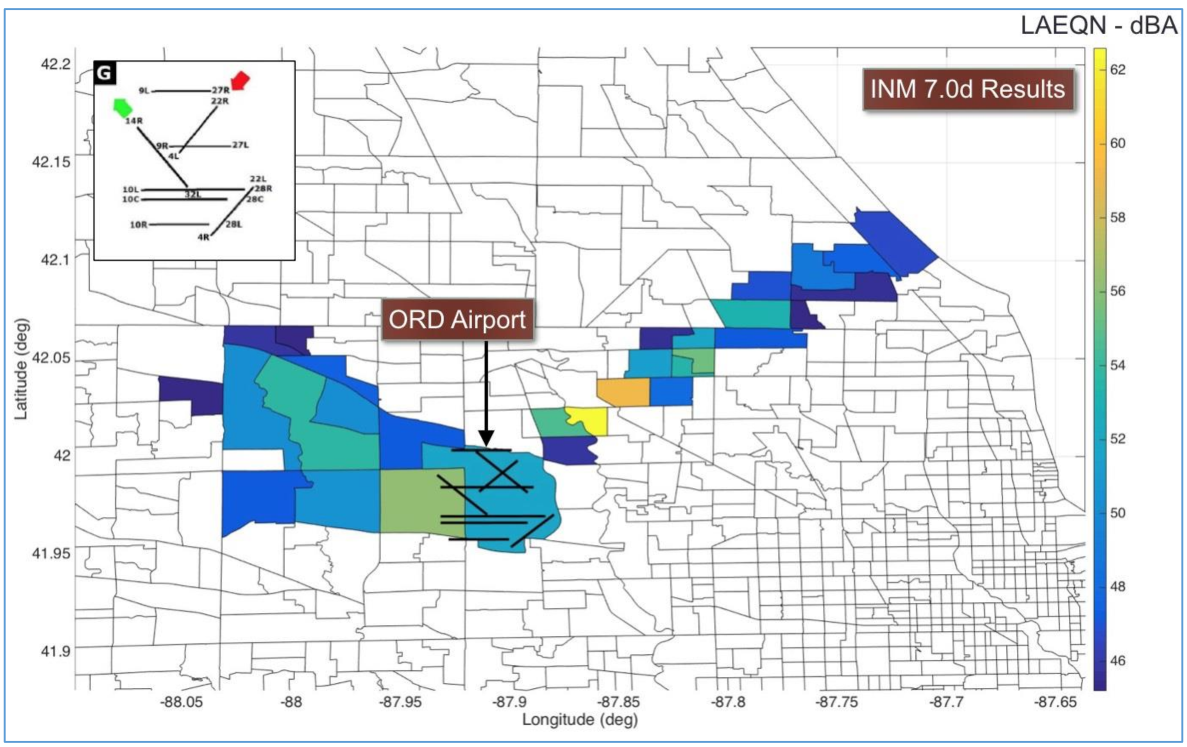

Figure 25: Runway Configuration G Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 22R Used for Arrivals and Runway 32L for Departures. Runway 10L Used for Very Long Range Flights with Route Lengths Greater than 4,000 nm.

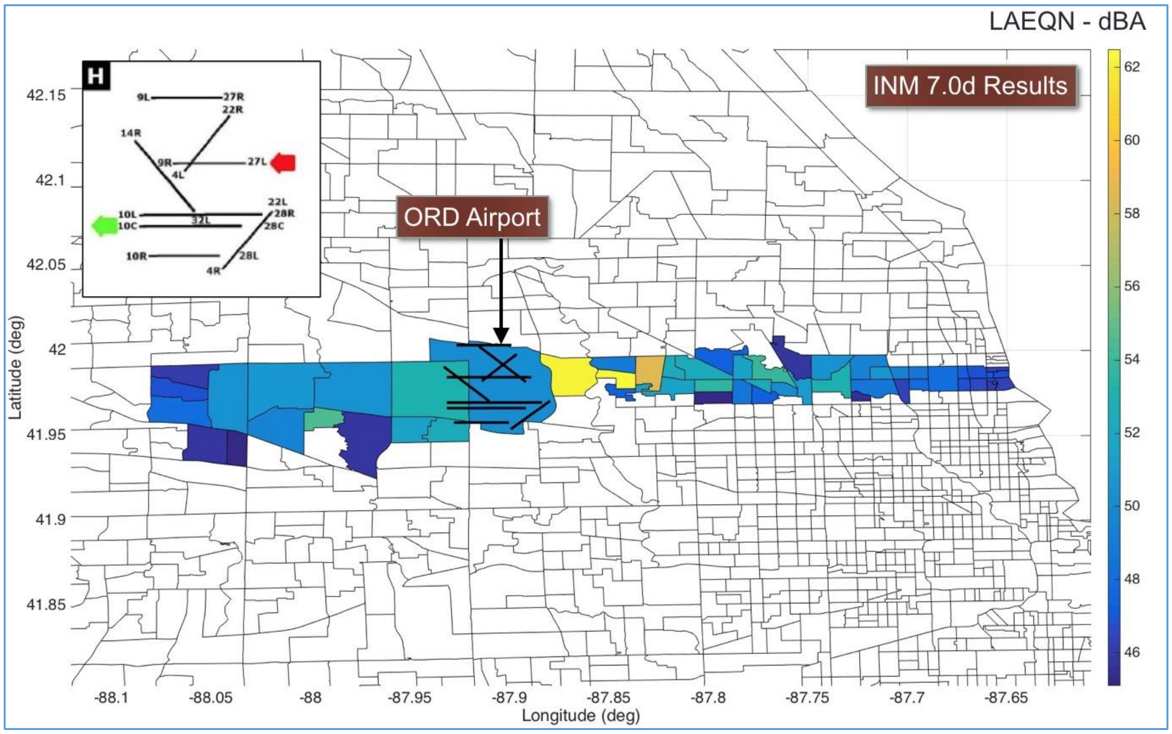

Figure 26: Runway Configuration H Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 27L Used for Arrivals and Runway 28C for Departures.

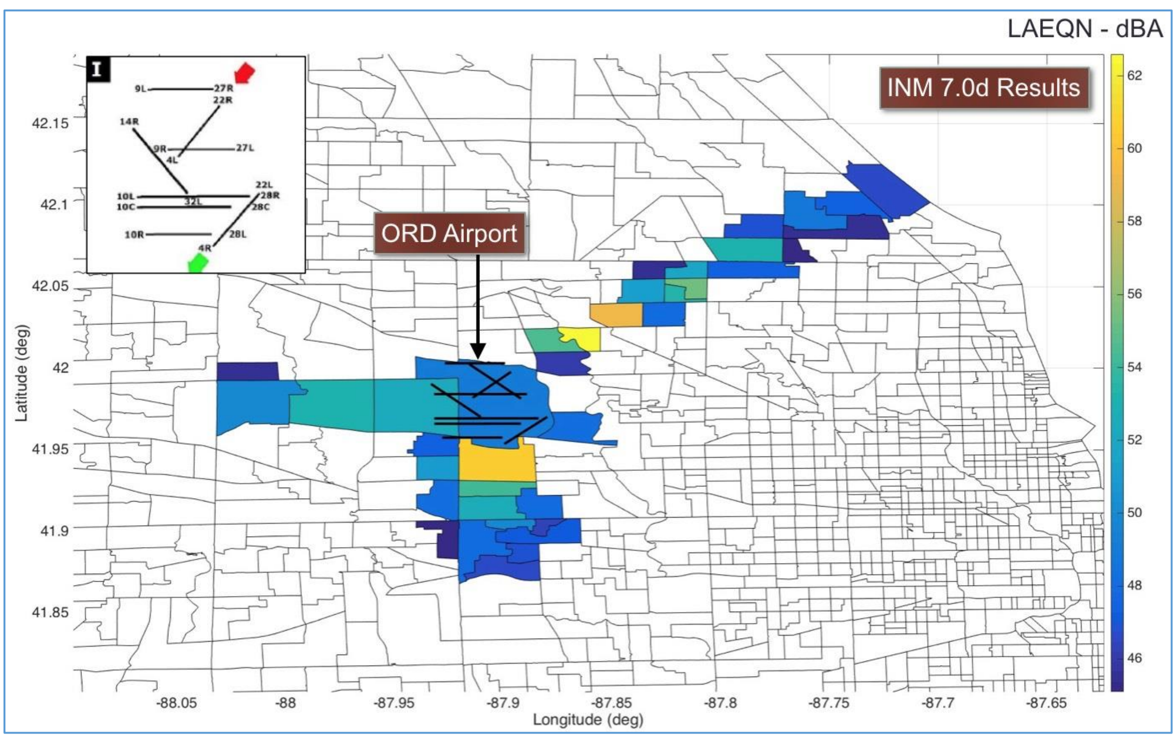

Figure 27: Runway Configuration I Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 22R Used for Arrivals and Runway 22L for Departures. Runway 10L Used for Long Range Flights with Route Lengths Greater than 3,000 nm.

