BNA
MASTER PLAN
NASHVILLE INTERNATIONAL AIRPORT

Facility Requirements

Nashville International Airport® (BNA®)

Master Plan Update

June 5, 2019

DRAFT

BNA
Nashville International Airport®

AECOM

Quality information

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Disclaimer

All forecasts are subject to levels of uncertainty. The forecasts provided in this Technical Report are based on the information available at the time of their creation. Various factors, other than those included in the forecast models, can influence future aviation demand. Unexpected events may occur and some underlying forecast assumptions and/or expectations may not materialize. Therefore, actual performance may differ from the forecasts presented in this report and could be significant.

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4.1. Introduction

This chapter identifies facility requirements for airfield, terminal, landside, and support facilities at Nashville International Airport (BNA) throughout the 20-year planning period. The determination of facility requirements is achieved first by analyzing the impacts of forecast demand on the capacity of existing facilities to accommodate expected activity. After summarizing the capacity of existing airfield, terminal, landside, and support facilities, improvement requirements are identified for four future planning activity levels (PAL) corresponding to 5-year (2022), 10-year (2027), 15-year (2032), and 20-year (2037) forecasts. Facility requirements are identified in this chapter for the following elements:

1. Airfield facilities
2. Passenger terminal facilities
3. Landside facilities (roadway access, circulation roadways, parking)
4. Air cargo
5. General aviation
6. Airport and airline support facilities
7. Sustainability

4.1.1. Summary of Demand Forecasts

The timing of facility improvements is driven by *when* future aviation activity levels will be reached, not a predicted set point in time. The actual timing of development may vary from the Master Plan forecast depending upon the actual progression of future activity. As a result, "planning activity levels" (PALs) are encouraged to be used by the Federal Aviation Administration (FAA) in evaluating the need for additional facilities. The FAA's guidance on Master Plans suggests that "… planners should identify what demand levels will trigger the need for expansion or improvement of a specific facility. In this way, the airport sponsor can monitor growth trends and expand the airport as demand warrants."

As summarized in **Table 4-1**, the PALs used in this Master Plan correspond approximately to five-year increments presented in the Forecasts of Aviation Demand chapter. These PALs represent activity-based milestones that can be used to make future facility improvement decisions, focusing on the specific volumes of activity that trigger the facility improvement requirement. It is important to note that the Master Plan forecasts make certain assumptions about the mix of airlines and aircraft, as well as assumptions about the processes required to move passengers through the terminal building, provide security, etc. By monitoring future aviation activity continually, the Metropolitan Nashville Airport Authority (MNAA) can detect changes in these assumptions and adjust capital improvement schedules as appropriate.

Table 4-1. Summary of Demand Forecasts

	2017 (Baseline)	2022 (5-year)	2027 (10-year)	2032 (15-year)	2037 (20-year)
Annual Enplanements	7,076,371	9,047,142	9,938,318	10,886,036	11,935,070
Total Annual Operations	**205,802**	**256,599**	**273,924**	**291,664**	**311,114**
Annual Air Carrier Operations	135,135	183,362	191,530	200,815	210,387
Annual Cargo Operations	2,662	3,099	3,343	3,610	3,901
Annual GA Operations	67,117	69,686	78,844	87,299	97,176
Annual Military Operations	3,550	3,550	3,550	3,550	3,550
Annual Cargo Tonnage	48,353	58,224	64,213	70,787	78,055
Based Aircraft	107	122	140	160	184

Source: BNA Master Plan Update 2018: Aviation Demand Forecasts Chapter

4.2. Airfield Capacity & Requirements

Airfield capacity is defined as the number of aircraft that can use the airfield during a specified amount of time, usually expressed as aircraft movements per hour or year. The estimation of airfield capacity also considers the amount of aircraft delay that may occur with an airport's airfield configuration. An airfield's capacity is a function of its physical facilities, including runway orientation and configuration, runway length, runway exit locations, and the available taxiway system that accommodates the various destinations of aircraft on the ground (i.e. passenger terminal, general aviation area, etc.). The capacity of any given airfield system is also affected by operating characteristics such as aircraft fleet mix, wind, and weather, as well as air traffic control (ATC) procedures used to coordinate air traffic movement on the ground and in the immediate airport vicinity. Each of these components is examined as part of the airfield capacity analysis.

4.2.1. Airfield Capacity Analysis

4.2.1.1. Methodology and Assumptions

The methodology used to estimate airfield capacity is based on Federal Aviation Administration (FAA) guidance. In 1983, the FAA published Advisory Circular 150/5060-5, *Airport Capacity and Delay*. That document described how to compute airfield capacity for airport planning and design purposes and had been the standard methodology for many years. Using this methodology, users could identify an airfield layout and then provide parameters such as aircraft fleet mix and limitations to taxi flows to determine an estimated hourly and annual airfield capacity for an airport.

Subsequently, in 2012, the National Academies of Science, Engineering, and Medicine's (NASEM) Transportation Research Board (TRB), through its Airport Cooperative Research Program (ACRP), sponsored ACRP project 03-17 which published ACRP Report 79 "*Evaluating Airfield Capacity*". This report evaluated models beyond methods used in FAA AC 150/5060-5 and was further enhanced with a capacity spreadsheet model. The updated tool for determining airfield capacity is the *Airfield*

Capacity Spreadsheet Model. ACRP's Airfield Capacity Spreadsheet Model was used to estimate BNA's airfield capacity. Guidance and procedures were taken from ACRP Report 79, *Appendix A: Prototype Airfield Capacity Spreadsheet Model User's Guide*.

The *Airfield Capacity Spreadsheet Model* requires a number of parameters and assumptions regarding runway layout, fleet mix, aircraft separation assumptions, and weather conditions to be defined. These assumptions and inputs are described below.

Runway Layout

BNA airport has a total of four (4) runways, as depicted in **Figure 4-1**. These consist of three (3) parallel, approximately 8,000-foot long northeast/southwest runways (Runways 2L/20R, 2C/20C, and 2R/20L) and one intersecting 11,000-foot long northwest/southeast "crosswind" runway (Runway 13/31). Runways 2L/20R and 2C/20C are separated by 1,176 feet. Runway 2R/20L is approximately 5,000 feet from Runway 2C/20C. For the purposes of the airfield capacity estimate, only the three parallel runways were evaluated. Intersecting runways provide less capacity than parallel runways due to operating restrictions that require aircraft to be separated by a greater distance and/or spacing than with parallel runways. Thus, while crosswind Runway 13-31 provides an operational benefit when its runway length is needed for aircraft operations or when the wind dictates its use, generally the runway does not add measurable capacity to the BNA airfield, and was not considered in the capacity calculations due to its relatively infrequent usage.

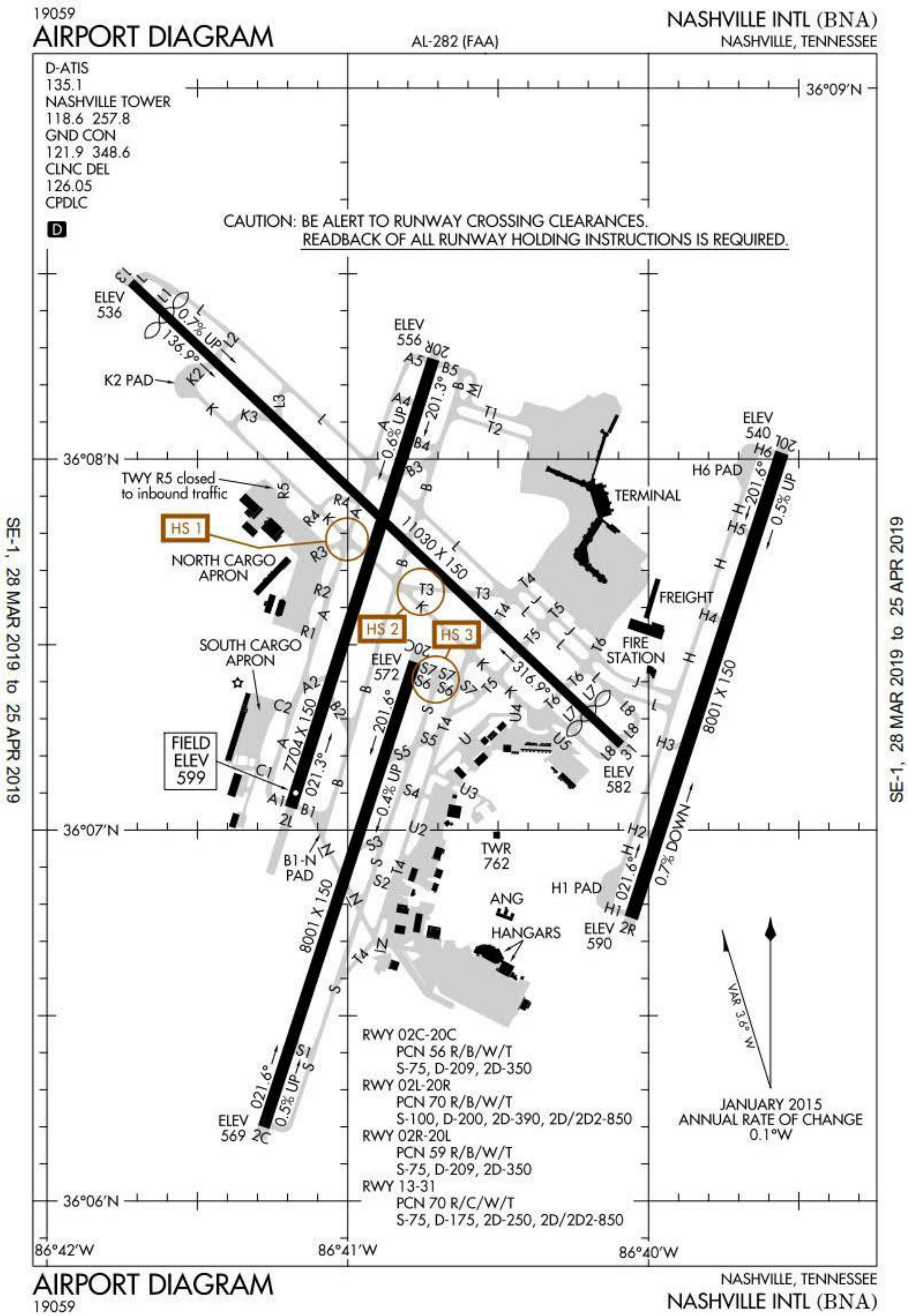
Runway Utilization and Wind Conditions

Aircraft perform most safely and efficiently when they arrive and depart into the wind. At BNA, approximately 50 percent of BNA's annual operational pattern is a north flow and similarly 50 percent of activity operates in a south flow. Notably, less than one percent of annual activity operates in a northwest/southeast flow due to the infrequency of strong northwest or southeast winds.

Visibility

Visibility for controlling aircraft movements is important to airfield capacity, since it directly affects how easily aircraft can be separated in the air and on the ground. An airport operates most efficiently and with greatest capacity when weather conditions allow unobstructed visibility of the airfield. Based on information gathered from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) and data from the BNA Master Plan inventory, Nashville International Airport experiences Visual Meteorological Conditions (VMC) (greatest visibility) about 90.8% of the time and Instrument Meteorological Conditions (IMC) (lower visibility) conditions approximately 9.2% of annual operations.

