APPENDIX D

MSP Airfield Simulation Analysis

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MSP Airfield Simulation Analysis Technical Report

Prepared by:

HNTB

November 2011

Minneapolis-St. Paul International Airport 2020 Improvements Environmental Assessment/ Environmental Assessment Worksheet

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TABLE OF CONTENTS **Page**

LIST OF FIGURES **Page**

LIST OF TABLES **Page**

APPENDIX D
MSP Airfield Simulation Analysis

INTRODUCTION

The purpose of this technical report is to document the procedures and assumptions incorporated into the airfield simulation analysis performed for the Environmental Assessment (EA) for 2020 Airport Improvements at the Minneapolis-St. Paul International Airport (MSP) as identified in MSP's Long Term Comprehensive Plan (LTCP). The simulation modeling was completed using SIMMOD PRO!® (SIMMOD). Lastly, this technical report summarizes the simulation results used to analyze potential noise and air quality impacts of the alternatives considered in the aforementioned EA.

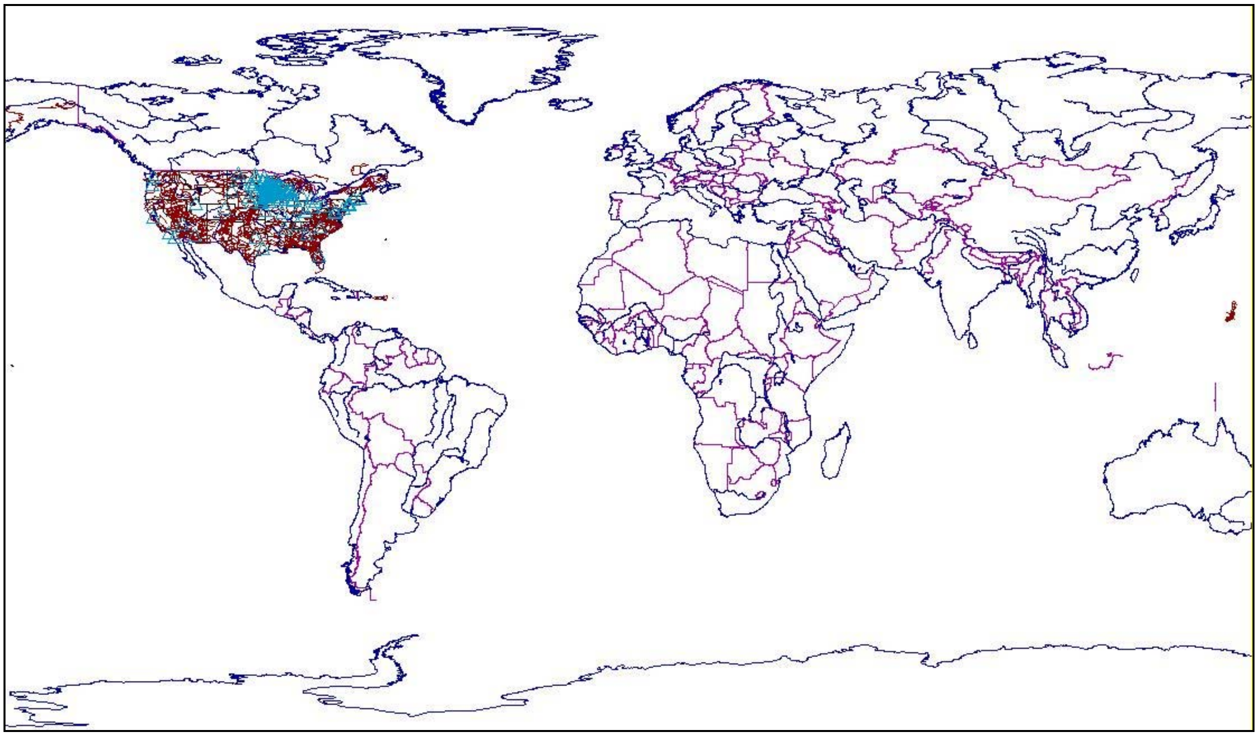
1 SIMMOD Development Steps

1.1 Create Link/Node Structure

One of the first steps in creating any SIMMOD analysis is the creation of the link and node structures that define the airspace and ground travel patterns. Fortunately, SIMMOD contains several databases of graphical information, such as coastlines, state and national boundaries, and many airspace routes and fixes to allow users to easily create their models in the appropriate location. **Figure D.1-1** shows some of the data included with the software.

Figure D.1-1

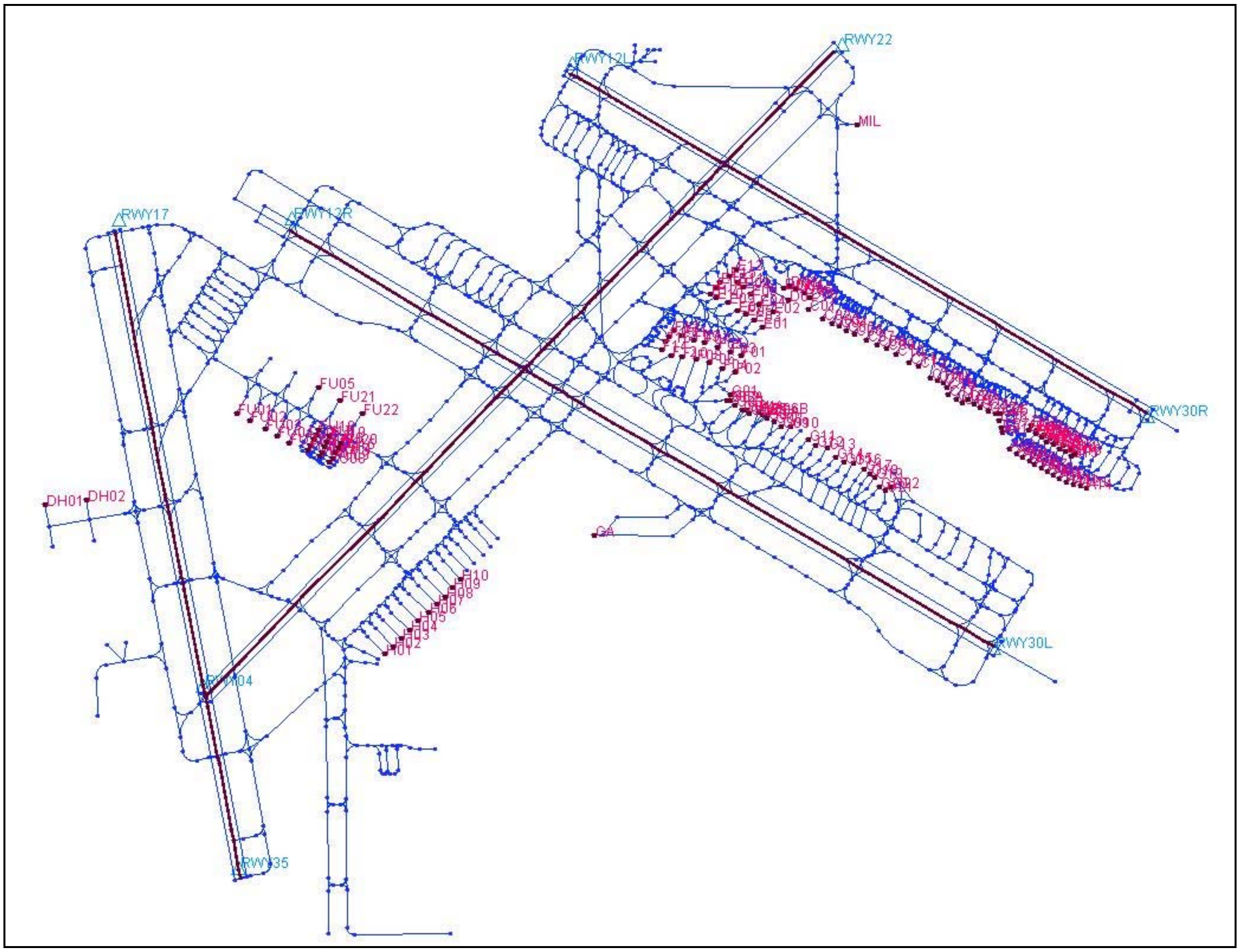
SIMMOD Coordinate System and Maps



Using FAA Instrument Approach Charts, which show the latitude and longitude for all nearby airspace fixes, intersections, and runway ends, a series of points were defined in SIMMOD to provide the basis for building all airspace routes. Using the fixes, intersections, and runway ends provided in SIMMOD, ground nodes were created from AutoCAD files, as provided by the MAC and the LTCP team. For the MSP analysis, runways were created first, and then existing and proposed taxiways were added, as shown in **Figure D.1-2**.