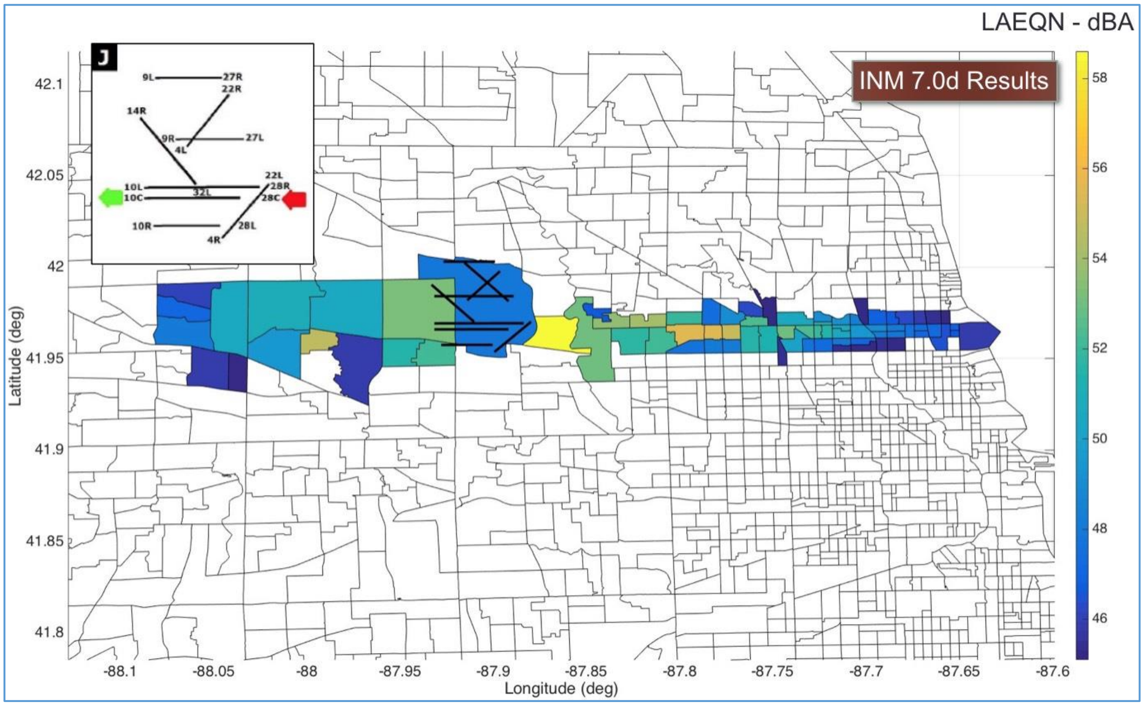

Figure 28: Runway Configuration J Night Equivalent Sound Level (LAEQN) Map with Areas above 45 dBA. Noise Results Using FAA INM 7.0d Model. Runway 28C Used for both Arrivals and Departures.

We combined the runway configurations shown in Figures 19-28 into one case (with appropriate weights considering that configurations D and G are used twice during the runway rotation program) and estimated the noise footprint using the LAEQN metric. The complete runway rotation pattern noise heat map is shown in Figure *29*. As expected, the figure shows a different shape than the baseline condition. Specifically, long and thin approach impacts associated with the use of runways 22R and 04R are shown the figure. Both of these runways were seldom used in the 117 days of data provided to the JDA team. In the runway rotation plan both runway 04R and 22R are used in three of the ten runway configurations.

Comparing the 55 LAEQN impact areas between the baseline and the proposed runway rotation plan it is **shown that the RRP solution reduces the size of the impact area at the 55 LAEQN level**. A reduction of 0.2 square miles in the 55 LAEQN level area is estimated if the runway rotation plan is implemented. While the reduction represents a small change, the most important benefit of the runway rotation plan is that it will offer more predictable noise impacts to the communities surrounding the airport on a weekly basis. The overall objective in the runway rotation program is to spread the noise patterns around the airport. Figure *29* suggest that will be the case if the primary runway configurations are used reliably every night. This analysis assumed the primary runway configurations shown in Figures 4 and 5 are used 100% of the time in the week they are scheduled.

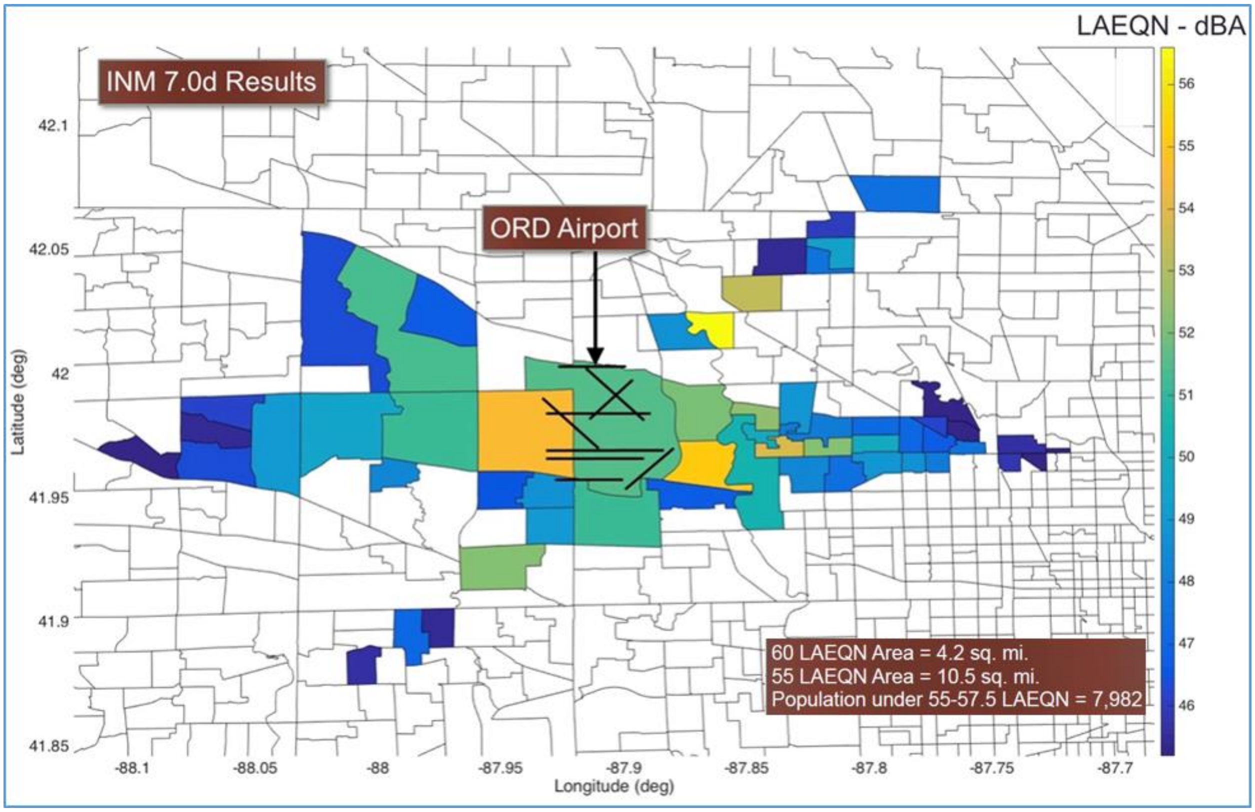

Figure 29: Proposed Runway Rotation Plan Noise Impacts. LAEQN Noise Metric Used in the Analysis. Map with Areas above 45 dBA Shown. Noise Results Obtained Using INM 7.0d.

c. Noise Metric Comparisons by Community

The noise analysis also produced noise level metrics at specific locations. For this analysis, we used the centroids of 1,685 Census tracts as location points of interest to understand the noise impacts at each community around ORD. Figures 30 through 38 illustrate the potential impacts of the runway rotation program for each of the SOC communities. Each figure shows the average value of LAEQN taken from all Census tracts inside each town over a twelve-week runway rotation period. The analysis presented assumes that each week of the runway rotation program, the primary runway configuration will be used as scheduled 100% of the time. For example, the town of Itasca has an average LAEQN of 49.7 dBA in the baseline configuration. During the 12-week rotation program, the town will experience 5 weeks of reduced noise levels compared to the baseline. Specifically, during week 2 with runway configuration B in place, Itasca will be a much quieter place because all the runway operations will be conducted on runway 14R (takeoffs and landings). Similarly, Elk Grove Village will have very quiet nights on weeks 7 and 11 when runway configurations A and E are used. These configurations use runways 10L and 10C for their operations and have aircraft flying further from Elk Grove.