Figure 4-1. BNA Airport Diagram



Source: FAA Airport Diagram, retrieved on April 1st, 2019 from https://www.faa.gov/airports/runway_safety/diagrams/

Arrivals Percentage

An airfield must accommodate both arriving and departing aircraft. Arriving aircraft must be sequenced into the flow of departing aircraft that might be using the same runway. Also, an arriving aircraft occupies a runway for a period of time that is factored into the capacity calculations. While there are periods throughout a day where aircraft arrivals and departures are not balanced, a 50/50 arrivals and departures balance typically occurs in any 24-hour period. Thus, a factor of 50% arrivals and 50% departures was assumed for the capacity model.

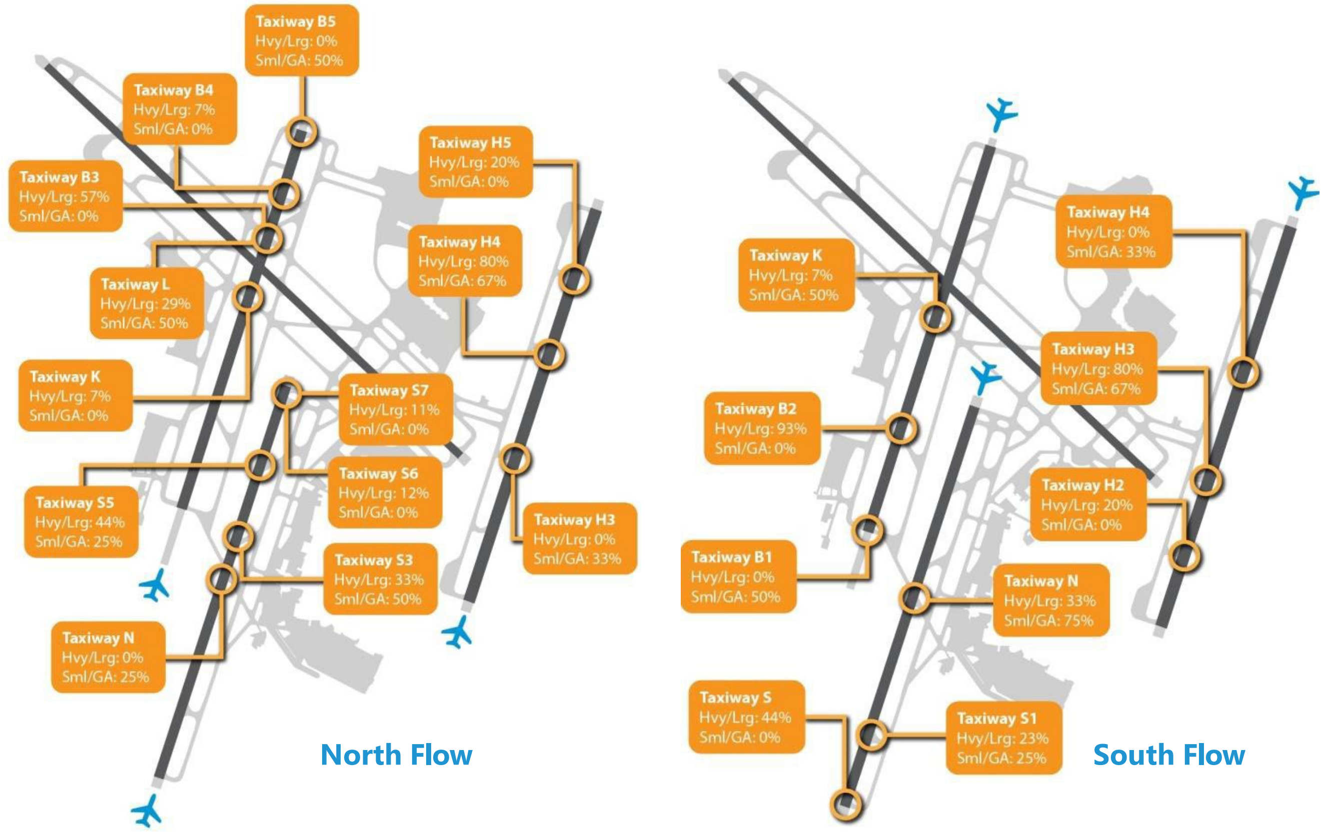
Touch and Go

Touch-and-Go's are operations where an aircraft touches down on the runway during landing but immediately takes off again, and is typically associated with small general aviation aircraft training operations. For the purposes of the model, touch and go operations were assumed to be less than 1% of the annual operations and calculated to have no impact on the annual capacity of the airport.

Taxiway Factors

Airfield capacity is affected by an aircraft's runway occupancy time and the availability of appropriately-spaced runway exit taxiways. The model allows for limiting runway activity if taxiway exits are not sufficient. Because each of the runways at BNA has full-length parallel taxiways and a sufficient number of appropriately-spaced runway exit taxiways, no limitations on aircraft exiting the runways due to the taxiway system was considered in the calculation of airfield capacity. **Figure 4-2** illustrates the available runway exit txiways in north and south flow, and indicates the approximate usage of each exit.

Figure 4-2. Arrival Runway Exits – North and South Flow



Data Source: North-flow Data Collected at BNA by TransSolutions, December 2016; South-flow approximated from north-flow landing roll distances.

Aircraft Fleet Mix

The original FAA Advisory Circular for calculating airfield capacity (AC 150/5060-5) used a mathematical formula to determine aircraft fleet mix based on the size of aircraft. Aircraft between 12,500 pounds and 300,000 pounds were identified as Category C, and aircraft heavier than 300,000 pounds were identified as Category D. The formula of "**C+3D**" was used by the original AC to calculate a fleet mix index number.

For BNA, the base year aircraft mix shows:

- Class C = 81.2 percent of airport operations
- Class D = 2.0 percent of airport operations

Therefore, for BNA, the fleet mix index formula for airfield capacity estimation purposes would be:

- C + 3 * D = Fleet Mix Index
- 81.2 + (3* 2.0) = 87.2

The FAA established fleet mix index ranges for use in capacity calculations as listed below:

0 to 20 | 21 to 50 | 51 to 80 | 81 to 120 | 121 to 180

Based on the forecasted aircraft mix for BNA, it is expected the airport will stay in the 81 to 120 range for the foreseeable future. The *Airport Capacity Spreadsheet Model* requires these classifications be even further broken down as shown in **Table 4-2**. Aircraft classification share allocations were estimated from operational data.

Table 4-2. Fleet Mix Share Allocations

New Category	Small - S	Small - T	Small +	Large-TP	Large-Jet	Large-757	Heavy
Previous FAA Category	A	B	C	C	C	C	D
Maximum Gross Takeoff Weight (MTOW)	Less than 12,500 lbs. (Single Engine)	Less than 12,500 lbs. (Twin Engine)	Between 12,500 lbs. and 41,000 lbs.	Between 41,000 lbs. and 255,000 lbs.	Between 41,000 lbs. and 300,000 lbs.	Boeing 757 Series	More than 300,000 lbs.
Share Allocations	9.0%	9.0%	25.0%	25.0%	30.0%	1.2%	0.8%

Source: Airfield Capacity Spreadsheet and 2018 forecasted fleet mix

Airspace Departure/Arrival Separation

Another factor to be considered in the estimation of airfield capacity is the ability of aircraft to arrive and depart the airport in as smooth a flow as possible. Congested airspace at the busiest airports reduces airfield capacity, since the sequencing of aircraft arrivals can often interfere with the smooth sequencing of aircraft departures, resulting in ground delays. Related to airspace analysis, aircraft arrival and departure sequencing is affected by visibility in IMC conditions, where aircraft separation must be increased to account for reduced Air Traffic Control (ATC) visibility. For calculating airfield capacity in VMC conditions the departure-arrival separation was set to 2 nm, and for IMC conditions the departure-arrival separation was set to 3 nm.

4.2.1.2. Airfield Capacity Summary

Using the parameters and assumptions listed above, as well as information from the Master Plan Update's Aviation Demand Forecasts, airfield capacity was calculated. To account for the uniqueness of the BNA airfield layout having three (3) parallel runways, two model configurations were used to estimate capacity. One model configuration was established to calculate the capacity of Runways 2L/20R and 2C/20C (dual runway model), and one model configuration was established for Runway 2R/20L (single runway model). The overall airfield capacity was estimated by summing the results of the individual configuration estimates together.

For the dual runway model, the lateral separation between Runways 2L/20R and 2C/20C (1,176 feet) is considered too close to allow independent arrivals and departures in IMC weather conditions. This is because, even with current technology, ATC controllers require increased aircraft separation in reduced visibility weather conditions. Thus, these two runways are considered "dependent" – they cannot be used at the same time for arrivals and departures without increased aircraft separation, which reduces airfield capacity in those weather conditions. For the modeling effort, dependent parallel runway configuration scenario number 7 was chosen to best represent these runways.

Hourly VMC Capacity

Hourly VMC capacity was estimated at 92 for the dual configuration and another 54 operations for the single runway totaling to an overall estimate of 146 hourly operations in both north flow and south flow operations.

Hourly IMC Capacity

Hourly IMC capacity was estimated at 64 for the dual configuration and another 43 operations for the single runway totaling to an overall estimate of 107 hourly operations in both north flow and south flow operations.

Annual Service Volume (ASV)

Annual Service Volume is the estimate of the annual capacity of total aircraft operations at the airport. It is calculated from the hourly capacities noted above along with factors to adjust for peak hours and peak days.

From ACRP 03-17, *Appendix A: Prototype Aircraft Capacity Spreadsheet Model User's Guide*, the following calculation is used to estimate ASV:

> **ASV = Cw * D * H**, where **Cw** is the weighted average of hourly capacities at their respective percent occurrence over a period of time. The model capacity outputs can be calculated for VMC and IMC. The ASV model asks the user to input the hourly capacity values determined from the single, dual or intersecting models and also the percent occurrence of those meteorological conditions to determine **Cw**.
>
> **D** and **H** are the demand ratios which represent the Annual Demand/Avg. Peak Month Daily Demand (**D**), and the Avg. Peak Month Daily Demand/Avg. Peak Hour Demand (**H**). Daily traffic activity data for at least the peak month and the annual traffic volume is required to determine these demand ratios.

For the calculation of (**D**), the following inputs were used:

- June 2018 Operations = 18,885
- 18,885 / 30 days in June = 629.5 Average Day peak month demand

- Total operations for year ending June 2018 = 210,357
- 210,357 / 629.5 = 334.2 = **D**

For the calculation of (**H**), the following inputs were used:

- 43 peak operations / hour (not including GA or Military) based on the Official Airline Guide (OAG) for June 18, 2018
- An estimated 162 GA operations were spread over 18 hours for an average of 9 per hour
- No Military or Cargo operations are forecasted during the peak hour (18:06-19:05)
- Total peak operations on 2018 ADPM = 52
- 629.5 / 52 = 12.1 = **H**

Based on these inputs, BNA's Annual Service Volume was calculated to be 495,300 operations. The annual operations in 2017 were at 42% of ASV. FAA guidance suggests that airport sponsors begin planning for capacity improvements when an airport reaches 60% of ASV. Compared to the ASV, BNA's forecast annual operations will reach above 60% ASV in 2037, as summarized in **Table 4-3**.