Figure D.1-2

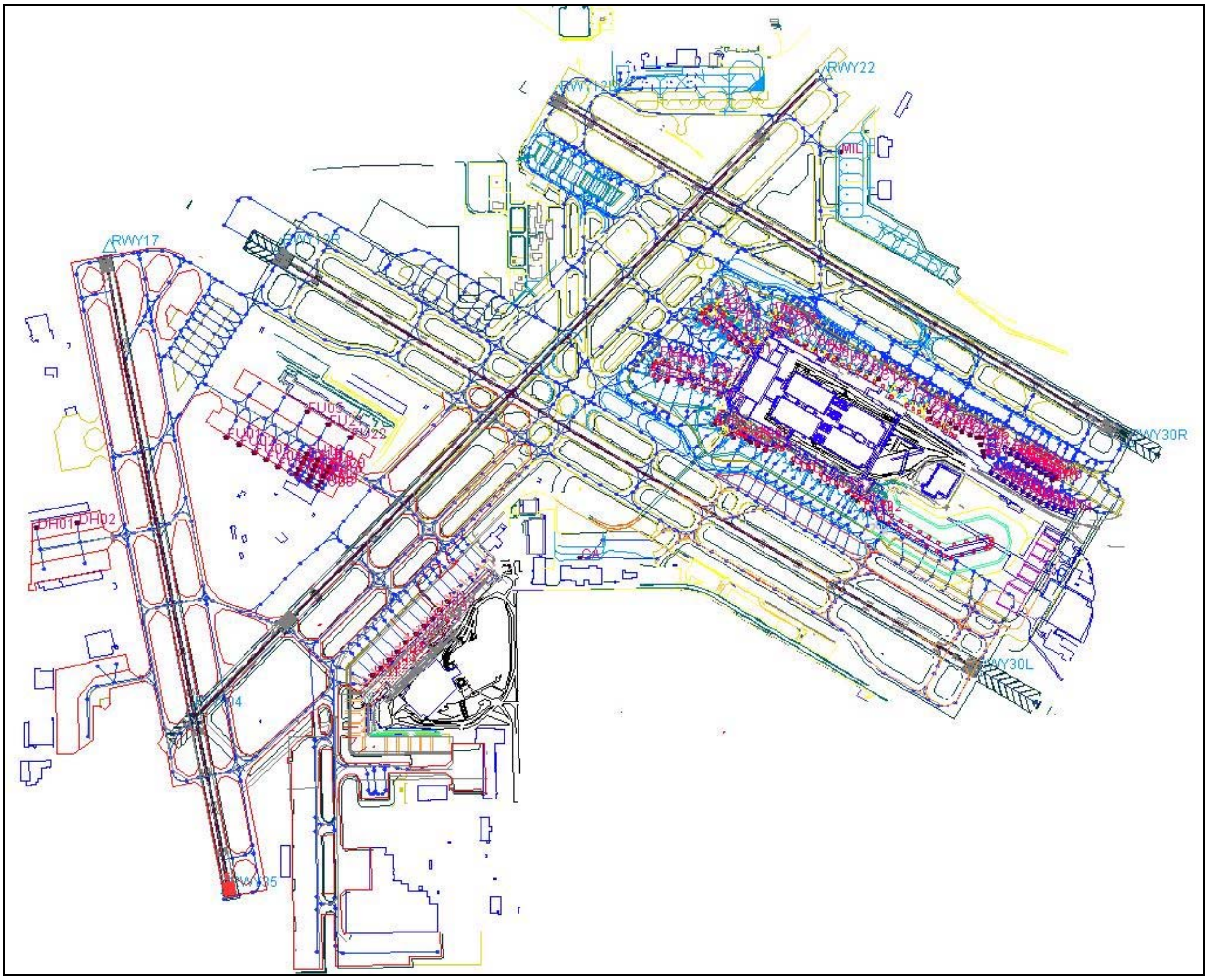
Runways, Taxiways Created with System of Links and Nodes



SIMMOD allows the background AutoCAD image to be imported as base information to be turned on or off for reference, as shown in **Figure D.1-3**.

Figure D.1-3

SIMMOD's Link/Node System Superimposed on Project CAD Drawings



1.2 Applying Appropriate Speeds

For this analysis, straight taxiway links were defined with 15 knots. Turns and intersections used 10 knots, and links near gates used only 5 knots. Runway links, when used for taxiing, used 35 knots. These speeds were based on previous simulation studies and professional experience.

1.3 Gate Definitions

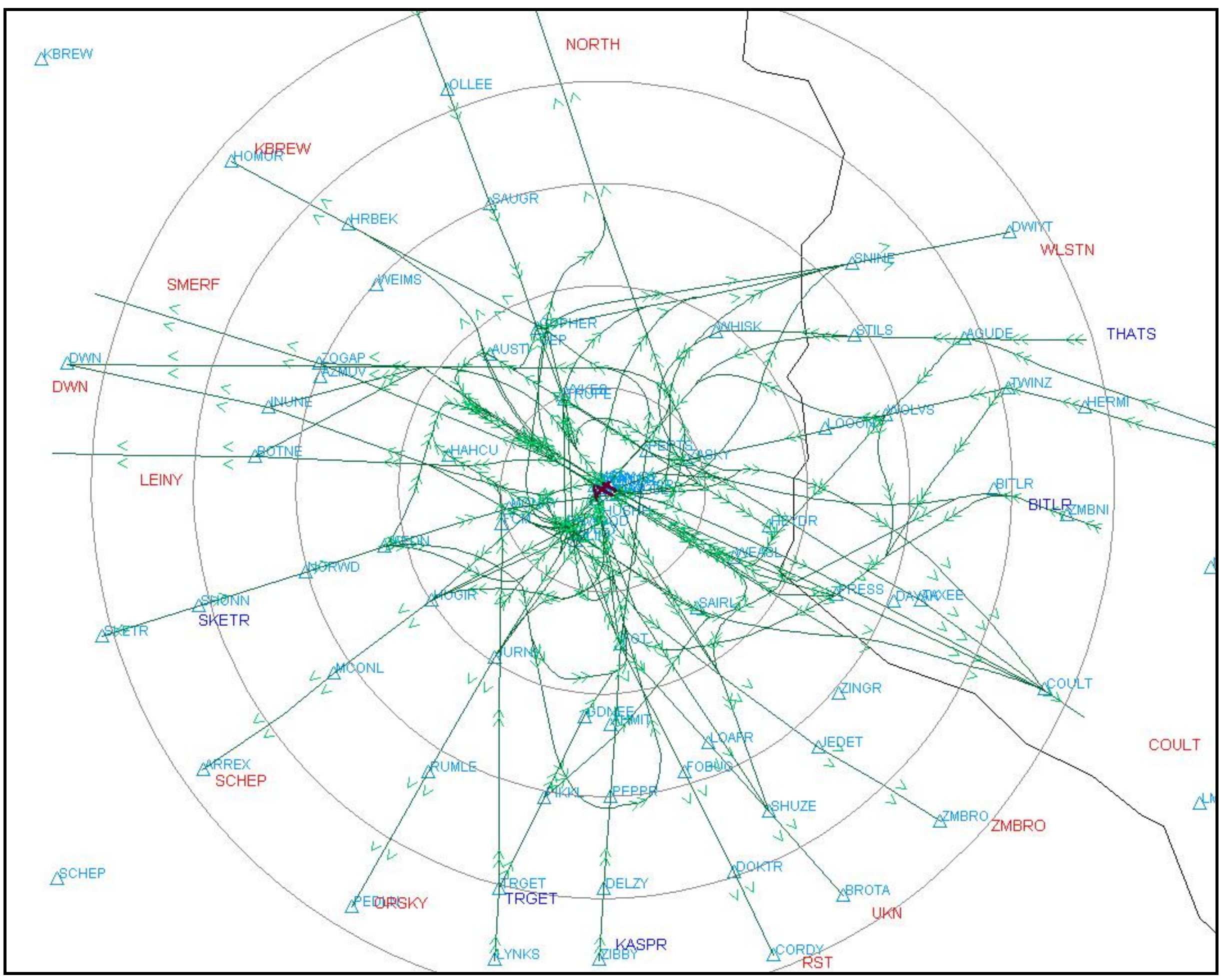
Gate locations were defined from gate charts provided by the MAC and using the terminal area maps. Similarly, gate definitions for different development alternatives were also created.

1.4 Airspace Links/Nodes

Similar to ground links, airspace links were created between airspace fixes and intersections to create all of the routes between airspace arrival and departure "gates" and runway ends. While it is possible to create links and routes between all combinations of runways and gates, only the routes that were used in the scenarios selected were created to simplify the graphics. For example, while it is possible that the Airport may operate with only Runway 4/22 in operation, that scenario was not modeled for this analysis, and therefore several routes that would be necessary for that scenario were not created. The airspace links are shown in **Figure D.1-4**.

Figure D.1-4

Airspace Links



1.5 Airspeed Link Definitions

Unlike ground segments, airspace links may experience a wide range of airspeeds. Therefore, airspeeds were calculated based on the type and location of the link, in combination with the size and type of aircraft that is operating on the link. Aircraft groups, discussed below, were developed and nominal speeds were created for each group on each type of airspace link.