It is important to note that the purpose of the runway rotation program is to spread noise and provide some predictability on when noise will occur at each community. There are exogenous factors that will cause deviations from the schedule. For example, wind conditions may limit the use of a primary runway configuration during the whole week. The summer 2016 runway rotation program test will provide more insight on the predictability of weekly rotation periods. Table 3 summarizes the LAEQN levels estimated for each community over a 12-week period if the runway rotation program is implemented as scheduled.

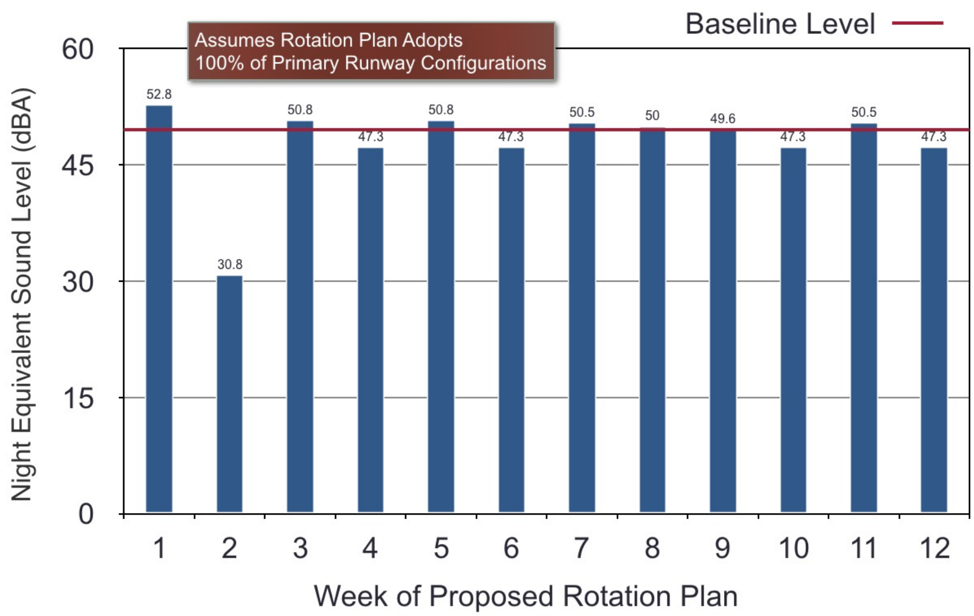

Figure 30: Estimated Values of Night Equivalent Sound Level (LAEQN) for Itasca. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

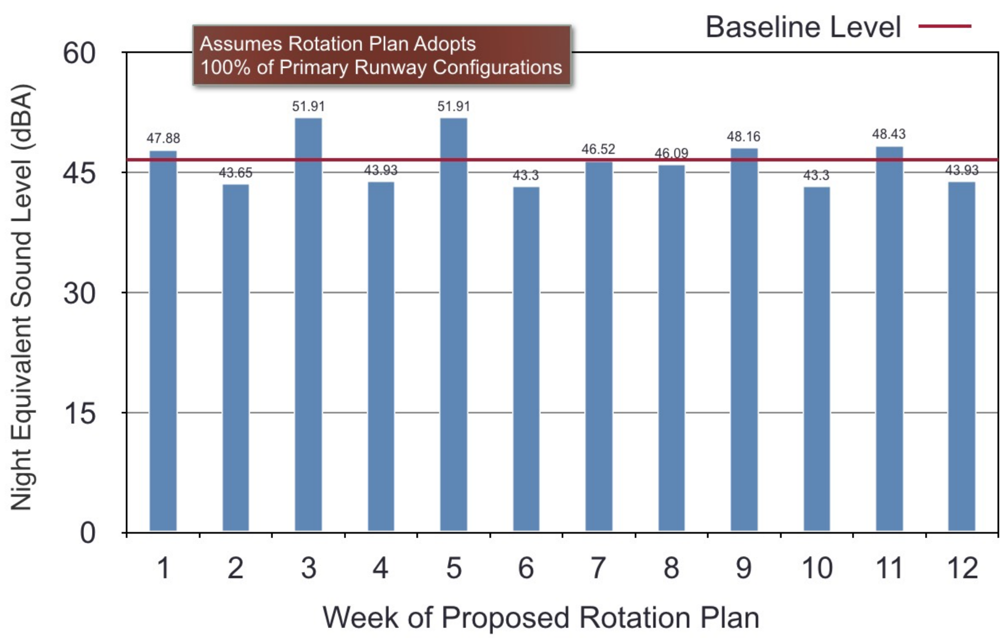

Figure 31: Estimated Values of Night Equivalent Sound Level (LAEQN) for Bensenville. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

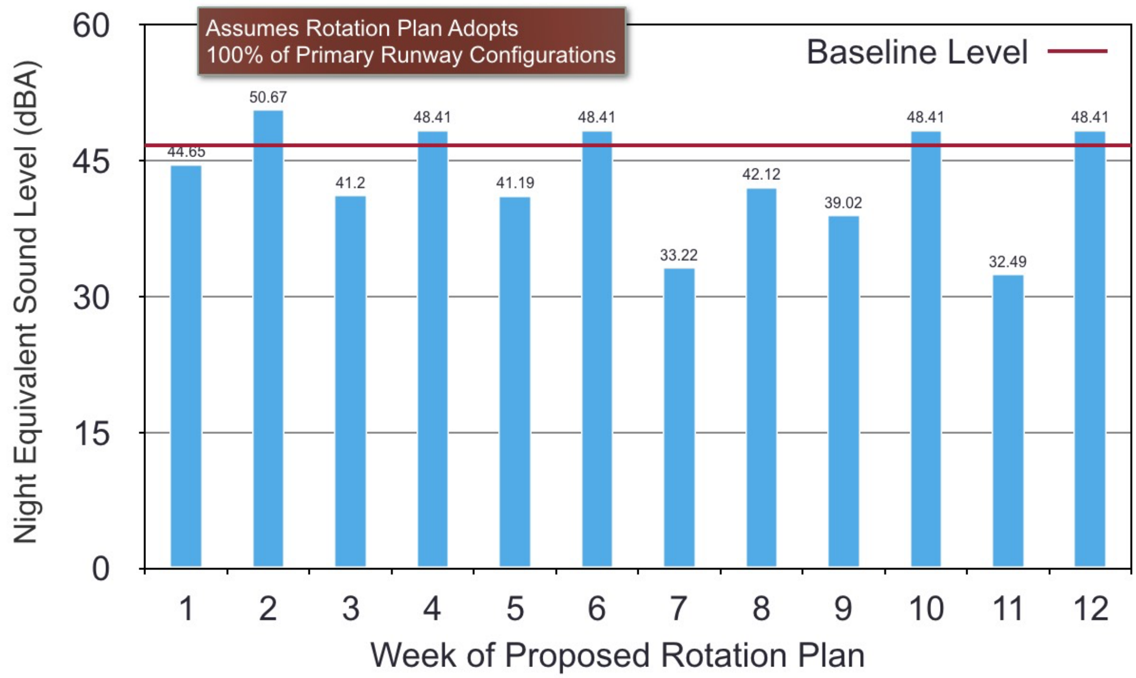

Figure 32: Estimated Values of Night Equivalent Sound Level (LAEQN) for Elk Grove Village. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