Table 4-3. Annual Service Volume vs. Annual Demand

Year	Annual Operations	Annual Service Volume	Percent of ASV
2017	205,802	495,300	42%
2022	256,599	495,300	52%
2027	273,924	495,300	55%
2032	291,664	495,300	59%
2037	311,114	495,300	63%

Source: TransSolutions calculations and BNA Master Plan Aviation Demand Forecasts

Aircraft Delay

The aviation industry uses aircraft delay as a means to identify when airfield improvements may be needed. As the number of annual aircraft operations approaches an airfield's capacity, increasing amounts of delays to aircraft operations begin to occur. Delays occur to arriving and departing aircraft during both VMC and IMC conditions. Arriving aircraft delays result in aircraft holding outside of the airport traffic area, constraining the smooth flow of sequencing arrivals and departures. Departing aircraft delays result in aircraft holding at the gate or on the terminal apron (or other airfield pavements) until cleared for departure. Aircraft delay can affect not only the airport that is experiencing the delay, but also airports where the arriving or departing flights are destined, as well as the national airspace in between airports. This is important to considering airport facilities' effects on the FAA's National Airspace System, and how airports are interrelated in their need to provide adequate airfield capacity. Based on an FAA delay benchmark, delays of six to ten minutes per aircraft operation indicate a degraded airport level of service. The FAA identifies 20 minutes of average delay per aircraft operation as a maximum tolerated delay in its guidance for benefit-cost analyses of airfield improvements.

An airfield capacity analysis was conducted using the Airport and Airspace Simulation Model (SIMMOD) program to assess aircraft delay at BNA. Aircraft delay is defined as the difference between the actual and the unimpeded time for aircraft ground movements using the system of runways and taxiways. The analysis identified the delays and aircraft taxi times at BNA for current conditions and two future demand levels – 2027 and 2037. The analysis relies on a very detailed identification and computer modeling for each segment of an aircraft movement on the airfield, from aircraft parking location to the runway for departing aircraft, and from the runway to the aircraft parking destination for arriving aircraft. The list of required assumptions and aircraft movement segments included in the modeling analysis for the current conditions and two future demand levels (2027 and 2037) include:

- Visual and Instrument Meteorological Conditions (VMC/IMC)
- Total daily flight demand
- Aircraft fleet mix
- Projected design day flight schedule
- Flight dependability (percent that operations are "on-time")
- Aircraft taxi speed for each aircraft type
- Projected airline parking locations at the terminal
- Time it takes for an aircraft "pushback" from a terminal gate
- Length of time needed for aircraft landing/take-off rolls
- Required separation between aircraft
- Assumptions regarding runway to be used by aircraft type

Once all inputs are quantified, the computer model output is calibrated with known information on actual aircraft operations. Two primary sources were used to calibrate the SIMMOD model – the U.S. Department of Transportation's (USDOT) Bureau of Transportation Statistics (BTS), and the airport's noise data. The calibrated models are then used for the study. **Table 4-4** compares the taxi times obtained from BTS to the simulation model's taxi times in both north flow and south flow.

Table 4-4. Taxi Times Calibration (minutes)

Flow	Operations	BTS	Simulated
North	Arrivals	6.2	7.0
	Departures	12.3	11.8
South	Arrivals	6.4	6.9
	Departures	11.0	11.2

Source: Commercial flights for July-August 2017 and June 2018, BTS

The 2018 average hourly runway throughputs for north flow and south flow were also calibrated with the peak month runway throughputs at BNA (Noise Data from May to August 2017 and 2018). **Table 4-5** summarizes the runway throughput calibrations.

Table 4-5. Hourly Runway Throughput Calibration

Flow	BNA Noise Data	Simulated
North	42	43
South	42	44

Source: BNA Noise Data, May – August 2017 and 2018

All taxi times and hourly throughputs are within 10% of the actual data, thus deeming the baseline simulation model to be calibrated and accurate for future capacity estimation analyses.

The results of the SIMMOD modeling for taxi times and average aircraft delay are presented in **Table 4-6** and **Table 4-7**. The parallel runway system at BNA, combined with sufficient runway exit taxiways, result in aircraft experiencing a minimum of ground movement delay through the planning period in both VMC and IMC conditions. Ground movement delays increase throughout the planning period as aircraft operations increase; however, the SIMMOD model predicts that ground delays will not exceed more than approximately two (2) minutes, which is considerably less than the FAA's benchmark of approximately 6 – 10 minutes of average annual aircraft delay per operation. This should not imply that airfield improvements are not needed; rather, it is a confirmation that the current airfield configuration and operating conditions are not contributing to aircraft movement delay.

Table 4-6. Comparison of Average Taxi Times (minutes) – VMC

Operations		2018			2027			2037		
		Unimpeded Taxi Time	Delay	Total	Unimpeded Taxi Time	Delay	Total	Unimpeded Taxi Time	Delay	Total
North Flow	Arrivals	5.7	0.3	6.0	6.0	0.5	6.5	6.0	0.5	6.5
	Departures	10.2	0.6	10.8	10.5	1.0	11.5	10.4	1.1	11.5
South Flow	Arrivals	6.0	0.2	6.2	6.1	0.4	6.5	6.2	0.5	6.7
	Departures	9.3	0.8	10.1	9.4	1.2	10.6	9.5	1.5	11.0

Source: TransSolutions analysis.

Table 4-7. Comparison of Average Taxi Times (minutes) – IMC

Operations		2018			2027			2037		
		Unimpeded Taxi Time	Delay	Total	Unimpeded Taxi Time	Delay	Total	Unimpeded Taxi Time	Delay	Total
North Flow	Arrivals	5.7	0.3	6.0	6.0	0.4	6.4	6.0	0.5	6.5
	Departures	10.2	0.8	11.0	10.5	1.3	11.8	10.4	1.7	12.1
South Flow	Arrivals	6.0	0.2	6.2	6.1	0.5	6.6	6.2	0.5	6.7
	Departures	9.3	1.1	10.4	9.4	1.9	11.3	9.5	2.3	11.8

Source: TransSolutions analysis.

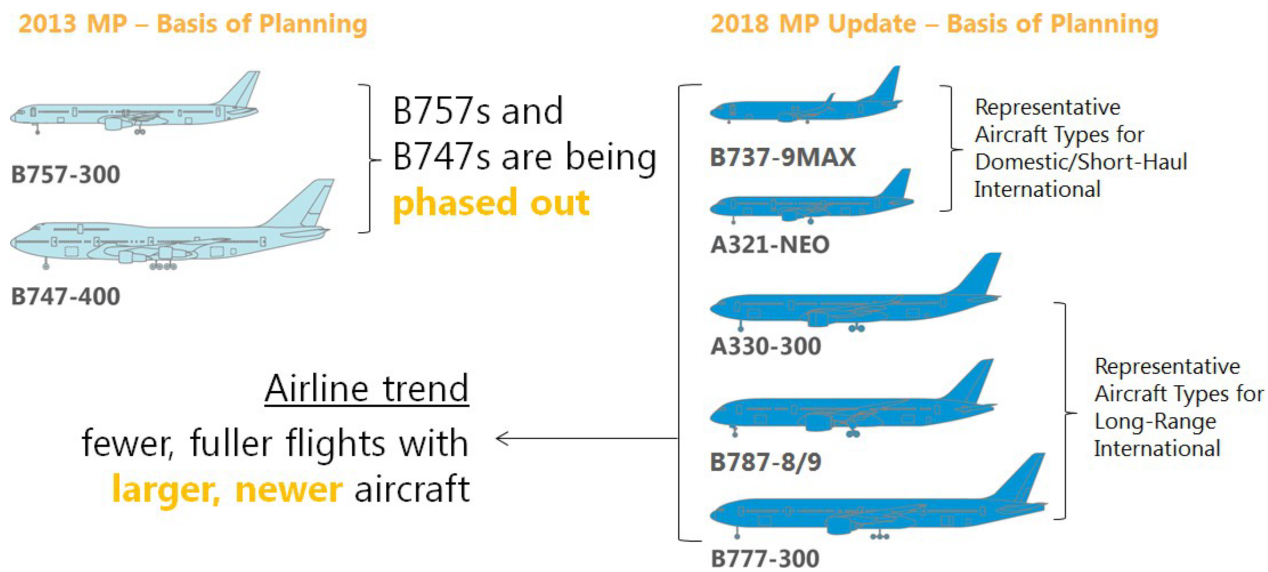
4.2.2. Runway Length Analysis

Runway length is critical to an airport's ability to accommodate the aircraft used for existing and future airline, cargo, general aviation, and military operations. Two major factors determine runway length requirements: the design aircraft and the longest nonstop distance to be flown by the design aircraft.

4.2.2.1. Design Aircraft

The design aircraft established in this Master Plan is ADG D-V, which includes the B787 currently serving the airport. Potential future aircraft having the same ADG include the B777, A330, A340, and A350. The aircraft fleet of the future is evolving differently than examined in the 2013 master plan, and this factor has an impact on the runway length needed at BNA. The 2013 Master Plan indicated that a runway length of 11,000 feet would suffice at BNA; however, the international destinations identified in the 2013 Plan were more indicative of the range capability of the narrowbody B757, which would be limited to Western Europe. **Figure 4-3** illustrates the general airline trend towards newer aircraft, and highlights the benefits of updating the runway length analysis from the 2013 Master Plan.

Figure 4-3. BNA Fleet & Market Demand Shift

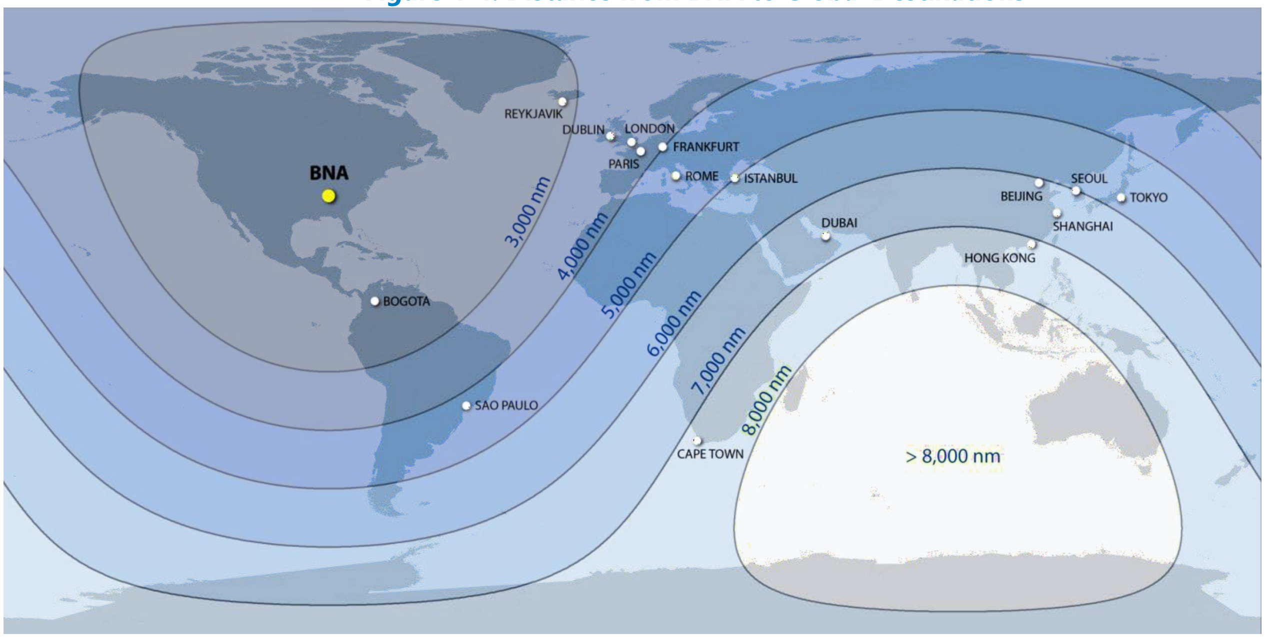


4.2.2.2. Longest Nonstop Distance

Figure 4-4 illustrates the distance from Nashville to several major global airport destinations. Generally, aircraft with capabilities of reaching a 4,000 nautical mile (nm) nonstop distance from BNA would include all Caribbean markets, the northern half of South America, the northwestern coast of Africa, and most of western Europe, including Iceland. A range of 5,000 nm from BNA would include almost all of South America, the western third of Africa, and all of western and central Europe. At a 6,000 nm range, the Far East, including Tokyo and Seoul can be reached, as well as most of the Middle East, all of South America, and the western half of Africa. A range of 6,500 nm from BNA includes the

China markets of Beijing and Shanghai, as well as the remainder of the Middle East. A range of 7,000 nm is needed to reach Hong Kong.