1.6 Aircraft Groups

To model different operating characteristics for aircraft of different sizes and types of operations, aircraft groups were created. Operating characteristics were then defined for each group, rather than for each specific equipment type. For this analysis, the following groups were defined:

- 757
- GA – General Aviation
- HVY – Heavy air carrier aircraft
- LRG – Large air carrier aircraft
- SML – Small air carrier, commuter, and general aviation jet aircraft

Table D.1.1

Airspeeds Assigned By Aircraft Groups

Groups Aircraft		Airspeeds		
	Air Link Type	**MAX**	**NOM**	**MIN**
757				
	ARR_DESC_ABV_10K	380	350	300
	ARR_DESC_BELOW_10K	250	250	220
	ARR_FINAL_APP	150	140	135
	ARR_IN_PATTERN	200	170	145
	DEP_CLIMB	250	220	200
	DEP_INITIAL_DEP	200	165	150
	ENROUTE_AND_DEFAULT	420	400	280
GA				
	ARR_DESC_ABV_10K	200	180	160
	ARR_DESC_BELOW_10K	200	180	160
	ARR_FINAL_APP	110	110	110
	ARR_IN_PATTERN	140	120	100
	DEP_CLIMB	180	160	140
	DEP_INITIAL_DEP	160	130	100

Table D.1.1

Airspeeds Assigned By Aircraft Groups

Groups Aircraft		Airspeeds		
	Air Link Type	MAX	NOM	MIN
	ENROUTE_AND_DEFAULT	200	180	160
HVY				
	ARR_DESC_ABV_10K	380	350	300
	ARR_DESC_BELOW_10K	250	250	220
	ARR_FINAL_APP	160	145	135
	ARR_IN_PATTERN	200	180	150
	DEP_CLIMB	250	220	200
	DEP_INITIAL_DEP	200	170	160
	ENROUTE_AND_DEFAULT	420	400	300
LRG				
	ARR_DESC_ABV_10K	380	350	300
	ARR_DESC_BELOW_10K	250	250	220
	ARR_FINAL_APP	150	140	130
	ARR_IN_PATTERN	200	170	145
	DEP_CLIMB	250	220	200
	DEP_INITIAL_DEP	200	165	150
	ENROUTE_AND_DEFAULT	420	400	300
SML				
	ARR_DESC_ABV_10K	300	250	200
	ARR_DESC_BELOW_10K	250	230	170
	ARR_FINAL_APP	150	130	120
	ARR_IN_PATTERN	180	140	120
	DEP_CLIMB	200	180	160
	DEP_INITIAL_DEP	200	160	140
	ENROUTE_AND_DEFAULT	350	300	200

Notes:
ARR_DESC_ABV_10K = the arrival flight segment above 10,000 AGL
ARR_DESC_BELOW_10K = the arrival flight segment below 10,000 AGL
ARR_FINAL_APP = the final approach segment
ARR_IN_PATTERN = an arrival pattern segment
DEP_CLIMB = a departure climb segment
DEP_INITIAL_DEP = the initial departure segment
ENROUTE_AND_DEFAULT = the enroute segment

Source: SIMMOD *Pro!*®

1.7 Flight Schedule

Gated flight schedules were created based on future demand levels and the locations of airlines for each of the development alternatives. Flights were assigned to arrival and departure airspace gates based on their origination or destination airports.

1.8 Operating Scenarios Modeled

To account for the vast majority of operations at the Airport, the following scenarios were modeled:

Table D.1.2

Operating Scenarios Modeled for MSP

Flight Rules	Flow	Runways Used	Percent of Time
VFR			
	North	Arrive and Depart Runways 30L and 30R, Arrive Runway 35	42%
	South	Arrive and Depart Runways 12R and 12L, Depart Runway 17 (Runway 12R Departures are minimal)	24%
	Partial South	Arrive and Depart Runways 12R and 12L Only	7%
	Mixed	Arrive and Depart 30L and 30R, Depart 17	4%
IFR			
	North	Arrive and Depart Runways 30L and 30R, 1.5 NM stagger required	11%
	South	Arrive and Depart Runways 12R and 12L, Depart Runway 17 (Runway 12 R Departures are minimal), 1.5 NM stagger required for Runways 12R and 12L, Runway 17 Departures from Terminal 1-Lindbergh use Taxiway T	6%
	Partial South	Arrive and Depart 12R and 12L Only, 1.5 NM stagger required	4%
	Mixed	Arrive and Depart 30L and 30R, Depart 17, 1.5 NM stagger required for Runways 30L and 30R	1%

Source: Consultation with Federal Aviation Administration Air Traffic Organization, 2011.

1.9 Alternatives Modeled

For each of the operating scenarios listed above, the following three development alternatives were modeled:

- Existing Conditions (No Action Alternative)
- Alternative 1: Airlines Remain
- Alternative 2: Airlines Relocate

To create these alternatives in SIMMOD, AutoCAD drawings of the gate layouts defined for each alternative were used to create new gates and associated taxiways and taxipaths.

1.10 Years Modeled

The Existing Conditions (No Action Alternative) was modeled using a gated flight schedule for 2010, for each of the operating scenarios. Results from these simulations were compared to actual runway use statistics to validate the results of the models.

All three alternatives were modeled for future years, 2020, and 2025, also using a gated flight schedule developed for those years. Traffic levels for these years are as follows:

Table D.1.3

Summary of Operational Levels Modeled

Year	Annual Operations	Average Daily Operations
2010	436,625	1,384
2020	485,000	1,552
2025	526,000	1,688

Notes: Average Daily Operations are from the Average Day-Peak Month
Future operations rounded to 1 thousand.

Source: MSP Aviation Activity Forecast, HNTB, 2011.

Table D.1.4 provides the 56 simulations that were created and modeled for the MSP analysis:

Table D.1.4

Simulations Modeled for MSP Analysis

Alternative and Operating Scenario	Year of Analysis					
	2010		2020		2025	
	IFR	VFR	IFR	VFR	IFR	VFR
Existing Conditions/No Action Alternative						
North Flow	●	●	●	●	●	●
South Flow	●	●	●	●	●	●
Partial South Flow	●	●	●	●	●	●
Mixed Flow	●	●	●	●	●	●
Alternative 1: Airlines Remain						
North Flow			●	●	●	●
South Flow			●	●	●	●
Partial South Flow			●	●	●	●
Mixed Flow			●	●	●	●
Alternative 2: Airlines Relocate						
North Flow			●	●	●	●
South Flow			●	●	●	●
Partial South Flow			●	●	●	●
Mixed Flow			●	●	●	●

1.11 Basic Modeling Parameters

The following parameters were used for the creation of the simulations:

- Common Rules for VFR
  - Visual Approaches (Runs 3 to 3.3 Miles In-Trail –MIT)
  - Visual Separation on Departures (Approx. 2 MIT, then diverge or increase to 3 NM+)
  - 12L and 12R Departures to COULT or ZMBRO are 3 MIT

- Common Rules for IFR
  - Instrument Approaches (Min. 4 MIT)
  - Instrument Departures (Min. 3.2 MIT unless Initial Course Divergence)

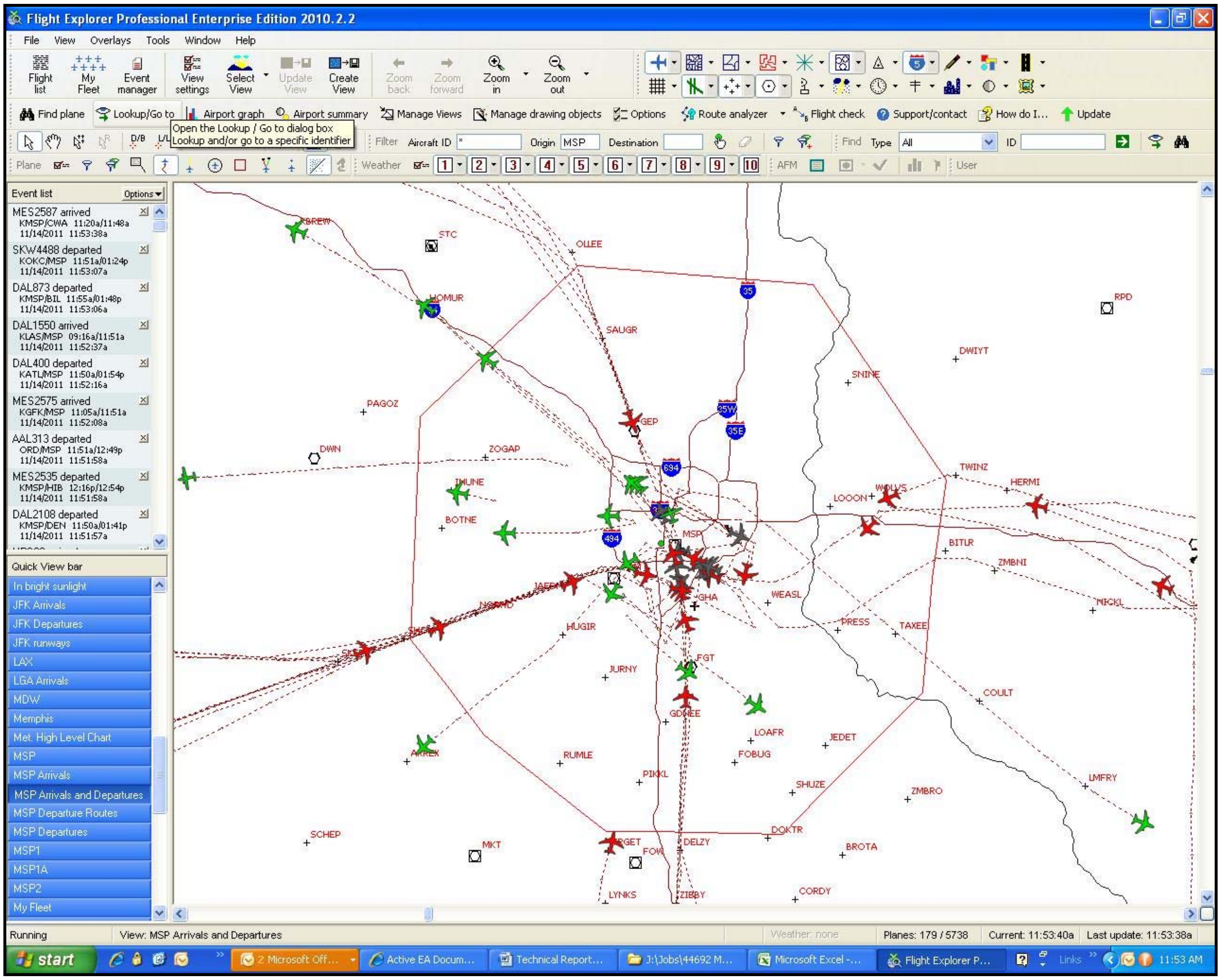
Additional rules were defined for specific aircraft to account for issues such as wake turbulence.