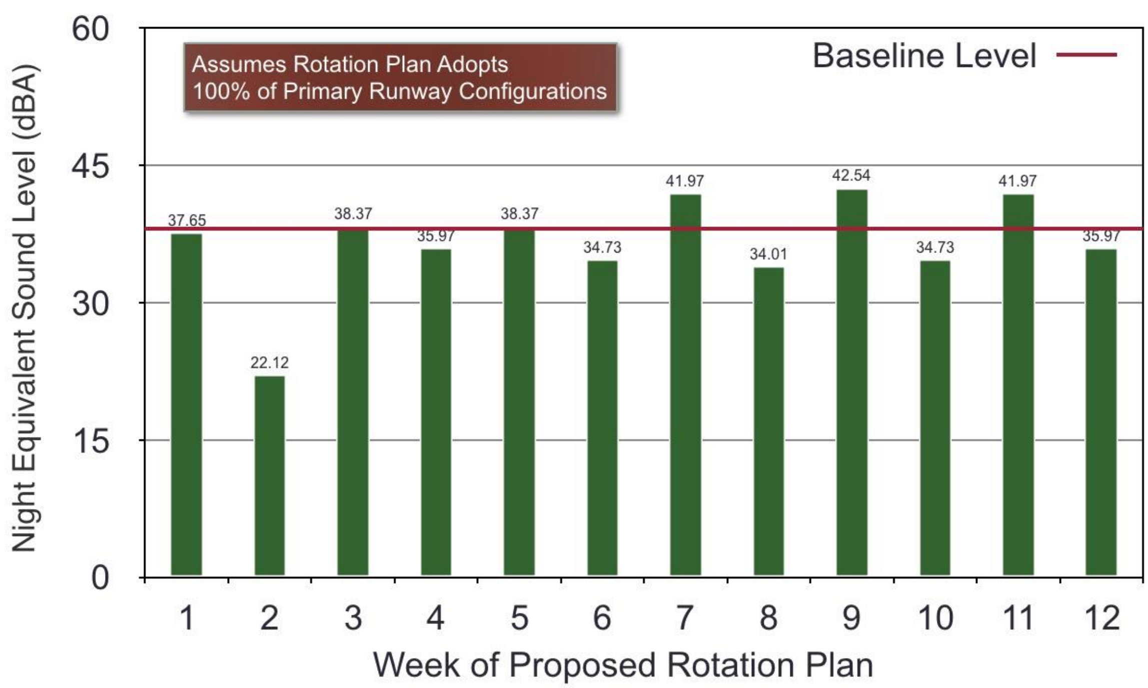

Figure 33: Estimated Values of Night Equivalent Sound Level (LAEQN) for Hanover Park. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

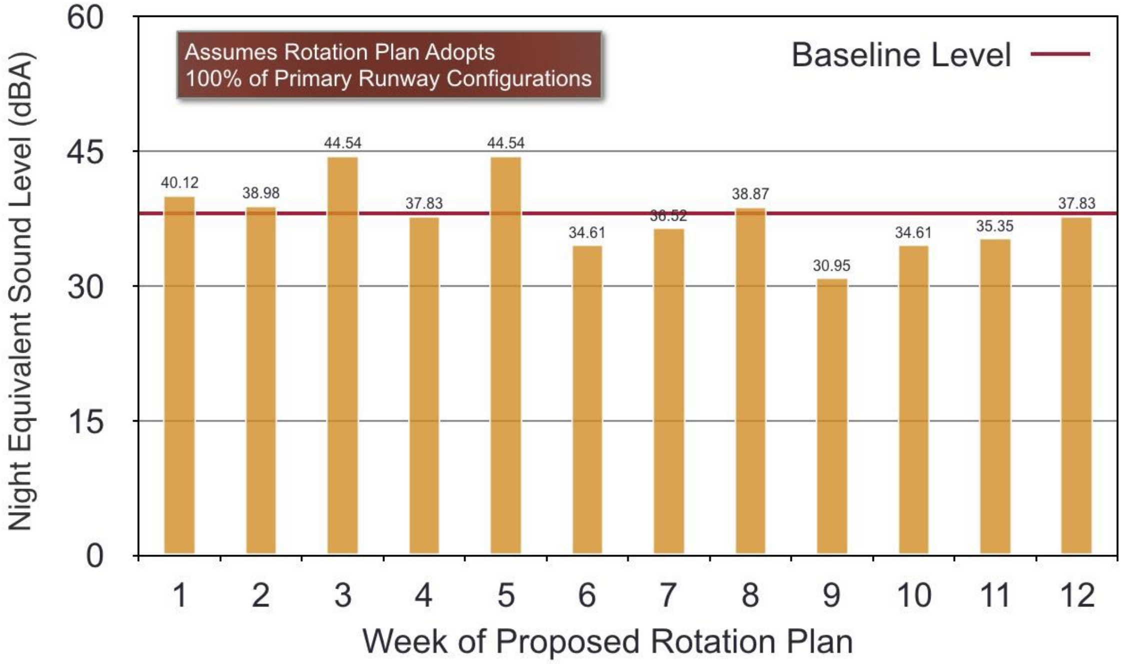

Figure 34: Estimated Values of Night Equivalent Sound Level (LAEQN) for Addison. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

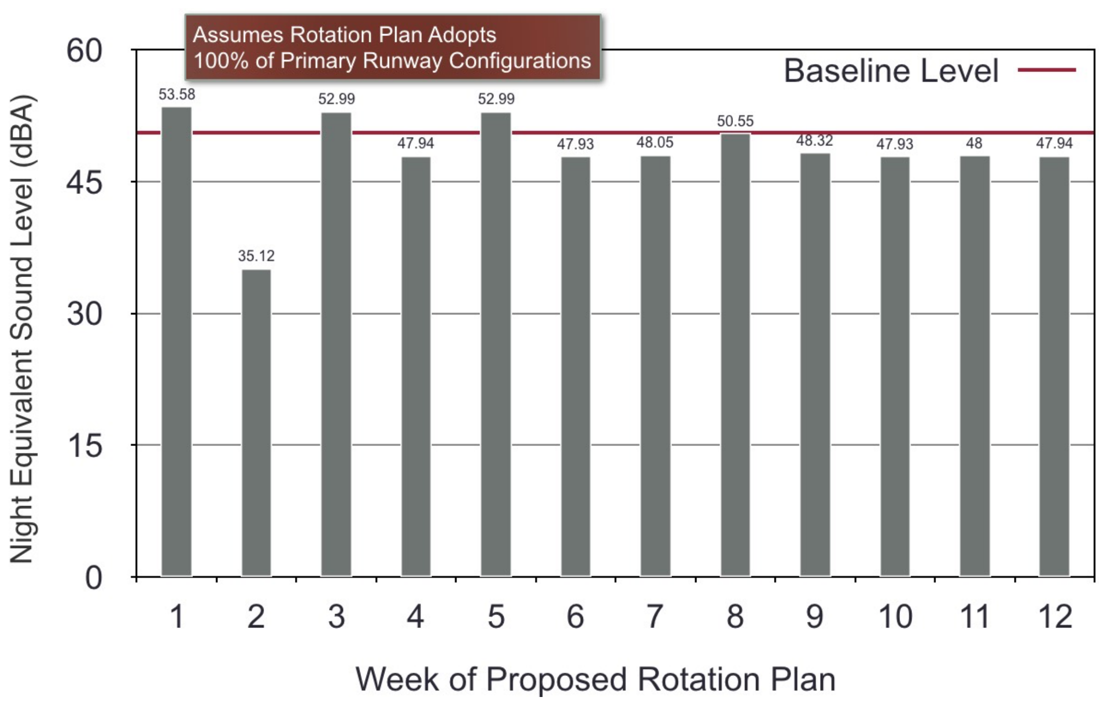

Figure 35: Estimated Values of Night Equivalent Sound Level (LAEQN) for Wood Dale. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