Figure 4-4. Distance from BNA to Global Destinations



Source: AECOM analysis.

4.2.2.3. Airport-Specific Factors

Airport-specific conditions such as airport elevation and runway characteristics (gradient and wet/dry pavement factors) affect runway length requirements. Aircraft performance is lessened by increases in airport elevation, the effect of which is defined as "density altitude". Also, aircraft takeoff and landing performance can be affected by wet pavements and/or runway gradients. These airport-specific factors are examined below.

Density Altitude

Density altitude is a natural phenomenon that decreases aircraft and engine performance. It is a function of the combination of an airport's elevation and air temperature - the higher the elevation and/or air temperature, the higher the density altitude and the greater its effect on runway length requirements. Higher density altitude decreases an aircraft's operational performance, thereby requiring longer runway distances for takeoff and landing operations.

The Nashville-specific density altitude parameters are as below:

Mean daily maximum temperature: 89.9 degrees Fahrenheit for the hottest month in the summer
Airport elevation: 599 feet Above Mean Sea Level (AMSL)

Runway Characteristics

Runway characteristics such as runway pavement slopes and wet surface conditions are also important inputs used to determine runway length requirements. In considering runway slope ("effective gradient"[1]) in runway length requirements, it would be ideal if runways could be constructed as flat surfaces. However, most airport runways are constructed with consideration of the natural terrain resulting in an effective gradient that increases an aircraft's runway length requirement when operating in the uphill direction. The FAA recommends using dry surface conditions for takeoff length requirements, and an additional 10 feet is added to the takeoff length requirement for each foot of difference in the high and low points of the runway centerline elevations. The manufacturer's performance manuals assume zero effective runway gradients and thus this additional factor is required. At Nashville, the effective gradient of the runways due to terrain differences from one runway end to the other (approximately 50 feet) results in the requirement for an additional 500 feet of takeoff runway length.

Wet runway pavements also require longer landing lengths than dry surfaces. Some aircraft manufacturers have calculated the effect of wet runways on the required landing length. For those manufacturers that do not offer these calculations, a standard 15 percent of additional required length is added to the dry landing length requirements to account for wet pavement conditions.

4.2.2.4. Takeoff Runway Length Analysis

The analysis of runway length requirements focuses on the length required for aircraft takeoffs, since this length is considerably greater than landing runway length requirements. Aircraft require more takeoff runway length as the aircraft is developing power and speed to begin flight rather than during landing when aircraft are typically operated at a reduced power setting thus requiring less length to slow down and exit the runway.

In order to identify a recommended takeoff runway length for the design aircraft, an analysis of aircraft manufacturer (Boeing, Airbus) flight performance characteristics manuals for several Group V aircraft types and models was conducted. These aircraft included the:

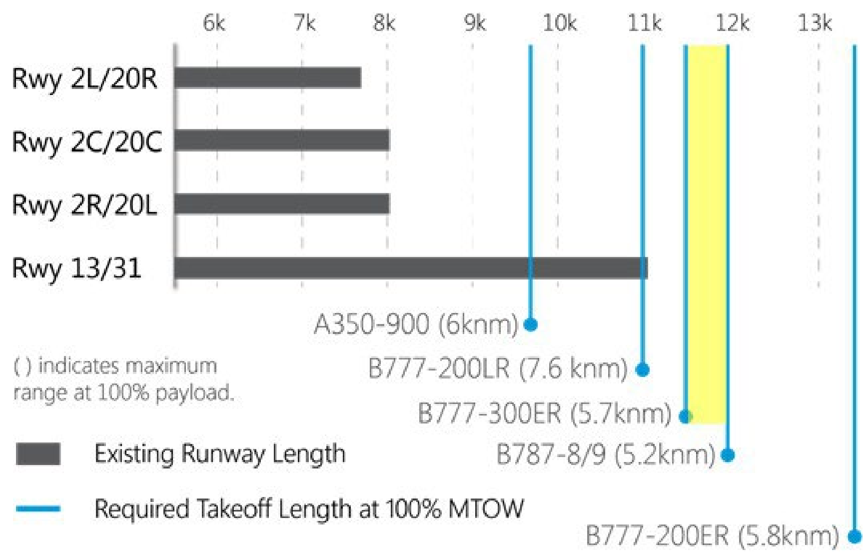
- Boeing 787-8 and Boeing 787-9
- Boeing 777 (various models, such as the -200ER, -200LR, and -300ER)
- Boeing 747-400ER
- Airbus 330 (various models, such as the -200 and -300)
- Airbus 340 (-300 and -600 models)
- Airbus 350-900

[1] Effective gradient is defined as the difference between the highest and lowest elevations of the runway centerline divided by the runway length.

The analysis of the various Group V aircraft performance manuals took into account the longest nonstop distance to be flown from Nashville to existing and potential destinations, as well as the airport's elevation (599' AMSL), effective runway gradient, and average annual high temperatures (89.9° F) in the Nashville area.

Figure 4-5 summarizes the analysis of runway length needed by various aircraft types. Only a selection of representative aircraft is depicted on this figure. The Table indicates that a takeoff runway length of approximately 11,500 – 12,000 feet is needed to serve most potential international markets from Nashville, assuming the representative aircraft types listed above are operating at a 100% payload at maximum takeoff weight (MTOW).

Figure 4-5. Existing Runway Lengths Compared Against Required Runway Lengths



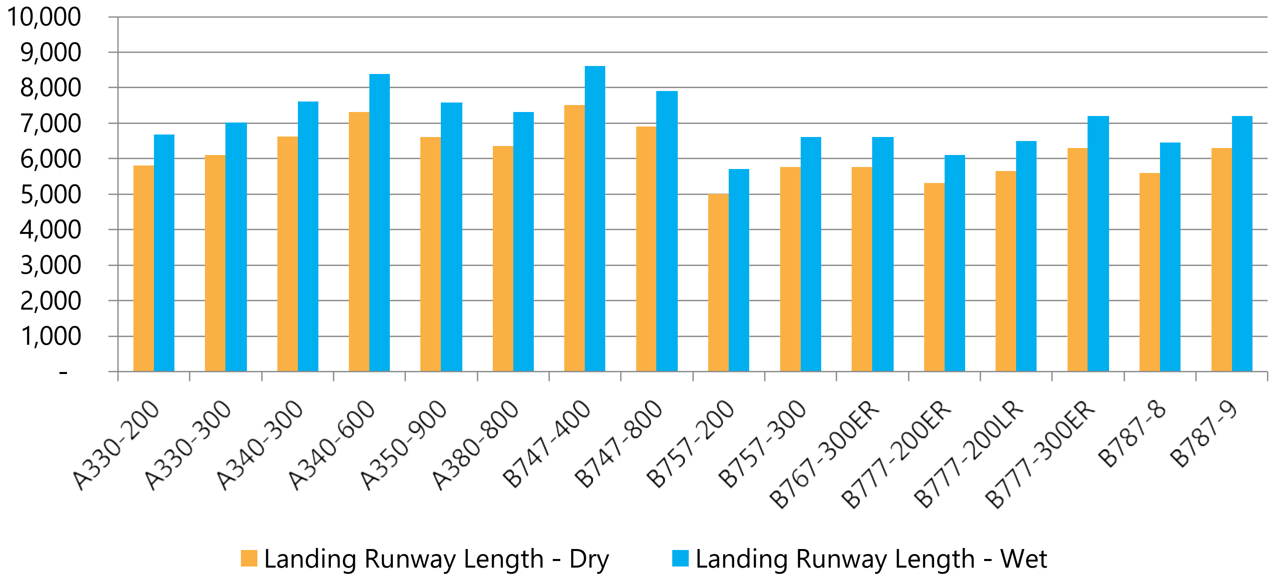
Source: AECOM analysis.

Regarding "payload", or the amount of passengers, cargo, and fuel an aircraft can carry, a 100% payload weight is the optimal condition for an operating airline. Operating flights at maximum payload and aircraft weight produces the greatest revenue opportunity for an airline. Not all of the Design Aircraft can reach all international destinations with maximum payload. If an airline nonstop destination cannot be reached due to insufficient runway length that doesn't allow the aircraft to operate at 100% payload, an airline has no choice but to reduce the amount of passengers, cargo, and/or fuel carried. Payload restrictions can be a deciding factor in an airline's decision to serve a nonstop destination.

4.2.2.5. Landing Runway Length Analysis

In addition to identifying the takeoff runway length required to accommodate the existing and future aircraft fleet, it is important to consider the runway length needed for landings. The landing runway length requirements were calculated using the aircraft's maximum landing weight (MLW) in dry and wet pavement conditions. The findings are summarized in Figure 4-6. Landing length requirements on dry pavement ranged from 5,000 feet (Boeing 757-200) to 7,500 feet (Boeing 747-400). For wet pavement conditions, landing length requirements ranged from 5,800 feet (Boeing 757-200) to 8,600 feet (Boeing 747-400). All existing and projected aircraft, other than the Boeing 747-400 and the Airbus 340-600, can land on BNA's primary north/south oriented runways in wet pavement conditions.

Figure 4-6. Landing Runway Length Requirement



Source: AECOM analysis.

4.2.2.6. Runway Length Analysis Summary

None of the existing runways has the length needed to serve potential international destinations using the Design Aircraft that can operate in these markets. While the length of Runway 13-31 comes close to providing suitable length for the aircraft listed, airlines serving destinations beyond approximately 4,000 nm would need to reduce payload.

Based on the analysis of aircraft performance using a range of ADG D-V aircraft serving the most likely international destinations from BNA during the 20-year planning horizon, it is recommended that a runway length of 11,500 – 12,000 feet be planned to meet future international travel demand.