1.12 Route Creation

Airspace arrival and departure routes were created based on discussions with Federal Aviation Administration Air Traffic Control (ATC), published instrument approaches, standard terminal arrivals routes (STARs), departure procedures, observations, and actual aircraft flight tracks using Flight Explorer as illustrated in **Figure D.1-5.**

Figure D.1-5

Flight Explorer



Initial route segments were created in the vicinity of arrival and departure “gates.” These routes, typically referred to as “enroute routes,” included the links that were common to all flights through those gates.

Flights from the gated flight schedule were assigned to these gates based on the direction of travel (direction to or from the flight’s origin or destination), as shown in **Figure D.1-6** and **Figure D.1-7**.

Figure D.1-6

Sectors for Arrival Gates

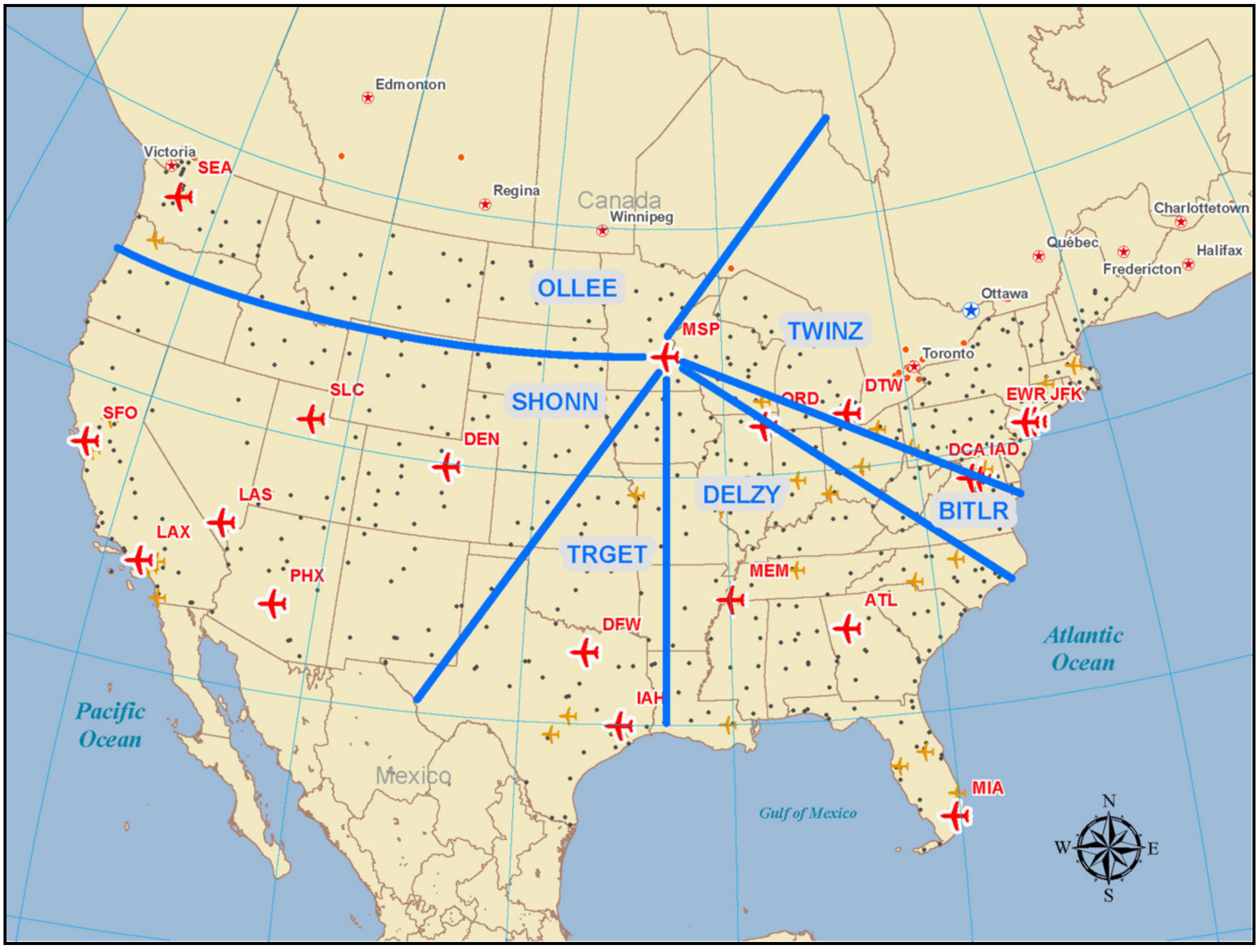
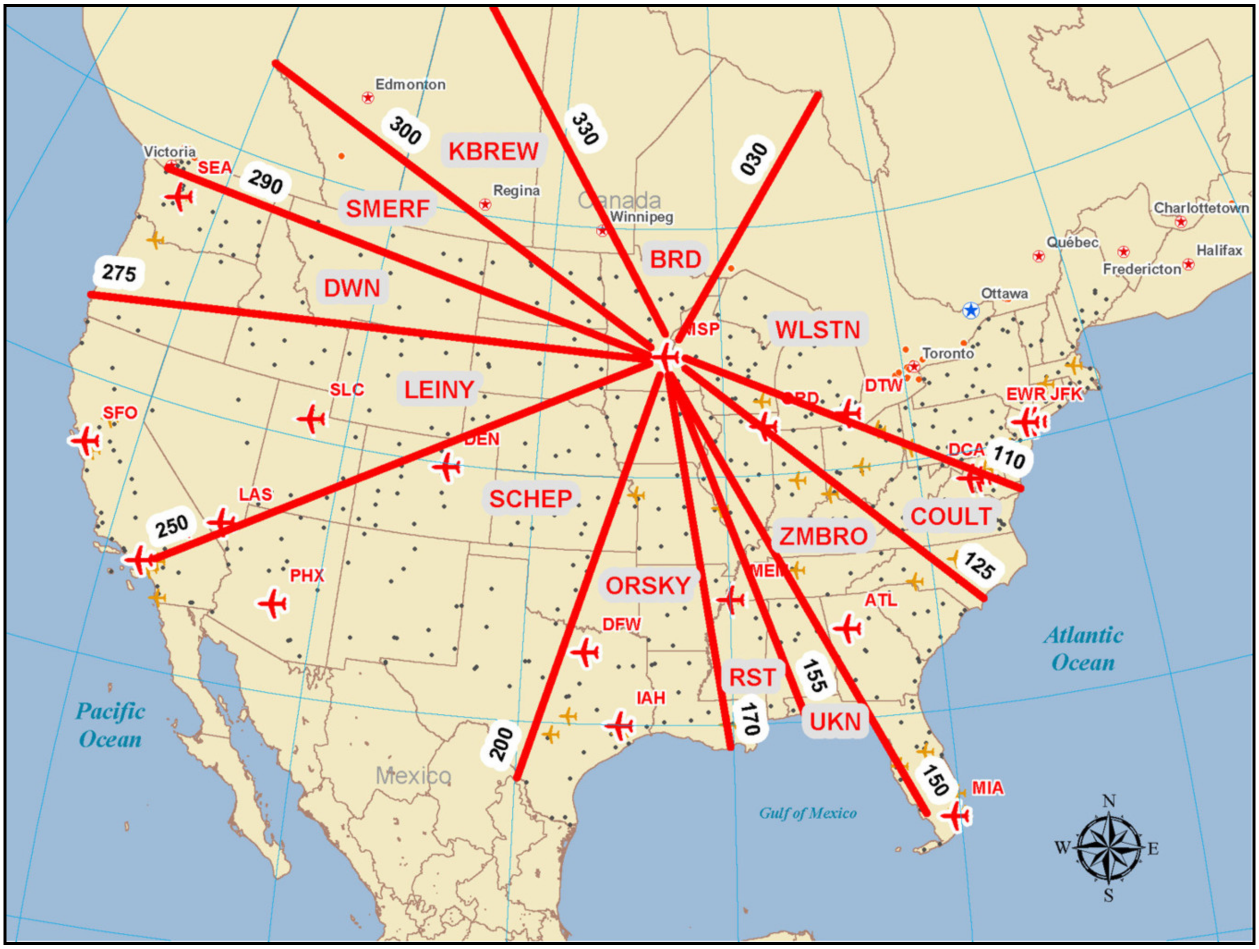


Figure D.1-7

Sectors for Departure Gates



Routes from these gates were then dispersed to and from specific runway ends and a second set of "terminal area" routes were created. The primary and secondary runway assignments to/from these gates are shown in **Figures D.1-8 through D.1-12.**

By having these different route segments, the models were able to move flights dynamically through the day to prevent a single runway from being overloaded with flights.