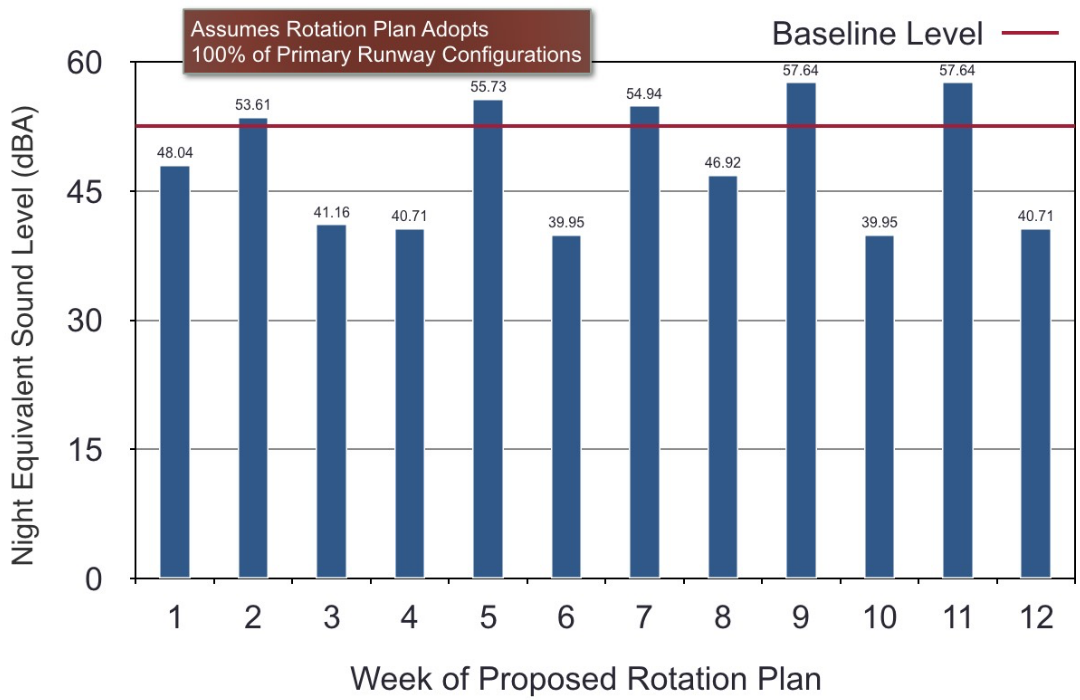

Figure 36: Estimated Values of Night Equivalent Sound Level (LAEQN) for Shiller Park. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

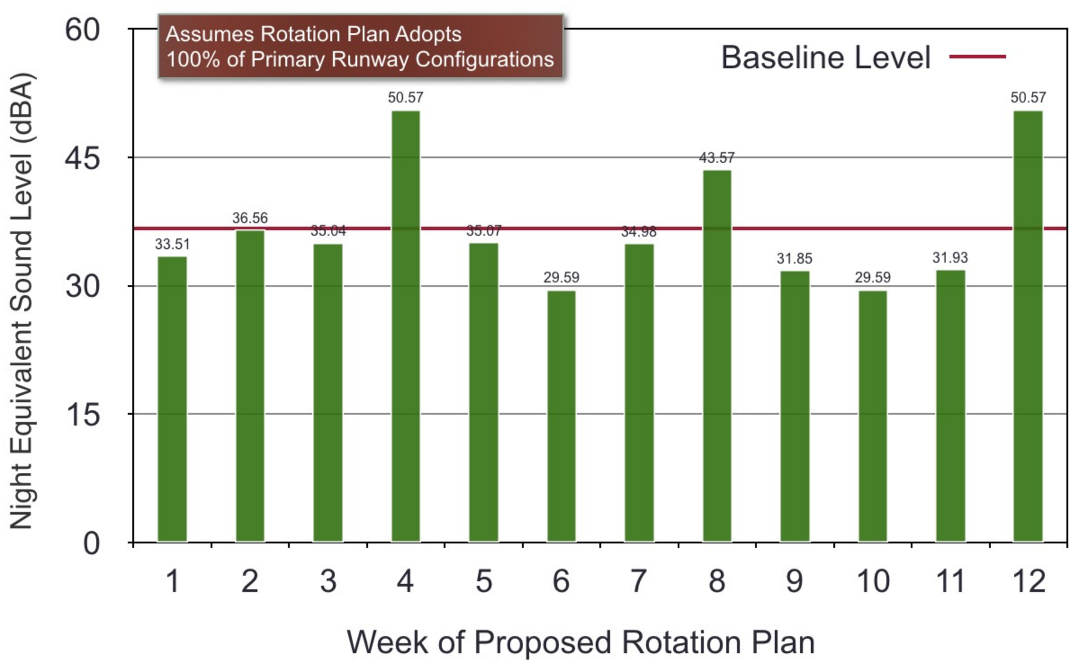

Figure 37: Estimated Values of Night Equivalent Sound Level (LAEQN) for Elmhurst. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

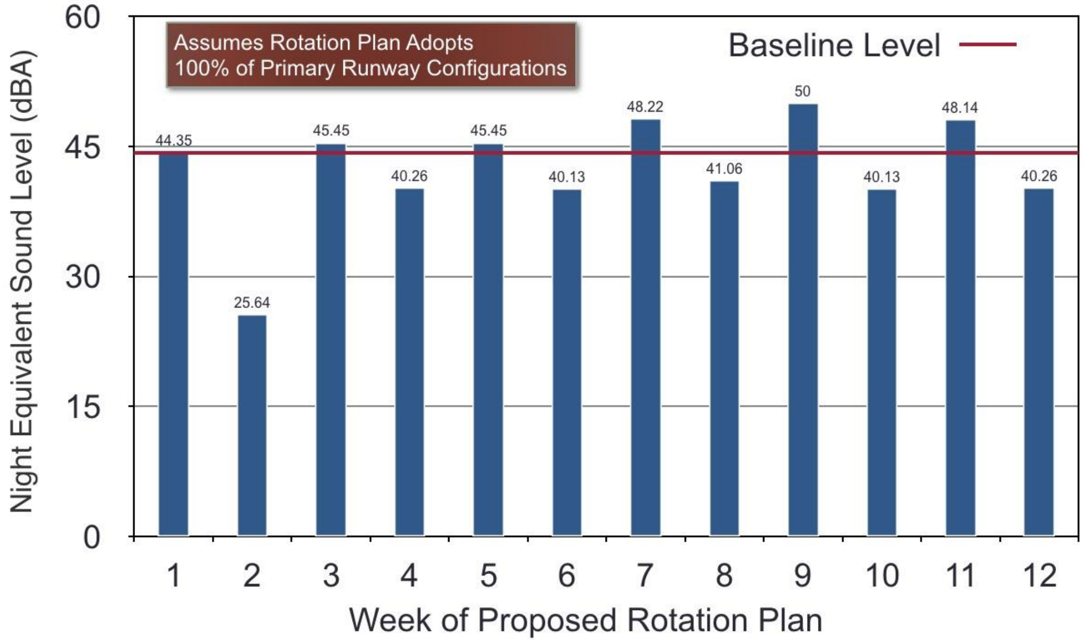

Figure 38: Estimated Values of Night Equivalent Sound Level (LAEQN) for Roselle. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

Table 3: Estimated LAEQN Levels at Various Communities around ORD International Airport. Cases Shown are the Baseline LAEQN Levels, Runway Rotation Plan Level (RRP) and Ten Runway Configurations.