4.2.3. Runway Design Standards & Requirements

FAA design standards for airfield facilities are based primarily on the characteristics of the aircraft expected to use the airport, and airports must comply with current design standards, unless a modification of standards (MOS) is approved by the FAA. The FAA also recognizes that it is sometimes not possible to base design of all airfield components on one aircraft. Therefore, the selection of a "design aircraft" for purposes of geometric design at an airport with multiple runways such as BNA is typically based on a composite aircraft representing a collection of aircraft classified by three parameters: Aircraft Approach Category (AAC), Airplane Design Group (ADG), and Taxiway Design Group (TDG).

For this Master Plan, it is important to note that the prior selection of the B757 and B747 aircraft as "design aircraft" (the largest aircraft expected to have more than 500 annual takeoffs/landings) has changed in favor of newer widebody aircraft, such as the B787. In FAA terminology, the B757 (ADG IV) aircraft is being replaced at BNA by the B787 (ADG V) aircraft, such as is being used by British Airways on its Nashville – London route.

Although the design aircraft for this Master Plan is D-V, some runways and taxiways at BNA were originally designed to meet D-IV standards or even lower standards. The analysis in this section identifies gaps in the ability of the existing airfield to meet D-V standards, and also reviews compliance with D-IV design standards.

4.2.3.1. Runway Design Code

With the design aircraft (ADG D-V) identified, the next step in evaluating BNA's airfield for compliance with current FAA design standards is to identify a Runway Design Code (RDC) for each runway. The RDC is used to determine the design standards that apply to a specific runway and parallel taxiway to allow unrestricted operations by the design aircraft under desired meteorological conditions. In addition to the design aircraft designation, each runway's planned instrument approach visibility minimums combines to establish the RDC.

The RDC is comprised of three components, the Aircraft Approach Category (AAC), the Airplane Design Group (ADG), and visibility minimums. **Table 4-8** below indicates the various aircraft classifications and design groups based on approach speed, wingspan, and approach visibility.

Table 4-8. FAA Runway Design Code (RDC) Parameters:

Aircraft Approach Category (AAC) Classification		
Approach Category	Approach Speed (Knots)	
A	Less than 91 knots	
B	91-<121	
C	121-<141	
D	141-<166	
E	166 or greater	
Airplane Design Group (ADG) Classification		
Design Group	Wingspan (Feet)	Tail Height (Feet)
I	<49	<20
II	49 - <79	20 - <30
III	709 - <118	30 - <45
IV	118 - <171	45 - <60
V	171 - <214	60 - <66
VI	214 - <262	66 - <80
RVR (ft.)	Instrument Flight Visibility Category (statute mile)	
5000	Not lower than one mile	
4000	Lower than 1 mile but not lower than ¾ mile	
2400	Lower than ¾ mile but not lower than ½ mile	
1600	Lower than ½ mile but not lower than ¼ mile	
1200	Lower than ¼ mile	

Source: FAA Advisory Circular (AC) 150/5300-13A, Airport Design, Change 1

The RDCs for all the runway ends at BNA are summarized in **Table 4-9**, together with approach type and runway end elevation for each runway. Runways 2L-20R and 13-31 were designed as D-V runways, whereas Runways 2C-20C and 2R-20L were designed as D-IV runways. These are the crucial data in determining the object clearing surfaces applicable to each runway end.

Table 4-9. Runway End Information

Runway	RDC	Approach Type[1]	Runway End Elevation (ft MSL)[2]
2L	D-V-1200	CAT II/III	598.7
20R	D-V-4000	CAT I	555.4
2C	D-IV-2400	CAT I	569.0
20C	D-IV-5000	RNAV RNP & GPS	571.8
2R	D-IV-1200	CAT II/III	589.7
20L	D-IV-2400	CAT I	539.9
13	D-V-5000	RNAV RNP & GPS	535.8
31	D-V-4000	CAT I	582.2

Sources:
1. *Approach plates*
2. *BNA Airport Layout Plan 2013*

4.2.3.2. Runway Physical Dimensions

Table 4-10 summarizes the required runway physical dimensions for D-IV and D-V runways per AC 150/5300-13A, in comparison to the dimensions of the existing runways at BNA. All the runways are of sufficient D-V width. The shoulders of Runways 2C-20C and 2R-20L need to be widened to meet both D-IV and D-V standards. The blast pads of Runways 2C-20C, 2R-20L, and 13-31 are sufficient for D-IV standards, but need to be enlarged to meet D-V standards. The blast pads for Runway 2L-20R need to be enlarged to meet D-IV and D-V standards.

Table 4-10. Runway Physical Dimensions

Runway Design	D-IV	D-V	2L	20R	2C	20C	2R	20L	13	31
Runway Width (ft)	150	150	150		150		150		150	
Shoulder Width (ft)	25	35	35		**12**		**12**		35	
Blast Pad Width (ft)	200	220	**150**	**150**	**200**	**200**	**200**	**200**	**200**[a]	**200**
Blast Pad Length (ft)	200	400	**200**	**150**	**200**	**200**	**200**	**200**	**200**[a]	**200**

Notes:

- *a. Blast pad is in irregular shape*
- *b. **Orange text** denotes insufficiency based on ADG-V standards*
- *c. **Red text** denotes insufficiency based on both ADG-IV and ADG-V standards*

4.2.3.3. Runway Object Clearing Surfaces

While all design standards are important for safe and efficient aircraft movements, the design criteria established to protect the area immediately surrounding the runway environment is the most critical. These areas consist of:

- Runway Safety Areas (RSAs)
- Runway Object Free Areas (ROFAs)
- Obstacle Free Zones (OFZs)
- Runway Protection Zones (RPZs)

As indicated below in **Table 4-11**, the required dimensions of these object clearing surfaces are the same for design aircraft categories D-IV and D-V. Each of these critical areas is discussed in detail in subsequent sections.

An object clearing analysis was performed for each of these surfaces, as depicted on **Figure 4-7**. Obstacles analyzed included man-made structures such as navaids, poles, signs, buildings, and fences; as well as natural objects such as trees and ground. The obstacles falling within each surface are identified in subsequent sections. (It is noted that wetlands and open water features fall within the object clearing surfaces. However, these environmental features are not categorized as structures or obstructions. When projects evolve from planning to design, there would need to be an assessment of the wetlands and waters to determine their function (such as stormwater management or habitat), their quality, and whether the impacts to them can be minimized).

Table 4-11. Required Dimensions of Runway Object Clearing Surfaces

Object Clearing Surfaces	ADG IV	ADG V
RSA		
Length beyond Departure End	1,000 FT	1,000 FT
Width	500 FT	500 FT
ROFA		
Length beyond Departure End	1,000 FT	1,000 FT
Width	800 FT	800 FT
ROFZ		
Length beyond Departure End	200 FT	200 FT
Width	400 FT	400 FT
Other OFZs		
IAOFZ	Details specified in AC 150/5300-13A Para. 308 (b)	
ITOFZ	Details specified in AC 150/5300-13A Para. 308 (c)	
POFZ	Details specified in AC 150/5300-13A Para. 308 (d)	
Approach RPZ		
Outer Width	1,750 FT	1,750 FT
Inner Width	1,000 FT	1,000 FT
Length	2,500 FT	2,500 FT
Departure RPZ		
Outer Width	1,010 FT	1,010 FT
Inner Width	500 FT	500 FT
Length	1,700 FT	1,700 FT

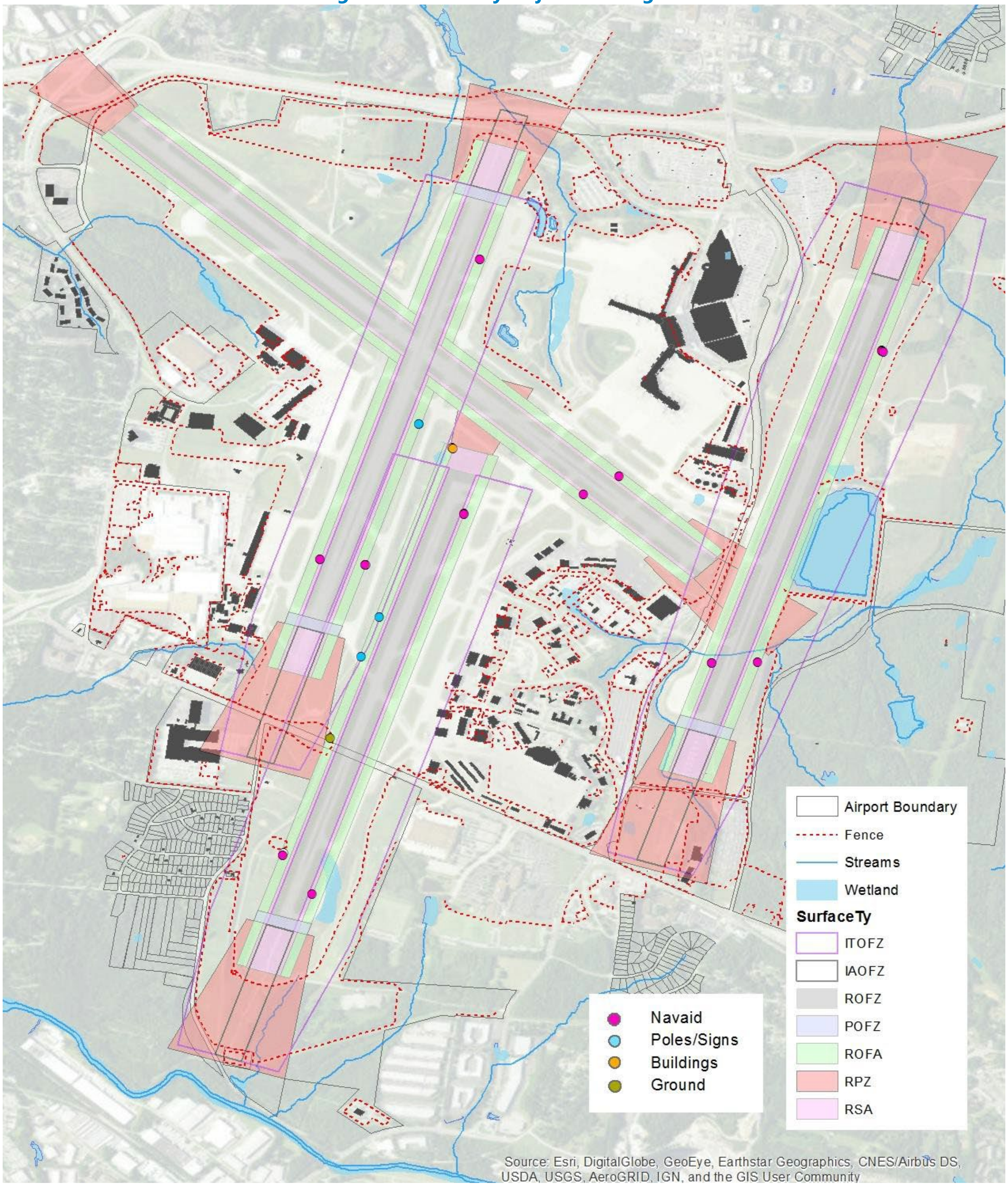
Source: FAA Advisory Circular (AC) 150/5300-13A, Airport Design, Change 1

Runway Safety Areas

A runway safety area (RSA) is a defined surface surrounding a runway prepared or suitable for reducing the risk of damage to aircraft in the event of undershoot, overshoot, or excursion from the runway. An RSA: must be cleared and graded and have no potentially hazardous ruts or other surface variations; must be drained to prevent water accumulations; and must be free of objects exceeding three (3) inches in height. Mandated by the U.S. Congress, all RSA's at the 529 commercial airports in the U.S. were expected to comply with RSA standards by December, 2015. RSA standards cannot be modified, and any airport facing challenges in meeting with RSA standards must have implemented alternative means of compliance, including declaring reduced available runway lengths for arriving and/or departing aircraft.