Figure D.1-8

North Flow VFR

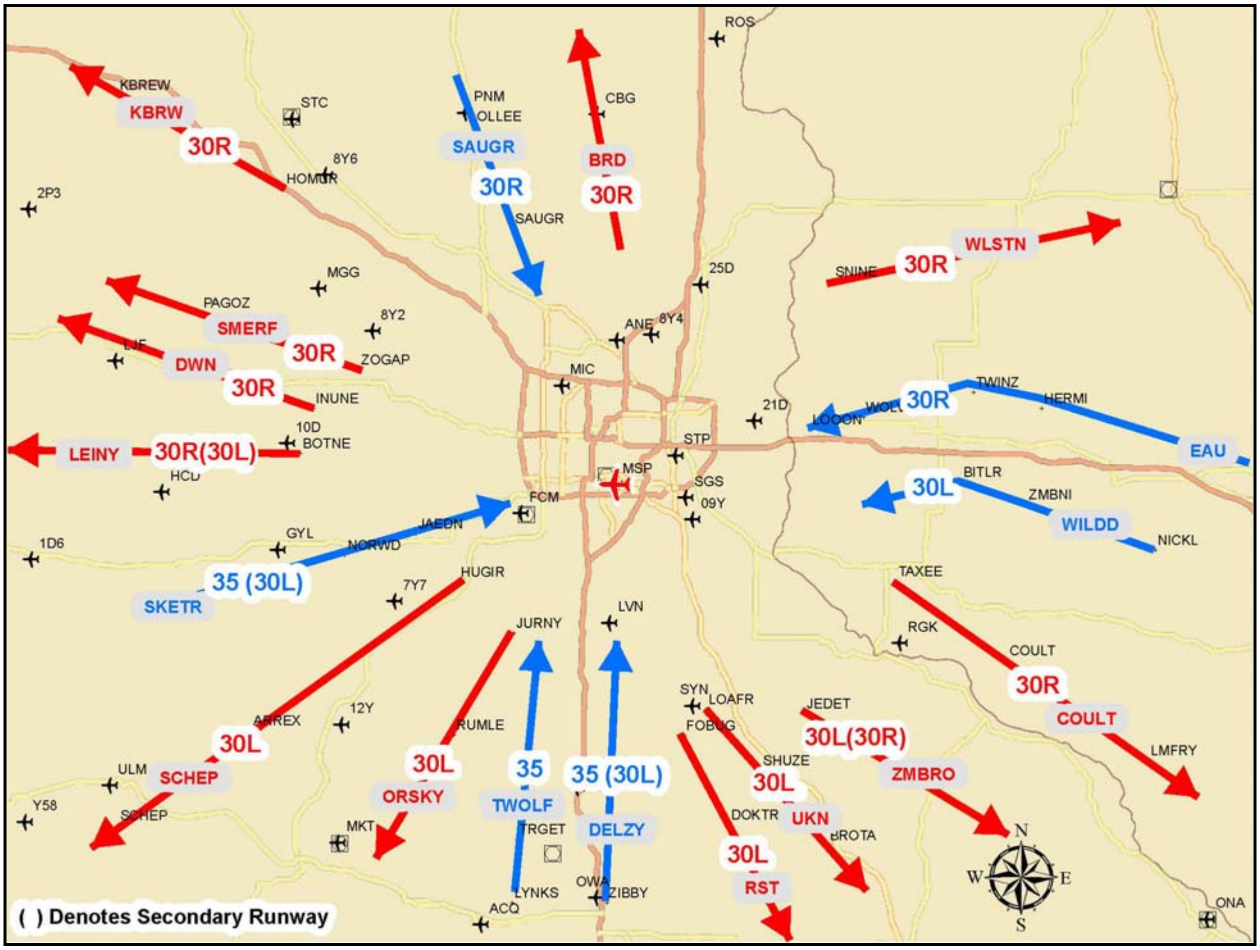


Figure D.1-9

North Flow IFR

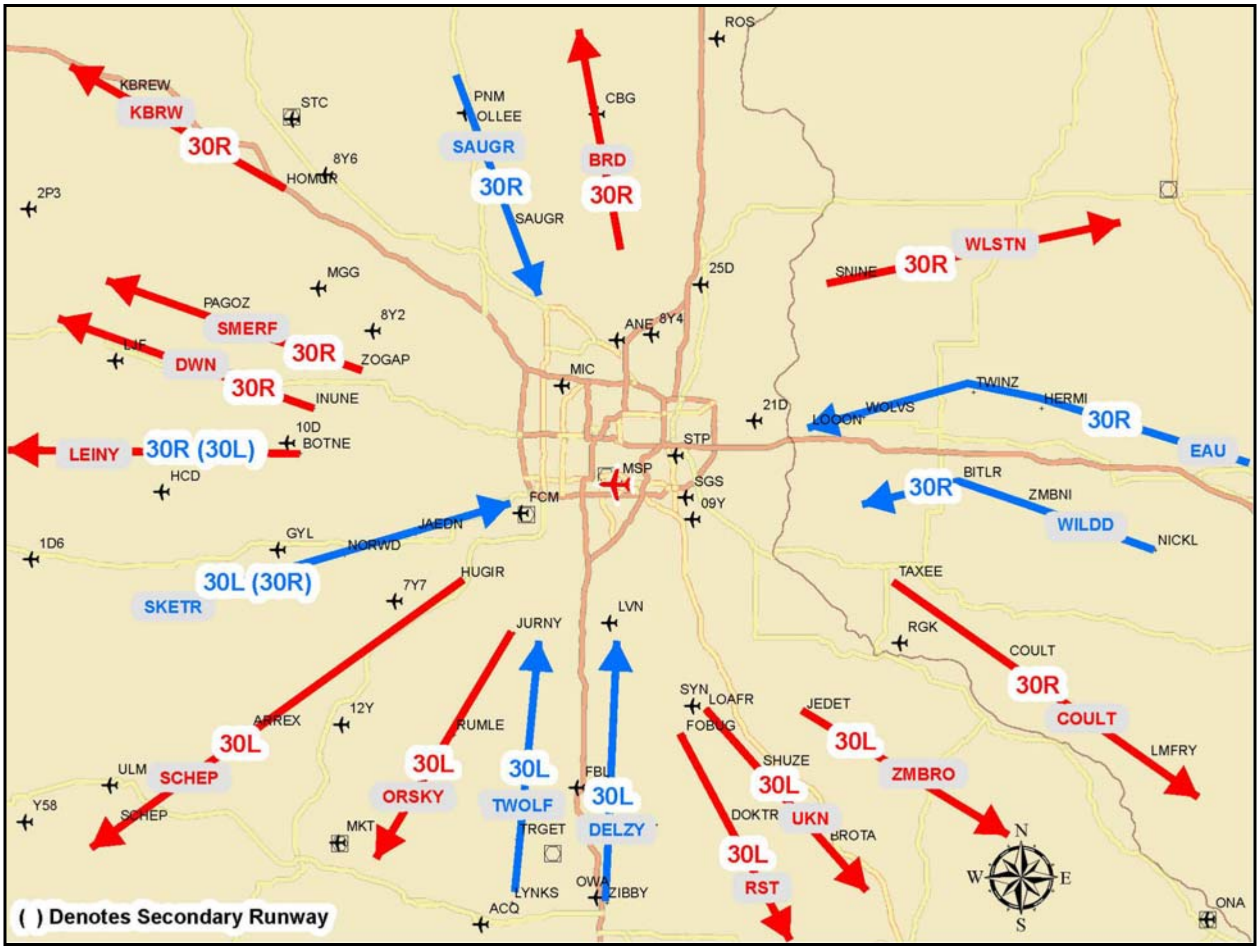


Figure D.1-10

South Flow VFR/IFR