Town	Baseline	Rotation Plan	A	B	C	D	E	F	G	H	I	J
Itasca	49.70	49.50	50.50	30.80	49.60	47.30	50.50	52.80	47.30	50.80	50.00	50.80
Bensenville	46.75	47.71	46.52	43.65	48.16	43.93	48.43	47.88	43.30	51.91	46.09	51.91
Elk Grove Village	46.39	46.07	33.22	50.67	39.02	48.41	32.49	44.65	48.41	41.20	42.12	41.19
Hanover Park	38.19	38.56	41.97	22.12	42.54	35.97	41.97	37.65	34.73	38.37	34.01	38.37
Addison	38.72	39.63	36.52	38.98	30.95	37.83	35.35	40.12	34.61	44.54	38.87	44.54
Wood Dale	50.52	50.02	48.05	35.12	48.32	47.94	48.00	53.58	47.93	52.99	50.55	52.99
Schiller Park	52.77	52.68	54.94	53.61	57.64	40.71	57.64	48.04	39.95	41.16	46.92	55.73
Elmhurst	37.26	43.50	34.98	36.56	31.85	50.57	31.93	33.51	29.59	35.04	43.57	35.07
Roselle	44.45	45.05	48.22	25.64	50.00	40.26	48.14	44.35	40.13	45.45	41.06	45.45

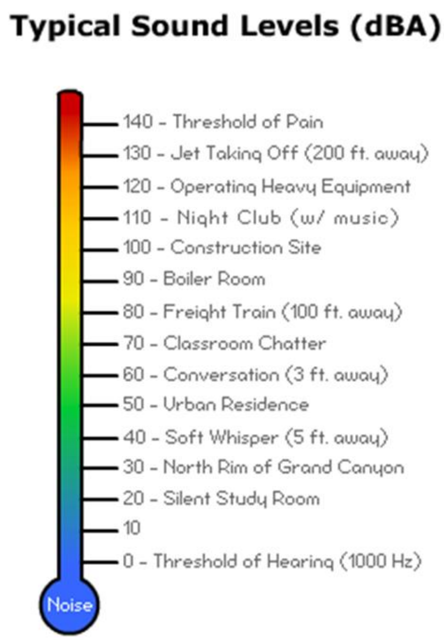

Figure 39: OSHA Technical Manual Decibel Scale

d. Population Impacts and Overflights

Considering 1,685 Census tracts around the airport, we estimate the population affected by the proposed runway rotation plan by calculating the number of people living within a range of LAEQN values. Figure 40 shows the results obtained for both the baseline scenario and the proposed runway rotation program. It is clear that the runway rotation program offers some relief for the communities surrounding the airport. For example, the number of people living within the 55-57.5 LAEQN area is reduced in half. The changes in population are attributed to the larger spread of the noise to areas on the Northeast and Southwest of the airport with a corresponding reduction the noise impact directly to the East and West-Northwest areas around the airport. The analysis presented here is a first-order approximation of the population affected by the runway rotation program. The analysis can be improved if population block level data is used instead. Block data provides roughly an order of magnitude more data points to draw final conclusions on the subject.

A final impact of the runway rotation program to communities is the number of overflights people will perceive every night during the program. Figure 41 shows the average number of overflights observed for ten SOC communities using observed data and estimated for the Runway Rotation Plan.

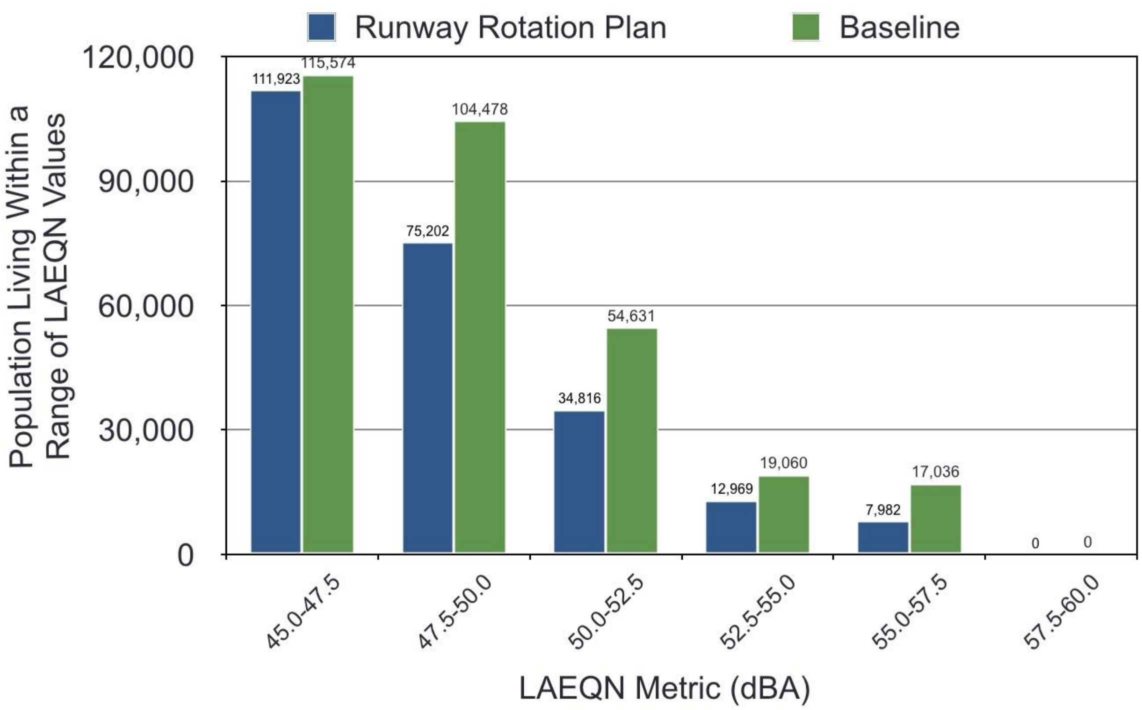

Figure 40: Estimated Population Affected by Runway Rotation Plan. LAEQN Values Reported. Noise Results Using FAA INM 7.0d Model. Assumes Runway Rotation Plan Adopts 100% of the Primary Runway Configurations.

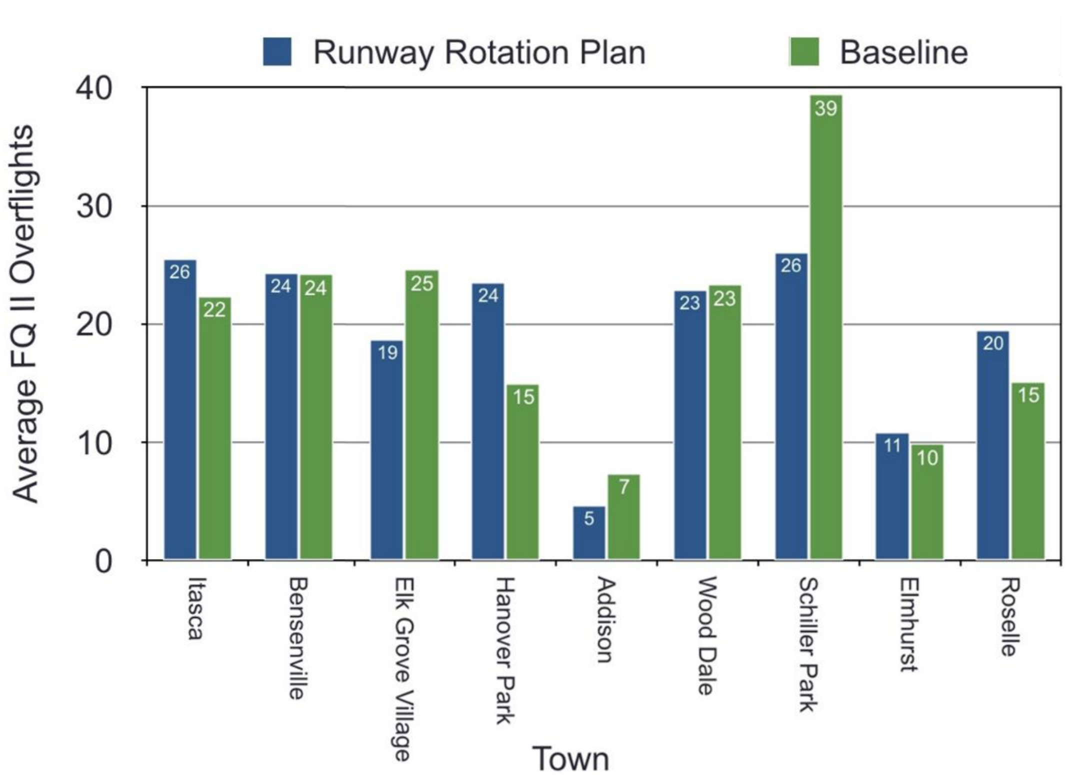

Figure 41: Estimated Baseline and Runway Rotation Plan FQ II Overflights over SOC Communities.