Table 4-12 summarizes the RSA dimensions at each runway end, in comparison to the required runway design standards for D-IV and D-V. Runways 2L/20R and 2R/20L have fully compliant RSA dimensions of 1,000 feet beyond runway ends. Based on clear RSAs for these two runways, there is no requirement to apply declared distances or reduce runway length to comply with FAA design standards.

Figure 4-7. Runway Object Clearing Surfaces



Data Source:

- *Object clearing surfaces created through AECOM analysis*
- *All man-made and natural obstacles data are from GIS shapefiles provided by the MNAA.*

The RSA for Runway 2C-20C was not fully compliant by December 2015, as Taxiway K and the Runway 2C Localizer fell within the RSA off the Runway 20C end. Considering the Localizer location, the RSA off Runway 20C end was out of compliance by 400 feet, which reduced Runway 2C's Accelerate-Stop Distance Available (ASDA) and Landing Distance Available (LDA) from 8,001 feet to 7,601 feet. Runway 20C's ASDA and LDA remained at 8,001 feet.

For Runway 13-31, the RSAs at both runway ends were penetrated by objects such as localizers, public roads, airport service roads, and fences. At the approach end of Runway 13, U.S. Route 40, Briley Parkway, and the Runway 31 localizer all fell within the standard 500-foot x 1,000-foot RSA; therefore the RSA only provided 198 feet, requiring a displacement of the Runway 13 threshold by 802 feet to meet the 1,000-foot RSA design standard. At the approach end of Runway 31, the airport service road, airport fence, Donelson Pike, Runway 2R/20L, and Taxiway H all fell within the standard RSA; therefore the RSA only provided 176 feet, requiring a threshold displacement of 824 feet from the Runway 31 end to provide a standard RSA.

As a result, the ASDAs for Runways 13 and 31 are shorter than the runway pavement length. More details about declared distances are discussed in a subsequent section.

Table 4-12. RSA Dimensions at BNA

RSA	Length beyond Runway End (ft.)[1]	Width (ft.)[1]	Object Clearance
Required (D-IV & D-V)	1,000	500	-
2L	1,000	500	Clear
20R	1,000	500	Clear
2C	1,000	500	Clear
20C	**600**[a]	500	Clear
2R	1,000	500	Clear
20L	1,000	500	Clear
13	**198**[b]	500	Clear
31	**176**[c]	500	Clear

Source:
1. *BNA 2013 ALP & 5010.*

Notes:
a. *RSA length reduced due to Runway 2C Localizer and Twy K*
b. *RSA length reduced due to Runway 31 Localizer*
c. *RSA length reduced due to vehicle service road, fence, and Donelson Pike*

Runway Object Free Areas

In addition to RSAs, each runway is required to maintain an object free area that prohibits above-ground objects protruding above the nearest point of its adjacent RSA. Only objects that need to be located in the ROFA for air navigation or aircraft ground maneuvering purposes, such as airfield signage and certain navaids (PAPI, VASI, REIL, RVR, etc.), are allowable within the ROFA. To the extent practicable, objects in the ROFA should meet the same frangibility requirements as the RSA. For airports across the country, typical objects that fall within ROFA but are not allowable include airport service roads, windsocks, glide slope antennas, localizers, airport fences, aircraft parking apron, and sometimes even public roads. All such objects should be cleared from the ROFA.

Per FAA design standards, a ROFA is 800 feet wide and 1,000 feet beyond the departure end of runway. Due to the obstacles discussed in the previous section about RSAs, the ends of Runways 20C, 13, and 31 had to be displaced with the RSAs to provide standard ROFAs. Although the ROFAs beyond the runway ends are now clear, several objects not allowable within the ROFA on the sides of the runways remain within the ROFA, as summarized in **Table 4-13**.

Table 4-13. ROFA Dimensions at BNA

ROFA	Length beyond Runway End (ft.)[1]	Width (ft.)[1]	Object Clearance
D-IV & D-V	1,000	800	
2L	1,000	800	Airport service road near 2L Windsock; Glide slope antenna near 2L end; Control box near the runway intersection;
20R	1,000	800	Glide slope antenna near 20R end; Fence and airport service road near 20R end;
2C	1,000	800	Fence along Murfreesboro Pike tunnel; Glide slope antenna and its fence near 2C; Windsock near 2C;
20C	**600**[a]	800	Localizer shelter near 20C end; Windsock near 20C; Airport service road west of runway;
2R	1,000	800	Airport service road near 2R; Glide slope antenna near 2R; Windsock near 2R; Quarry & fence around the quarry
20L	1,000	800	Glide slope antenna near 20L; Airport service road & fence near 20L;
13	**198**[b]	800	Clear
31	**176**[c]	800	Windsock near 31; Glide slope antenna near 31;

Data Source:
- *All man-made and natural obstacles data are from GIS shapefiles provided by the MNAA.*

Notes:
- *a. ROFA length reduced due to Runway 2C Localizer and Twy K*
- *b. ROFA length reduced due to Runway 31 Localizer*
- *c. ROFA length reduced due to vehicle service road, fence, and Donelson Pike*

Obstacle Free Zones

As specified in FAA AC 150/5300-13A, the obstacle free zone clearing standard precludes aircraft and other object penetrations, except for frangible navaids that need to be located in the OFZs because of their function. OFZs must be kept clear during operations.

There are four types of OFZs – Runway OFZ, inner-approach OFZ (IAOFZ), inner-transitional OFZ (ITOFZ), and Precision OFZ (POFZ). The shape, size, and applicability of the OFZs depend on various factors specific to each runway end. **Table 4-14** summarizes the applicability of each OFZ to each runway.

Table 4-14. OFZ Applicability

Runway	Approach Minimums	Equipped with ALS	OFZ Applicability			
			ROFZ	IAOFZ	ITOFZ	POFZ
2L	600 ft.	Y	Y	Y	Y	Y
20R	¾ mile	Y	Y	Y	N	N
2C	½ mile	Y	Y	Y	Y	Y
20C	1 mile	N	Y	N	N	N
2R	600 ft.	Y	Y	Y	Y	Y
20L	½ mile	Y	Y	Y	Y	Y
13	1 mile	N	Y	N	N	N
31	¾ mile	N	Y	N	N	N

Source: AECOM analysis.

Runway Obstacle Free Zone (ROFZ)

ROFZ is a design surface and an operational surface that must be kept clear during aircraft operations. An ROFZ is applicable to each runway end at BNA. The ROFZ is a defined volume of airspace centered above the runway centerline, above a surface whose elevation at any point is the same as the elevation of the nearest point on the runway centerline.

Inner-approach OFZ (IAOFZ)

IAOFZ is a defined volume of airspace centered on the approach area. It applies only to runways with an approach lighting system (ALS). Runways 20C, 13, and 31 are not equipped with an ALS and thus do not have an IAOFZ.

An IAOFZ begins 200 feet from the runway threshold at the same elevation as the threshold, and extends 200 feet beyond the last light unit in the ALS. Its width is the same as the ROFZ and rises at a slope of 50 (horizontal) to 1 (vertical) from its beginning.

Inner-transitional OFZ (ITOFZ)

An ITOFZ is a defined volume of airspace along the sides of the ROFZ and the IAOFZ. It applies only to runways with **lower than** ¾ statute mile approach minimums. Therefore, Runways 20R, 20C, 13, and

31 do not have ITOFZs. The shape, dimensions, and slopes of the ITOFZs are calculated based on the specifications in AC 150/5300-13A, paragraph 308c.

Precision OFZ (POFZ)

A POFZ is a defined volume of airspace above an area beginning at the threshold at the threshold elevation and centered on the extended runway centerline. A POFZ is 200 feet long by 800 feet wide, and is only applicable when all three of the following conditions are met:

(1) The approach includes vertical guidance
(2) The reported ceiling is below 250 feet or visibility is less than ¾ statute mile
(3) An aircraft is on final approach within 2 miles of the runway threshold

Therefore, only Runways 2L, 2C, 2R, and 20L have POFZs.

Object Clearing Analysis

Table 4-15 summarizes the object clearing analysis results for each of the runways. ROFZs and POFZs for all runways are clear from objects. As shown on **Figure 4-7**, objects exist below the IAOFZs and ITOFZs, but due to the sloping nature of these surfaces, the objects do not penetrate these surfaces. Therefore, all OFZs at BNA are clear from objects.

Table 4-15. OFZ Object Clearing Analysis

Runway	ROFZ	IAOFZ	ITOFZ	POFZ
2L	Clear	Murfreesboro Pike about 40 feet below the surface	Hangar 4160 and Monell's more than 70 feet below surface; Fence much lower than the surface	Clear
20R		VSR and I-40 more than 40 feet below the surface	Not Applicable	Not Applicable
2C		Substation below the surface	Several GA hangars more than 100 feet below the surface	Clear
20C		Not Applicable	Not Applicable	Not Applicable
2R		Knapp Blvd 30 feet below the surface.	Building near employee parking lot more than 100 feet below the surface	Clear
20L		VSR more than 40 feet below the surface	DPS office and USPS office more than 100 feet below the surface	Clear
13		Not Applicable	Not Applicable	Not Applicable
31		Not Applicable	Not Applicable	Not Applicable

Data Source:
- *All man-made and natural obstacles data are from GIS shapefiles provided by the MNAA.*

Runway Protection Zones

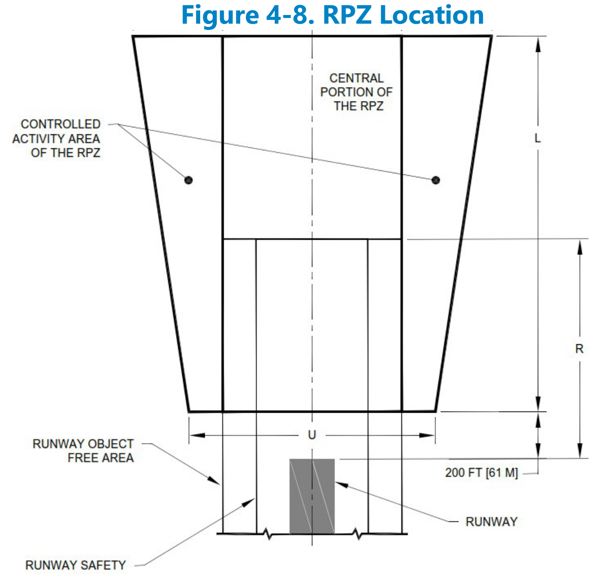
The RPZ is a trapezoidal area located prior to the runway threshold or beyond the departure end of the runway to provide unobstructed passage of aircraft through the airspace above it. **Figure 4-8** illustrates the location and relationship of the RPZ to the physical runway environment.