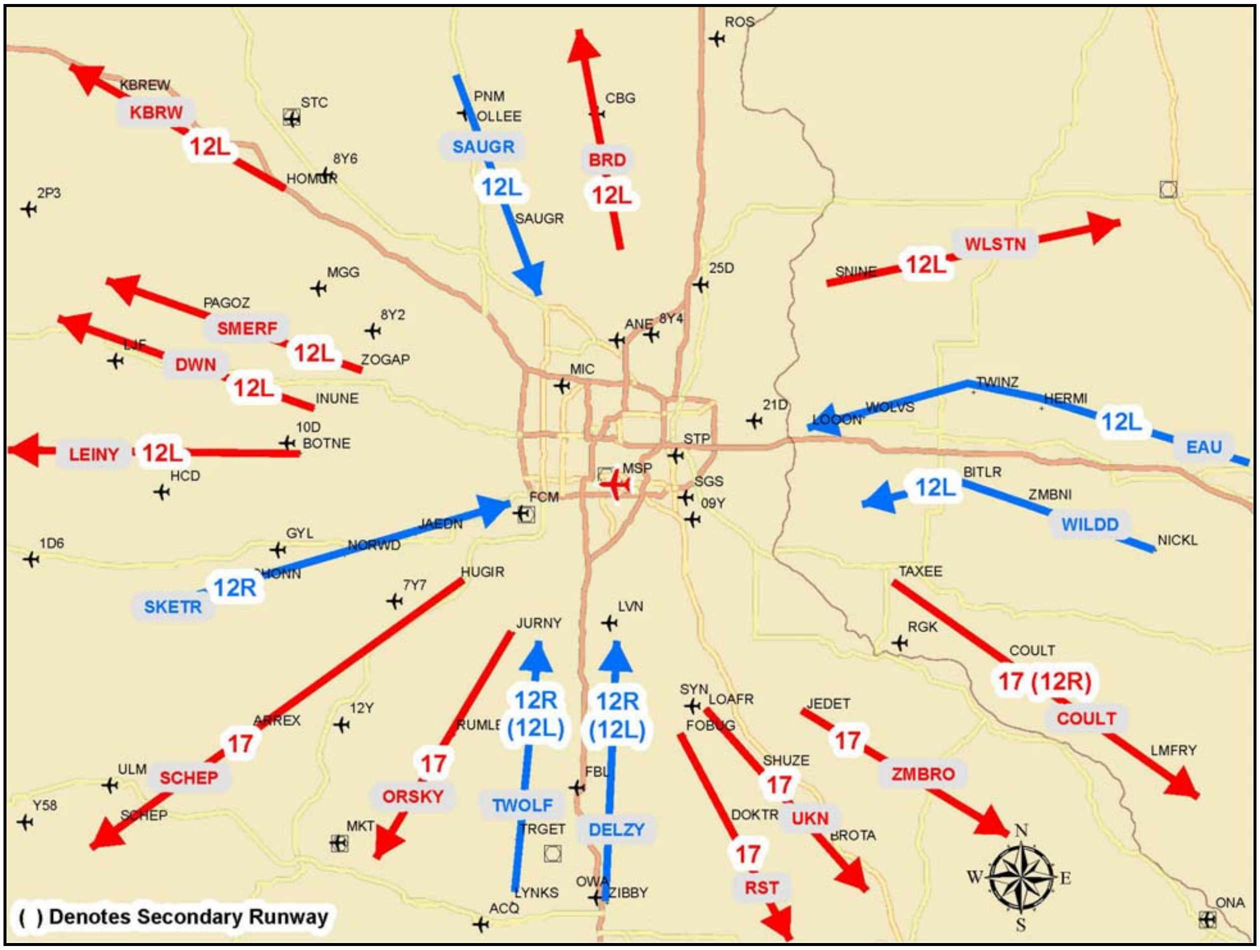


Figure D.1-11

Partial South Flow VFR/IFR

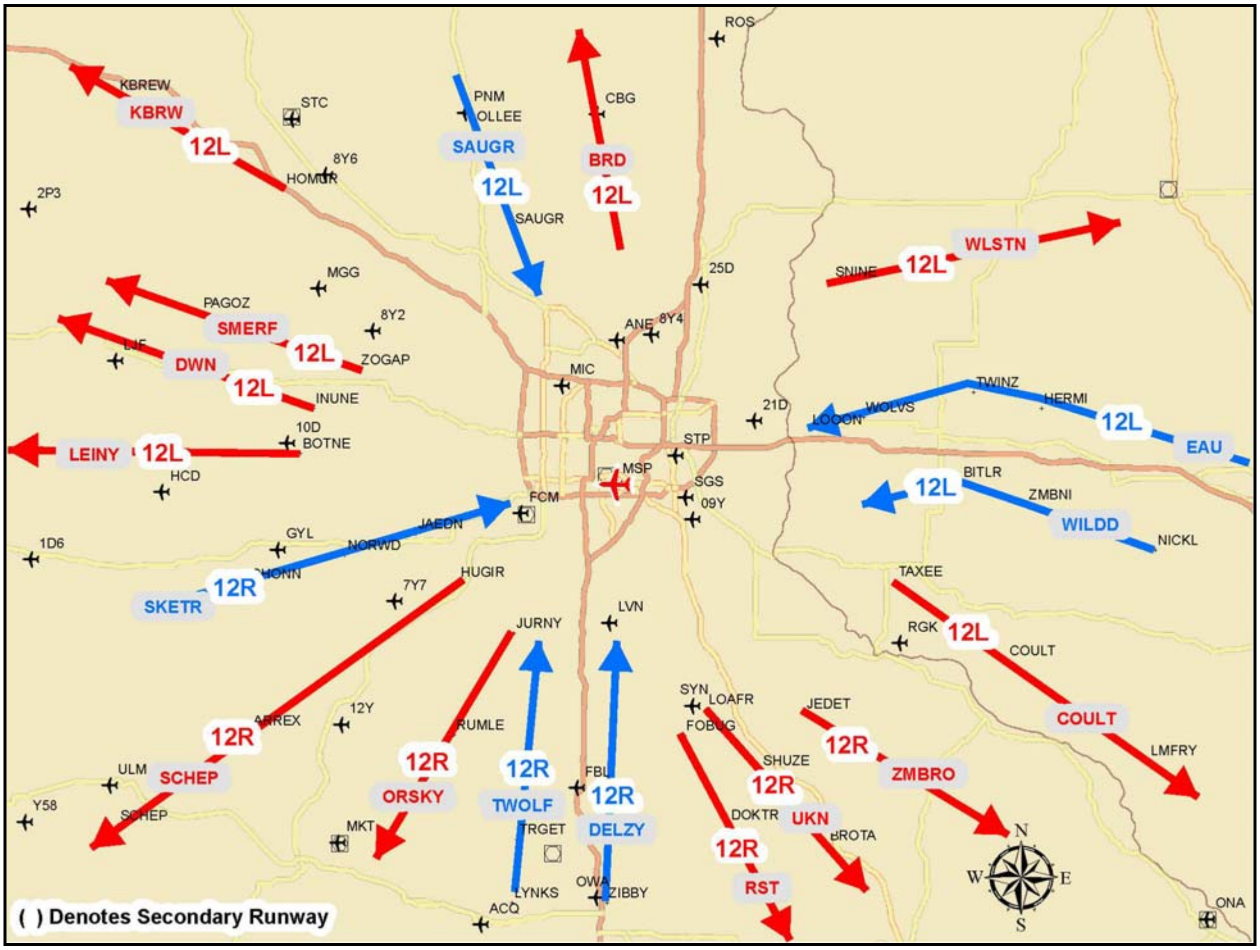
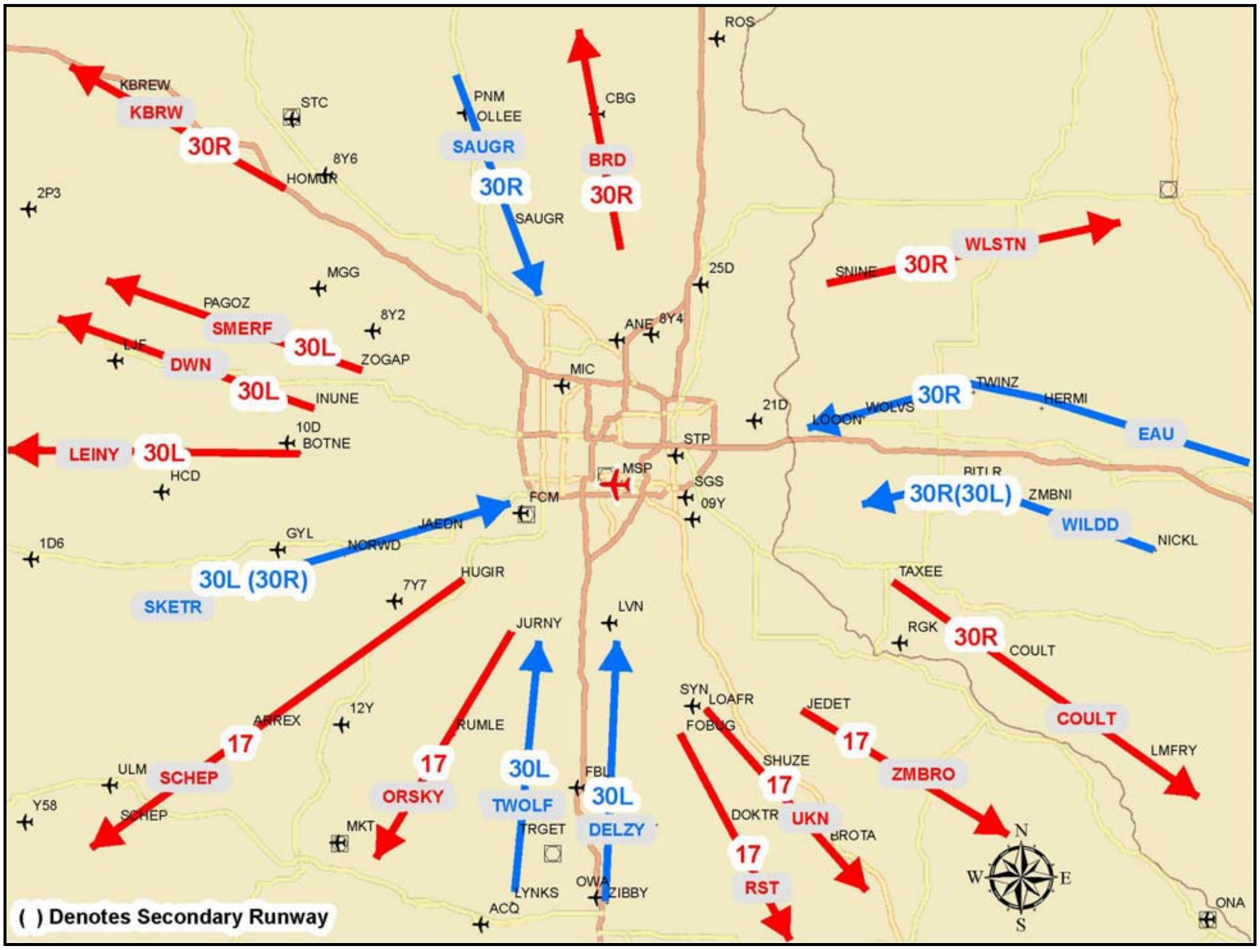