It is clear that Schiller Park, Elk Grove and Bensenville are the communities with higher number of overflights today. While not all overflights are the same, the numbers shown in the figure serve to illustrate a few points about the runway rotation program:

a) For some weekly runway configurations, the number of overflights could be greatly reduced because of the spread in flight operations around all quadrants of the airport
b) Overflights can be influenced by examining departure headings assigned to flights in the FQ II hours

To illustrate the first point, consider the typical number of overflights for Bensenville and Wood Dale during FQ II hours today (24 and 23, respectively). During the second week of the runway rotation program (i.e., runway configuration B), these communities will experience practically zero overflights because runway 14R will be operating in mixed mode. Some of these benefits are reflected in the values of LAEQN for the two communities shown in Table 3.

The overflight numbers should be viewed with care. An overflight at low altitude is more annoying that overflights at high altitude. For example, overflights over Roselle and Hanover Park are less annoying than those over Bensenville due to the altitude of the flying aircraft. According to the analysis Schiller Park could benefit in terms of overflights because some of the landing operations will be shifted to runways 22R and 4R.

The second issue stated above requires further examination of potential headings to further mitigate the impact of flight operations at the airport. Figure 42 shows the large dispersion patterns observed at ORD runway 28R. While some of the dispersion is due to aircraft performance limits (i.e., aircraft do not climb at the same rate every takeoff), new procedures (such as RNAV departure procedures) could help reduce the dispersion pattern and further mitigate noise. This issue was not investigated in this phase of the project.

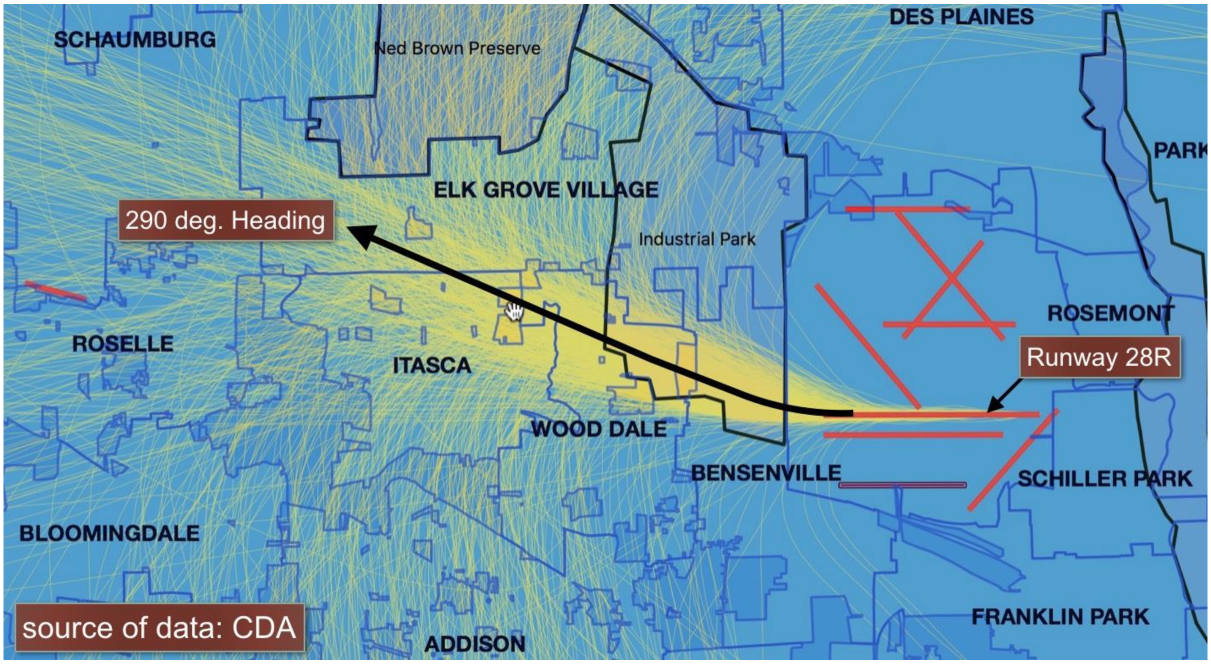

Figure 42: Departure Heading 290 for Flights Using Runway 28R.

6. CONCLUSIONS AND RECOMMENDATIONS

This study attempted to quantify various noise metrics for a proposed runway rotation plan. The study employs observed flight track data to construct realistic flight profiles using 5,286 tracks flown at ORD during FQ II hours. The study employed the FAA Integrated Noise Model to estimate noise impacts on communities surrounding ORD airport using the night sound equivalent level metric (LAEQN).

Several conclusions and observations from our analysis are summarized below:

a) The proposed runway rotation plan is expected to reduce the overall size of the area impacted by 55 LAEQN by an estimated 0.2 square miles around ORD if the primary configurations in the rotation plan are adopted with 100% reliability.
b) The reductions in the number of people affected by each LAEQN range evaluated was significant. The number of people living within 55 to 57.5 LAEQN area was reduced by half. The number of people living within the 52.5 to 55 LAEQN area was reduced by 31%.
c) Some communities underneath flight paths that are seldom uses at the airport today will experience more noise with the runway rotation plan. For example, communities underneath the flight path to runways 22R and 04R are likely to experience more noise due to more frequent use of those runways.

d) The FQ II period constitutes a small, yet important, period in the noise impacts around ORD. The number of operations affected by the runway rotation plan during FQ II hours averages 87 operations (i.e., 35 departures and 52 arrivals).
e) The number of heavy aircraft requiring long runways while departing ORD during FQ II hours is estimated to range between 4-6 operations per FQ II period. This analysis considered stage length flown and also observed takeoff performance derived from flight track data supplied by CDA.
f) The data provided by CDA shows that ORD operates 11.4% of the flights during the nighttime period. This is slightly above the 10.4% of nighttime operations studied in a previous phase of this project.
g) Twenty-eight of the operations during FQ II hours are attributed to heavy aircraft whose takeoff weights are above 260,000 lb. This fleet mix is significantly different to that observed during daytime operations at the airport. Heavy aircraft generate more noise than small regional jets (i.e., by a factor of 13:1 for some of the largest cargo aircraft).
h) Perhaps the most valuable contribution of the runway rotation program is that it will add some degree of predictability to the noise impacts around ORD. This is demonstrated in Table 3 in the report where the value of the noise metric is estimated for each runway configuration proposed in the runway rotation program. Communities will appreciate knowing days of noise impact mitigation provided by the runway rotation program.

The following recommendations provide possible ways to improve the analysis presented here and to quantify other impacts of the runway rotation program.

1) The rotation plan constitutes a blue print on how the airport can be operated over a 12-week period of time. Many variables will play a role to disrupt a proposed runway rotation plan including wind conditions, emergencies, pilot requests for long landing runways, construction and re-habilitation of runways, etc. For this reason, it is recommended that more analysis be conducted to estimate the likely noise impacts considering random deviations from the scheduled runway rotation plan. This process could lead to the identification of an optimal solution on what the best runway rotation plan should be. It could also lead to more efficient departure paths (i.e., optimal headings) to further reduce community noise.
2) One of the best strategies at reducing noise at a busy airport is to control demand during nighttime hours. We recommend that communities establish a dialog with CDA and the airlines operating at Chicago O'Hare Airport to discuss additional benefits of **voluntary demand management**. Realistic demand management is particularly important if the community wants to reduce the number of flights during the so-called "shoulder" hours (22-23 hrs.) and 6-7 AM). Currently at ORD, the number of flights during shoulder hours (190 operations average) far exceeds the number flights in the FQ II period.

3) The evaluation of the runway rotation plan should be an important task for the community to follow through. In the end, computer noise modeling only provides a data point in the noise impact evaluation that will have to be correlated with follow-up community surveys and perhaps with close examination of noise monitor data in the summer.
4) Strong consideration should be given to runway headings as part of the rotation plan. For example, current Fly Quiet headings do not involve specific headings for some runways that will be used in the rotation program. These headings need to be examined and modeled to see their effect in noise mitigation.

7. APPENDICES

a. Appendix 1 INM Fleet Mix Used in the Analysis

Table 4: ORD Fleet Mix Used in the Noise Impact Study. Data Represents 117 Days of Observed Operations. Source of data: CDA.