The main purpose of RPZ is to avoid negatively impacting people and property on the ground. FAA requires airports to gain control over RPZs through acquisition of sufficient property interest (such as ownership, lease, or avigation easement) in the RPZs. While it is desirable to keep the entire RPZ clear of all above-ground objects, at a minimum RPZs should be maintained clear of all incompatible activities. Per the FAA, permissible land uses within RPZs include:

- Farming
- Irrigation channels
- Airport service roads
- Underground facilities
- Unstaffed NAVAIDS and facilities (only if fixed by function)

Public roads were a permissible land use in RPZs but the newest update of AC 150/5300-13A eliminated this exception. As a result, public roads that fall within RPZs should be examined closely to identify mitigation measures. The FAA's Memorandum, *Interim Guidance on Land Uses within a Runway Protection Zone*, dated September 27, 2012 is used to determine the appropriate action required for mitigation of incompatible land uses within existing RPZs.

Figure 4-8. RPZ Location



Source: AC 150/5300-13A, Figure 3-16.

Although the RPZ dimensional standards for D-IV and D-V runways are the same, the dimensions of approach RPZs vary for runways with different approach visibility minimums. **Table 4-16** summarizes the dimensions of approach RPZs at BNA. The different colors of the cells indicates the varying dimensions for visibility minimums (1) lower than ¾ mile, (2) NOT lower than ¾ mile, and (3) NOT lower than 1 mile.

Table 4-16. RPZ Dimensions at BNA

Approach RPZ	Approach Minimums	Length (ft)	Inner Width (ft)	Outer Width (ft)
D-IV & D-V				
2L	600 ft.	2,500	1,000	1,750
20R	¾ mile	1,700	1,000	1,510
2C	½ mile	2,500	1,000	1,750
20C	1 mile	1,700	500	1,010
2R	600 ft.	2,500	1,000	1,750
20L	½ mile	2,500	1,000	1,750
13	1 mile	1,700	500	1,010
31	¾ mile	1,700	1,000	1,510

Notes:

- *Blue: complies with visibility minimums lower than ¾ mile*
- *Orange: complies with visibility minimums NOT lower than ¾ mile*
- *Green: complies with visibility minimums NOT lower than 1 mile*

The departure RPZs have the same dimensions regardless of visibility minimums. All departure RPZs at BNA are 1,700 feet in length, 500 feet in inner width, and 1,010 feet in outer width. Departure RPZs start 200 feet from the runway **end**, and approach RPZs start 200 feet from the runway **threshold**. Except for Runways 13 and 31 which have displaced thresholds, all other departure RPZs start at the same location as the approach RPZs. Given that approach RPZs are larger than (or of equal size with) departure RPZs, all the departure RPZs fall completely within the approach RPZs at BNA, with the exception of Runways 13 and 31.

It is important to note that the Runway 31 departure RPZ, which is located before the approach end of Runway 13, is not located 200 feet from the runway end; instead it was displaced towards the southeast by 383 feet so that the Interstate AC Service buildings do not fall within this RPZ, as illustrated on **Figure 4-9**. Such displacement of the departure RPZ resulted in a reduction in the Runway 31 Takeoff Run Available (TORA), which will be discussed in more detail in a subsequent section.

Figure 4-9. Displaced Runway 31 Departure RPZ

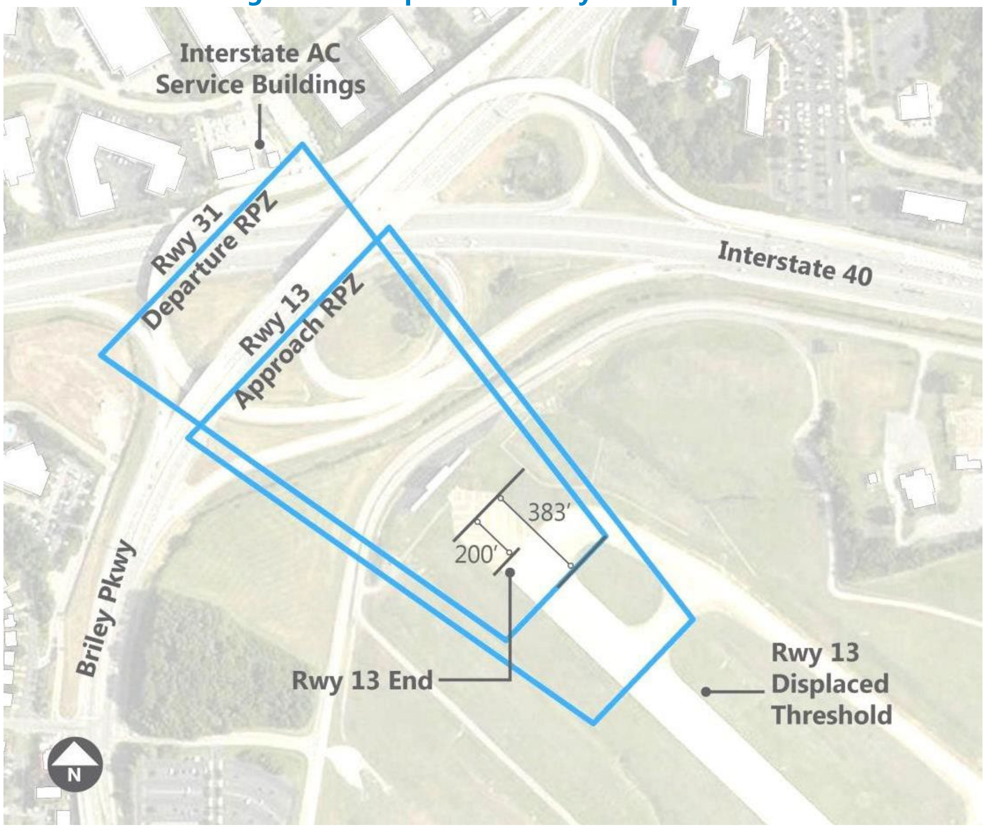


Table 4-17 summarizes incompatible objects and land uses within the RPZs of runways at BNA.

Table 4-17. Incompatible Objects and Land Uses within RPZs

RPZ	Object Clearance
2L	Davidson County Building, parking lot, light pole; Murfreesboro Pike & fence, light poles;
20R	I-40 & fence & poles; One small off-airport building;
2C	Knight Valley Dr., fence, light poles; Substation? Off-airport properties;
20C	Runway 13-31 and associated taxiways
2R	Donelson Pike, fence, light poles; Knapp Blvd; A corner of the Employee Lot
20L	I-40, fence, light poles
13	I-40 interchange with Briley Pkwy, fence, light poles;
31	Donelson Pike, fence, light poles (but lower than the runway); Runway 2R-20R and associated taxiways

Data Source:

- *All man-made and natural obstacles data are from GIS shapefiles provided by the MNAA.*

Declared Distances

Table 4-18 shows the declared distances for each runway end at BNA, based on BNA's Form 5010-1 (Airport Master Record). The declared distances for Runways 2L-20R, 2C-20C, and 2R-20L are correct; however the declared distances for Runway 13-31 do not correctly reflect the displaced thresholds that were implemented to meet RSA and ROFA standards, as well as the displaced Runway 31 departure RPZ. These records should be corrected based on the proposed changes in **Table 4-18**.

Table 4-18. Declared Distances

	Existing Conditions[1]				Required Changes[2]
	2L/20R	2C/20C	2R/20L	13/31	13/31
LENGTH	7,702'	8,001'	8,001'	11,030'	11,030
Displaced Threshold	N.A.	N.A.	N.A.	801'/741'	801'/741'
Takeoff Run Available (TORA)	7,702'/7,702'	8,001'/8,001'	8,000'/8,000'	10,288'/10,288'	11,030/10,647
Takeoff Distance Available (TODA)	7,702'/7,702'	8,001'/8,001'	8,000'/8,000'	11,029'/11,029'	11,030/11,030
Accelerate-Stop Distance Available (ASDA)	7,702'/7,702'	7,601'/8,001'	8,000'/8,000'	10,288'/10,288'	11,206'/10,228'
Landing Distance Available (LDA)	7,702'/7,702'	7,601'/8,001'	8,000'/8,000'	9,487'/9,487'	9,405'/9,487'

Sources:
1. *Form 5010-1, Airport Master Record*
2. *Calculated based on the RSA, ROFA, and RPZ displacements.*

4.2.4. Taxiway/Taxilane Design Standards & Requirements

The design standards for taxiways and taxilanes have evolved. Previous standards were based only on the Airplane Design Group (ADG) associated with runway design dimensions. More recently, the FAA established Taxiway Design Groups (TDG) to take into account the dimensions of Main Gear Width (MGW) and the Cockpit to Main Gear Distance (CMG) of specific aircraft. Considering that the height above the pavement of large aircraft cockpits can result in taxiway centerline tracking challenges, taxiway and taxilane design now considers the operating characteristics of aircraft maneuvering on the pavement to track more closely with "cockpit over centerline" rather than pilots using "judgmental oversteering".

The key taxiway design criteria evaluated include:

Taxiway Safety Areas (TSAs)
Taxiway Object Free Areas (TOFAs)
Taxiway Shoulders
Taxiway Fillets and Intersection Geometry
Taxiway "Hot Spots"

Table 4-19 presents the dimensional requirements for taxiways and taxilanes for Group IV and Group V aircraft. The width and separation requirements for ADG-V taxiways are higher than those for ADG-IV taxiways.

Table 4-19. Taxiway Object Clearing Standards

Taxiway Design	ADG IV	ADG V
Taxiway Safety Area	171 FT	214 FT
Taxiway Object Free Area	259 FT	320 FT
Taxilane Object Free Area	225 FT	276 FT

Source: FAA Advisory Circular 150/5300-13A

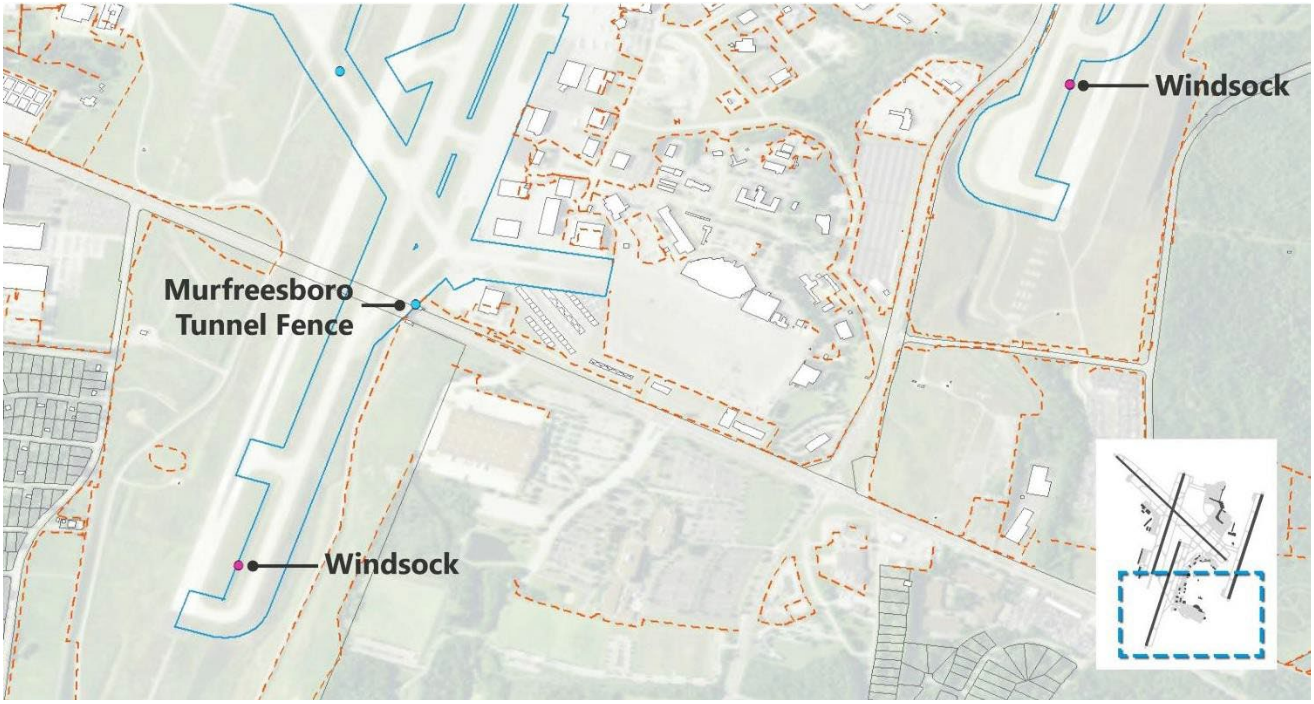
4.2.4.1. Taxiway Safety Area (TSA) and Taxiway Object Free Area (TOFA)

TSA and TOFA are centered on the taxiway/taxilane centerlines. Their widths correspond to their respective ADG and are summarized in **Table 4-19**. The function of TSAs and TOFAs is to allow enough separation and clearance for aircraft to navigate the airfield safely by providing adequate wingtip clearances.