Figure D.1-12

Mixed Flow VFR/IFR

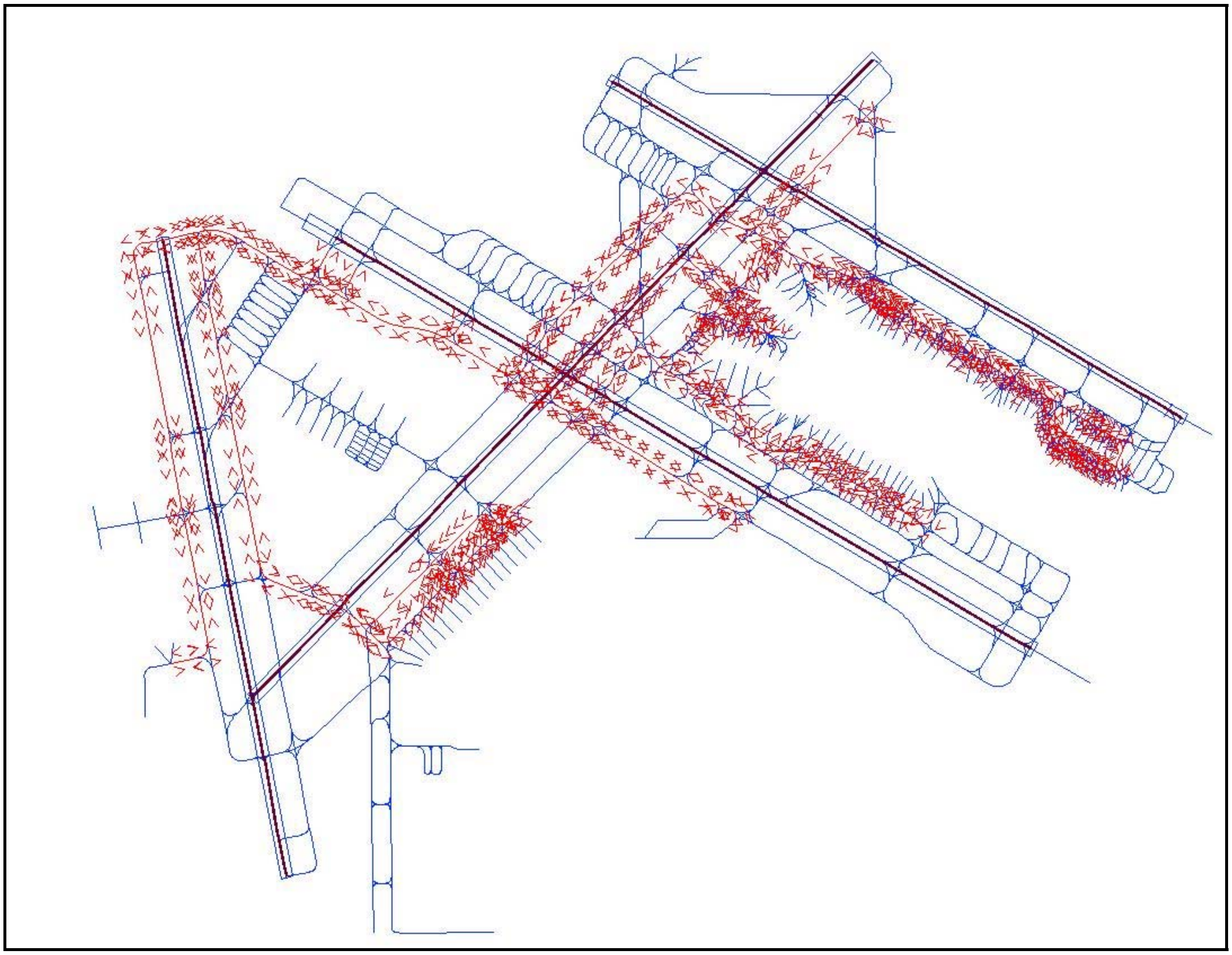


1.13 Taxi Paths

In each operating scenario, preferred taxi paths were created from each runway to each gate area, recognizing the current direction of travel, one-way taxi segments, etc. Taxi paths within the SIMMOD model force aircraft to use certain taxiways, to minimize the likelihood of conflicts with aircraft traveling in opposing directions, etc. An example of preferred taxi paths from parking positions to Runway 17 is shown in **Figure D.1-13.**

Figure D.1-13

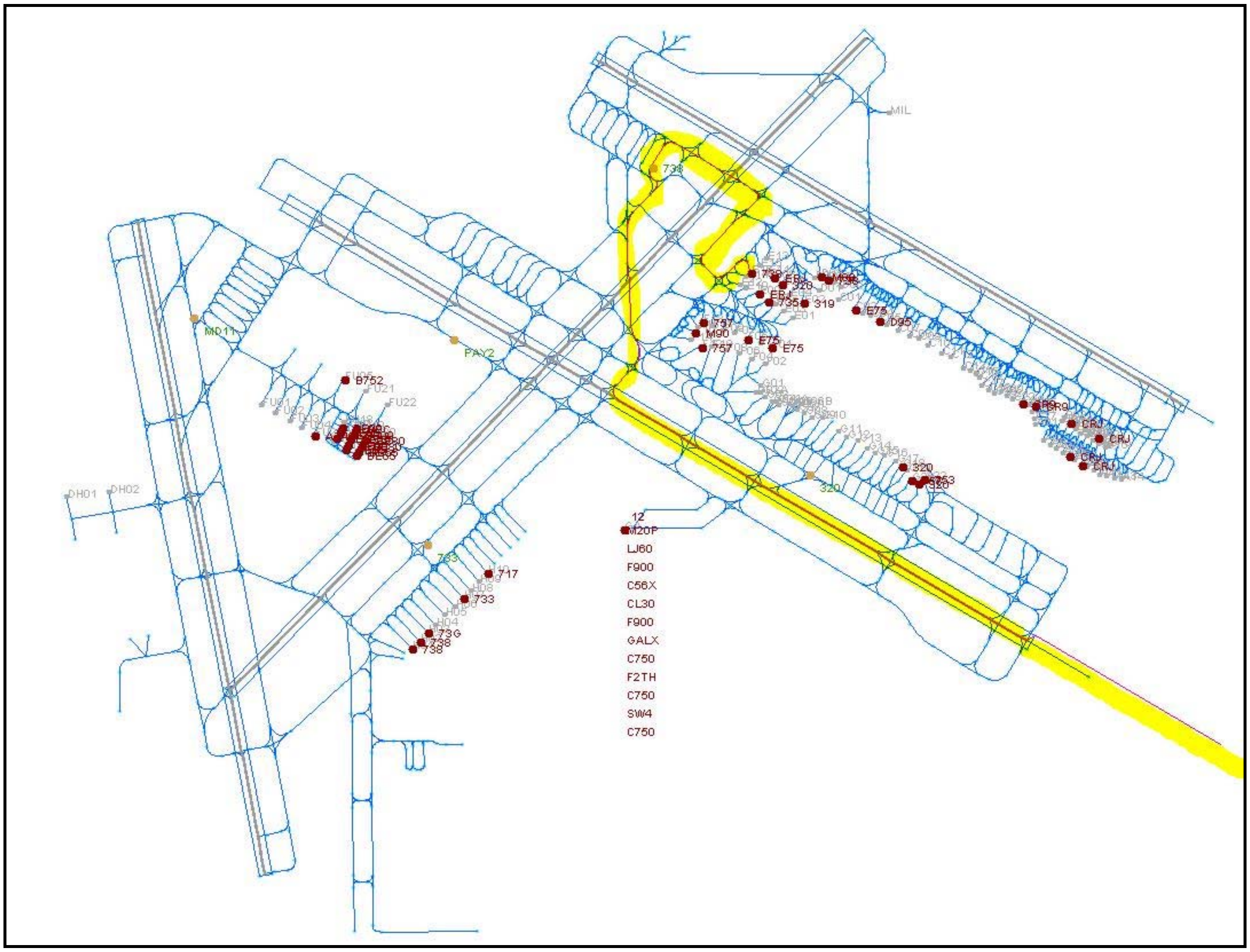
Taxi Paths to Runway 17 from Parking Positions around the Airport



Typically arriving aircraft, after leaving the arrival runway, taxi directly to their gate or parking position. For this analysis, however, HNTB also considered the possibility that the flight's gate or parking position is already occupied, requiring the new arrival to park and hold elsewhere on the airfield until the gate opens again. **Figure D.1-14** shows the path that was taken by a flight that landed on Runway 30L, but then went to a holding area, before proceeding to its assigned gate.