Aircraft	INM Aircraft	Arrivals	Departures	FQ II Arrivals	FQ II Departures
A306	'A300-622R'	194	130	1.64	1.03
A30B	'A300-622R'	9	5	0.08	0.04
A319	'A319-131'	204	91	1.73	0.72
A320	'A320-232'	782	271	6.63	2.14
A321	'A321-232'	306	88	2.59	0.70
A332	'A330-301'	0	88	0.00	0.70
A333	'A330-343'	0	88	0.00	0.70
A343	'A340-211'	0	88	0.00	0.70
A346	'A340-211'	0	88	0.00	0.70
AEST	'CL600'	0	0	0.00	0.00
B350	'1900D'	1	1	0.01	0.01
B712	'717200'	7	2	0.06	0.02
B734	'7373B2'	17	9	0.14	0.07
B737	'737700'	78	79	0.66	0.63
B738	'737800'	1347	509	11.41	4.03
B739	'737800'	917	189	7.77	1.50
B744	'747400'	282	333	2.39	2.64
B748	'7478'	111	363	0.94	2.87
B74F	'747R21'	4	3	0.03	0.02
B752	'757PW'	186	101	1.58	0.80
B753	'757PW'	4	3	0.03	0.02
B762	'767CF6'	59	77	0.50	0.61
B763	'767300'	25	49	0.21	0.39
B764	'767400'	5	1	0.04	0.01
B772	'777200'	167	69	1.42	0.55
B773	'777300'	1	1	0.01	0.01
B77L	'777300'	228	256	1.93	2.03
B77W	'777300'	4	64	0.03	0.51
B788	'7878R'	1	16	0.01	0.13
BE20	'1900D'	3	2	0.03	0.02
BE30	'1900D'	3	0	0.03	0.00
BE35	'1900D'	0	0	0.00	0.00

BE36	'GASEPV'	0	0	0.00	0.00
BE40	'CNA500'	1	1	0.01	0.01
C172	'GASEPF'	2	4	0.02	0.03
C182	'GASEPF'	2	0	0.02	0.00
C208	'PA28'	1	4	0.01	0.03
C310	'CNA441'	2	2	0.02	0.02
C421	'CNA441'	2	0	0.02	0.00
C510	'CNA500'	0	0	0.00	0.00
C550	'CNA560'	1	1	0.01	0.01
C560	'CNA560'	1	1	0.01	0.01
C56X	'CNA560'	5	5	0.04	0.04
C680	'CNA750'	3	3	0.03	0.02
C750	'CNA750'	1	2	0.01	0.02
CL30	'CL600'	1	0	0.01	0.00
CL60	'CL600'	0	0	0.00	0.00
CRJ2	'CL600'	38	70	0.32	0.55
CRJ7	'CRJ9-ER'	139	269	1.18	2.13
CRJ9	'CRJ9-ER'	8	1	0.07	0.01
DC10	'MD11GE'	164	123	1.39	0.97
E135	'EMB145'	9	19	0.08	0.15
E145	'EMB145'	193	233	1.64	1.84
E170	'EMB170'	180	301	1.53	2.38
E190	'EMB170'	9	6	0.08	0.05
E45X	'EMB145'	52	102	0.44	0.81
E55P	'CNA441'	1	2	0.01	0.02
F2TH	'CNA560'	2	1	0.02	0.01
F900	'CNA560'	1	1	0.01	0.01
FA10	'CIT3'	0	1	0.00	0.01
FA20	'CIT3'	1	1	0.01	0.01
FA7X	'CNA750'	1	0	0.01	0.00
G280	'CNA750'	0	0	0.00	0.00
GALX	'CNA750'	0	0	0.00	0.00
GL5T	'CNA750'	0	0	0.00	0.00
GLEX	'CNA750'	0	0	0.00	0.00
GLF4	'GIV'	6	4	0.05	0.03
GLF5	'GIV'	3	1	0.03	0.01
H25B	'CIT3'	3	4	0.03	0.03
J328	'SF340'	1	2	0.01	0.02
LJ31	'CIT3'	1	2	0.01	0.02

LJ35	'CIT3'	1	0	0.01	0.00
LJ45	'CIT3'	0	0	0.00	0.00
LJ55	'CIT3'	0	0	0.00	0.00
LJ60	'CIT3'	0	0	0.00	0.00
MD10	'MD11GE'	28	25	0.24	0.20
MD11	'MD11GE'	74	34	0.63	0.27
MD82	'MD82'	82	70	0.69	0.55
MD83	'MD83'	72	89	0.61	0.70
MD88	'MD83'	11	1	0.09	0.01
MD90	'MD83'	19	2	0.16	0.02
P28T	'GASEPF'	0	2	0.00	0.02
PA31	'GASEPF'	0	2	0.00	0.02
PC12	'1900D'	0	2	0.00	0.02
SKY	'1900D'	0	2	0.00	0.02
T182	'GASEPV'	0	2	0.00	0.02

b. Appendix 2: THE JDA TEAM

Author:

Dr. Antonio A. Trani, is a JDA associated consultant and Professor with the Department of Civil and Environmental Engineering at Virginia Tech University and is Co-Director of the National Center of Excellence for Aviation Operations Research (NEXTOR). He has been the Principal or Co-Principal Investigator on 68 research projects sponsored by the National Science Foundation, Federal Aviation Administration, National Aeronautics and Space Administration, National Consortium for Aviation Mobility, Federal Highway Administration, and the Center for Naval Analyses. Dr. Trani has provided noise, capacity and safety consulting services to the Norman Manley International Airport, Punta Cana International, National Institute for Aerospace (NIA), Xcelar, Quanta Technologies, Los Angeles World Airport, Charles Rivers Associates, Boeing Phantom Works, Civil Aviation Administration of China (CAAC), British Airports Authority (BAA), SEATAC Airport Authority, Louisville International Airport, Delta Airport Consultants, Celanese, and the MITRE Corporation.

Contributing:

Jim Krieger Senior Air Traffic Subject Matter Expert, has over 33 years of experience with the FAA, mostly in the Chicago area, working primarily at O'Hare Tower (ORD) as an air traffic controller, Area Supervisor, Area Manager, Staff Manager, Support Manager for Quality Assurance and finally, as the Air Traffic Manager. He was named Assistant Air Traffic Manager at Chicago Terminal Radar Approach Control (TRACON) in 2003 until 2008. Jim has FAA Headquarters experience too. In 2010, he was named the Chairman of the Airport Construction Advisory Council (ACAC), a panel of safety experts that was tasked with ensuring safety during airport construction projects. Jim served as the FAA's Group Manager for Runway Safety as well and used that experience as a tremendous opportunity to influence positive change nationwide and to move Runway Safety to the next level. Jim pioneered the conceptual procedure of the arrival-departure window tool to assist controllers with converging runway operations. He analyzed major airport construction projects across the National Airspace System to document and identify best practices during construction for air traffic managers and airport operators. Served as subject matter expert on many airport surface safety forums including "Navigating the Risks on the Airport Surface" for the Airline Pilots Association (ALPA) 59th Safety Forum. Mr. Krieger retired from the FAA in July 2015 as the Air Traffic Manager of O'Hare Tower.

Craig Burzych is an Air Traffic Operations Specialist, a JDA associated consultant and former career FAA Air Traffic Control Specialist. He spent 24 years working at the O'Hare Control Tower and 4 years working in the Chicago Midway Tower. He was detailed annually to lead the FAA Air Traffic Control support for the annual EAA Oshkosh "fly In" the single largest aviation show and exhibit held in the U.S. Craig served as President of the National Air Traffic Control Association (NATCA) (Chicago

ORD) 9 years and also was a NATCA Aviation Safety Inspector and a member of the FAA Runway Safety Action team for the Great Lakes Region.

Joe Del Balzo, JDA Founder and President, served as the highest-ranking career professional (Acting Administrator) in the Federal Aviation Administration (FAA). Both in his long career with FAA (where he also served as FAA's Executive Director of System Operations, Executive Director for System Development, Director of the Eastern Region and Director of the FAA Technical Center) and in his subsequent private role as an aviation consultant, he has earned wide respect for his expertise in a wide range of aviation issues.

Cynthia Schultz PE, AAE is JDA's Vice President of Airports where she manages the airport line of business including, airport safety, certification, compliance, development, training and expert witness services. Prior to joining JDA Cynthia managed a commercial airport and was a Senior Engineer for the Boeing Company where she was a project manager on the 777 new airplane program.