Figure D.1-14

Taxi Path Taken to a Temporary Holding Position before Proceeding to Gate



To model gate use, minimum gate occupancy times (called Turn Times) were used for different sized aircraft. **Table D.1.5** provides the turn times used in the MSP analysis.

Table D.1.5

Modeled Turn Times by Aircraft Size

Turn Time (minutes)	Aircraft Size
30	Turbo Props and RJs
40	318, 319, 320, 717, 733, 734, 735, 738, 73G, 73H, D95, E90, M80, M83, M87, M88, M90
50	321, 753, 757, 75W, B752
60	763, 764, 767, 76D, A300, B762, B763, DC10, DC87, MD11
70	332 (Domestic), 788
90	777 (Domestic)
120	333, 744, 772, 777 (International)

Source: SIMMOD *Pro!*®

Gate hold locations were used at different locations around the airport, including:

- Terminal 1
    - Concourses A, B, and C: 30R De-ice Pad
    - Concourses D and E: 12L De-ice Pad
    - Concourse F: 12R De-ice Pad
    - Concourse G: 30L De-ice Pad
- Terminal 2
    - Concourse H: Southwest Cargo Apron

1.14 Runway Exit Logic

To model landings, SIMMOD uses many factors, including landing roll distance probability. Once the landing roll distance has been calculated, the aircraft continues to the next runway exit. However, since the aircraft might have a choice of exiting on either side of the runway, additional steps are necessary to limit which runway exit is used. In each scenario, a different set of viable runway exits was developed. Additional information on runway exit logic variables are found within the SIMMOD model under “Builders” and “Runway Exit Builder.”

1.15 Metering

Metering allows the SIMMOD model to move flights from an initially-assigned route (and therefore runway) to a back-up runway, to allow demand to be equitably shared between runways. For this analysis, metering was used for both arrivals and departures and was triggered by the number of flights that have already been assigned to a specific runway, but which have not yet taken off or landed.

2 Validation of the Model and Presentation of Results

2.1 Comparison of Results/Actual Runway Use

The 2010 SIMMOD results were compared to actual runway use data provided by the MAC to verify the accuracy and validity of the model's results. These comparisons are shown in **Table D.2.1** and **Table D.2.2**. By adjusting (or "correcting" the SIMMOD results presented in Table D.1.2, future year SIMMOD results could be similarly adjusted to allow for more accurate results in those years.

Table D.2.1

Comparison of SIMMOD Runway Use to Actual (2010) Runway Use

Type of Operation	***North Flow***		***South Flow***		***Mixed Flow***		***Partial South Flow***		***SIMMOD (Weighted)***		***2010 Annual Data (Actual)***	
	VFR	***IFR***	***VFR***	***IFR***	***VFR***	***IFR***	***VFR***	***IFR***				
	42%	***11%***	***24%***	***6%***	***4%***	***1%***	***7%***	***4%***	***Daily Ops***	***Percent***	***Daily Ops***	***Percent***
Departures												
4									0	0.00%	0	0.08%
17			388	402	319	327			135	19.49%	125	21.23%
22									0	0.00%	2	0.38%
35									0	0.00%	0	0.01%
12L			241	248			331	336	110	15.89%	76	12.94%
12R			66	44			363	358	58	8.33%	47	7.97%
30L	318	326			108	101			177	25.48%	152	25.85%
30R	376	369			267	266			214	30.81%	186	31.55%
Departure Total:	**694**	**694**	**694**	**694**	**694**	**694**	**694**	**694**	**694**	**100%**	**590**	**100%**
Arrivals												
4									0		0	0.01%
17									0		0	0.06%
22									0		2	0.36%
35	326								138	19.99%	113	19.04%
12L			346	346			347	347	143	20.79%	115	19.39%
12R			344	344			343	343	143	20.66%	116	19.56%
30L	173	365			363	363			132	19.18%	115	19.41%
30R	191	325			327	327			134	19.38%	132	22.17%
Arrival Total:	**690**	**690**	**690**	**690**	**690**	**690**	**690**	**690**	**690**	**100%**	**594**	**100%**

Source: HNTB analysis, 2011.

Table D.2.2

SIMMOD Results Adjusted for 2010 Actual Activity

Type of Operation	*SIMMOD (Weighted)*		*2010 Annual Data (Actual)*		2010 SIMMOD Data (Corrected)	
	Daily Ops	*Percent*	*Daily Ops*	*Percent*	*Daily Ops*	*Percent*
Departures						
4	0	0.00%	0	0.08%	0.48	0.08%
17	135	19.49%	125	21.23%	127.12	21.23%
22	0	0.00%	2	0.38%	2.28	0.38%
35	0	0.00%	0	0.01%	0.06	0.01%
12L	110	15.89%	76	12.94%	77.42	12.93%
12R	58	8.33%	47	7.97%	47.72	7.97%
30L	177	25.48%	152	25.85%	154.78	25.85%
30R	214	30.81%	186	31.55%	188.91	31.55%
Departure Total:	**694**	**100.00%**	**590**	**100.00%**	**598.75**	**100.00%**
Arrivals						
4	0	0.00%	0	0.01%	0.06	0.01%
17	0	0.00%	0	0.06%	0.36	0.06%
22	0	0.00%	2	0.36%	2.16	0.36%
35	138	19.99%	113	19.04%	113.99	19.04%
12L	143	20.79%	115	19.39%	116.09	19.39%
12R	143	20.66%	116	19.56%	117.11	19.56%
30L	132	19.18%	115	19.41%	116.21	19.41%
30R	134	19.38%	132	22.17%	132.73	22.17%
Arrival Total:	**690**	**100.00%**	**594**	**100.00%**	**598.71**	**100.00%**

Source: HNTB analysis, 2011.

2.2 Weighting/Blending of Simulation Results

Using ten iterations of each scenario, the SIMMOD model calculated total travel and delay time for each flight in every scenario. The delay and travel time averages for each flight are presented in **Table D.2.3** and **Table D.2.4.**

Table D.2.3

Comparison of Delay by Operating Scenario/Flight Rules

(minutes/operation)

Operating Scenario/Flight Rules	2010	2020			2025		
	No Action	No Action	Alternative 1	Alternative 2	No Action	Alternative 1	Alternative 2
North Flow/VFR	3.22	4.20	4.71	4.12	5.11	5.08	5.32
North Flow/IFR	8.75	12.67	12.85	12.42	17.20	16.80	17.37
South Flow/VFR	2.70	3.61	3.46	3.45	4.28	4.02	4.19
South Flow/IFR	5.90	8.26	8.11	8.06	11.27	11.01	10.92
Mixed Flow/VFR	3.43	4.28	4.66	4.37	5.11	4.97	5.44
Mixed Flow/IFR	6.57	9.16	9.41	9.14	11.94	11.70	12.01
Partial South Flow/VFR	5.29	7.18	7.32	6.65	8.64	8.43	8.97
Partial South Flow/IFR	8.67	12.71	13.17	12.16	18.48	18.88	18.87

Notes: Alternative 1 = Airlines Remain; Alternative 2 = Airlines Relocate

Source: HNTB analysis, 2011.

Table D.2.4

Comparison of Delay and Travel Time by Operating Scenario/Flight Rules

(minutes/operation)

Operating Scenario/Flight Rules	2010	2020			2025		
	No Action	No Action	Alternative 1	Alternative 2	No Action	Alternative 1	Alternative 2
North Flow/VFR	23.24	23.99	24.40	23.84	24.80	24.81	25.16
North Flow/IFR	28.54	32.40	32.61	32.39	36.98	36.63	37.49
South Flow/VFR	24.31	25.01	24.91	24.82	25.64	25.50	25.71
South Flow/IFR	27.92	30.13	29.98	29.79	33.10	32.92	32.79
Mixed Flow/VFR	23.31	24.07	24.47	24.23	24.90	24.83	25.42
Mixed Flow/IFR	26.44	28.96	29.21	29.03	31.77	31.58	32.01
Partial South Flow/VFR	26.67	28.41	28.57	27.94	29.83	29.71	30.47
Partial South Flow/IFR	30.04	33.96	34.41	33.47	39.71	40.19	40.37

Notes: Alternative 1 = Airlines Remain; Alternative 2 = Airlines Relocate

Source: HNTB analysis, 2011.

Combing the results of each operating scenario with the percentage of time the operating scenario is in use (see Table D.1.2 of this technical report for percentage of time used) provides a weighted annual delay as provided in **Table D.2.5** and **Table D.2.6.**

Table D.2.5

Weighted Annual Delay

(minutes/operation)

Year	No Action	Alternative 1: Airlines Remain	Alternative 2: Airlines Relocate
2010	4.30	Not Modeled	Not Modeled
2020	5.88	6.12	5.71
2025	7.53	7.38	7.64

Source: HNTB analysis, 2011.

Table D.2.6

Weighted Annual Delay and Travel Time

(minutes/operation)

Year	No Action	Alternative 1: Airlines Remain	Alternative 2: Airlines Relocate
2010	24.95	Not Modeled	Not Modeled
2020	26.34	26.55	26.16
2025	27.94	27.86	28.24

Source: HNTB analysis, 2011.