The TSA must be cleared, graded, and drained properly per requirements in paragraph 404(d) of AC 150/5300-13A. TSAs must be free of objects, except those that need to be located within TSAs due to their function. The TOFA is wider than TSA, and the TOFA clearing standards prohibit vehicle service roads, parked aircraft, and other objects except for those that must be located in the OFA for air navigation or aircraft ground maneuvering purposes.

While the TSAs at BNA are clear of objects, there are objects that fall within the ADG-V taxiway or taxilane OFAs. Figure 4-10 shows the objects that are not allowed but fall within the 320-feet-wide ADG-V TOFA. Possible mitigation includes (1) removing/relocating the objects to outside of the TOFA, (2) limiting taxiway/taxilane design to ADG-IV aircraft at locations where objects cannot be cleared, or (3) requesting a modification of standards from the FAA.

Figure 4-10. Obstacles in TOFA



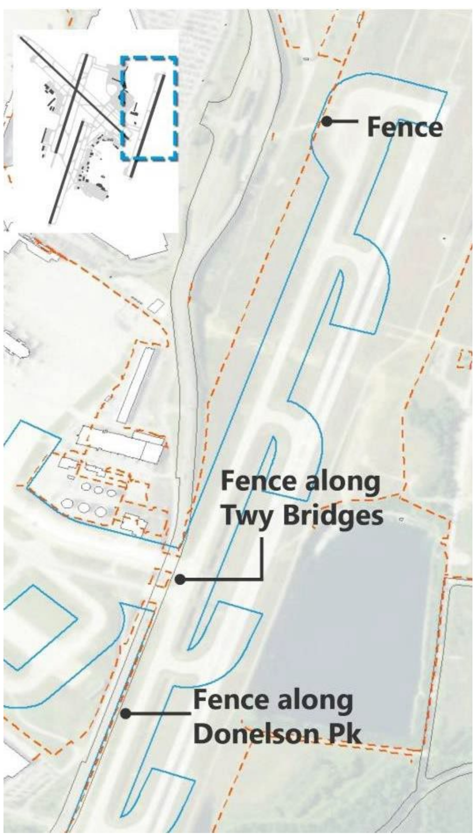


Figure 4-11. Obstacles in TOFA (Continued)

For instance, Donelson Pike and the airport fence along it falls within the ADG-V TOFA of Taxiway H, as shown on **Figure 4-11.** Since relocating Donelson Pike to provide the room for the perimeter fence is not a feasible/cost-effective alternative, but Taxiway H must serve as an ADG-V taxiway to support the increasing traffic in this ADG, the use of an aircraft-specific MOS through this area should be considered, as recommended in the technical memorandum, *Runway 2R-20L Geometry Review Final Report* (October 2018).

4.2.4.2. Taxiway Shoulders

Paved taxiway shoulders are required for taxiways serving ADG-IV and higher aircraft. Taxiway shoulder widths are determined based on TDG. For TDG 5 and 6, which typically include ADG-V aircraft, the required taxiway shoulder width is 30 feet.

A comprehensive analysis was performed throughout the BNA airfield to identify deficiencies in shoulder widths based on TDG 5 and 6 requirements. **Figure 4-12** shows (in orange) the existing shoulders that meet the TDG 5 and 6 requirements, and also shows (in blue) the shoulders that require widening to meet standards. Taxiways that require shoulder widening include Taxiways A, B, H, K, L, N, S, R1, and R2.

4.2.4.3. Taxiway Fillets and Intersection Geometry

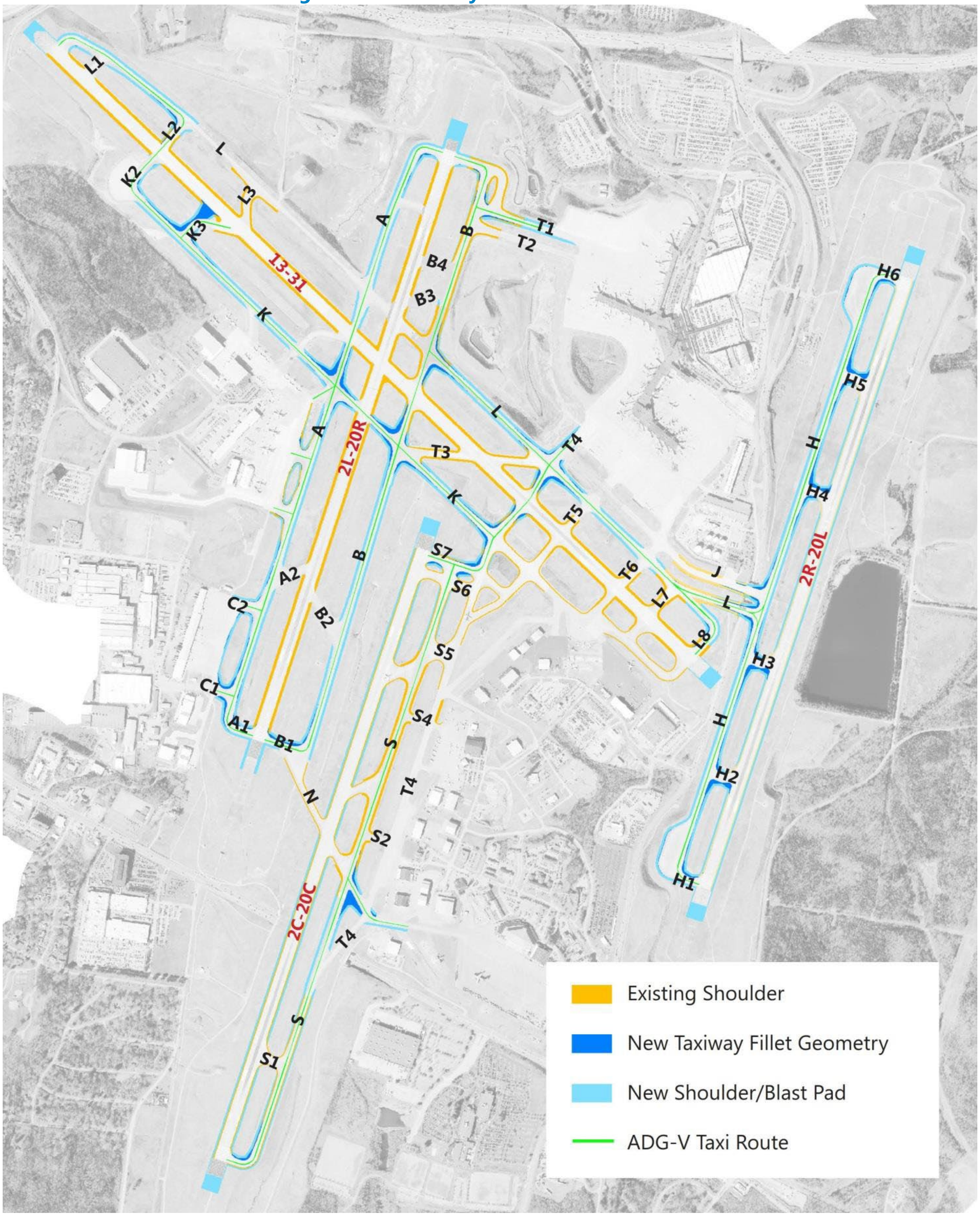
FAA AC 150/5300-13A specifies detailed dimensions for taxiway fillets and intersection geometries in paragraph 406. Pavement fillets at taxiway intersections are designed for the entire selected TDG and must accommodate all aircraft of lesser TDGs so that the main gear of the aircraft always remains on pavement of sufficient strength. Tables 4-3 through 4-10 in AC 150/5300-13Aprovide standard fillet dimensions for taxiway intersections with angles of 30, 45, 60 90, 120, 135, and 150 degrees. Such standards also apply to taxiway-apron intersections.

Taxiway fillets at intersections at many airports across the country are designed based on older standards, which typically require less pavement compared to the most current FAA design standards. Similar to the taxiway shoulder analysis, a comprehensive evaluation was performed throughout the BNA airfield to identify where additional pavement is needed to provide standard fillet geometries. **Figure 4-12** also shows the taxiway intersections that require fillet reconfiguration to meet standards, such as the intersections along Taxiways K, H, S, and L.

4.2.4.4. Taxiway "Hot Spots"

"Hot spots" are areas where the geometry of a taxiway intersection has the potential to cause confusion and/or reduced visibility for pilots, with the potential to affect safe ground movements. There are three taxiway intersections that have been designated as "hot spots" at BNA, and they have been appropriately identified on the published Airport Diagram to alert pilots. Hot spot 1 is located on the west side of Runway 2L-20R at the intersection of Taxiways A, K, and R3; hot spot 2 is located east of Runway 2L-20R at the intersection of Taxiways B, K, and T3; and hot spot 3 is located just to the east of Runway 20C at the intersection of Taxiways S, S6, and S7. As of this writing, hot spots 1 and 3 are being addressed by efforts to fix their geometry. Hot spot 2 remains an outstanding design standards deficiency, and will be reviewed for corrective options in the Alternatives chapter of this Master Plan.

Figure 4-12. Taxiway Shoulders & Fillets Deficiencies



4.2.5. Airfield Separation Standards

Since the design aircraft for this Master Plan is determined to be D-V, it is crucial to evaluate whether the required separations from runways and taxiways throughout the airfield are met based on D-V design standards. Several areas of the BNA airfield were initially designed to accommodate ADG-III or ADG-IV standards, which require smaller separation than those under D-V standards.

Table 4-20 summarizes the D-IV and D-V runway separation standards, in comparison with existing conditions of all four runways at BNA. The key findings are:

- The parallel runway separation is adequate for simultaneous VFR operations between Runways 2L-20R and 2C-20C. The parallel runway separation is adequate for simultaneous IFR operations between Runways 2L-20R and 2R-20L, and between Runways 2C-20C and 2R-20L;
- Several holding positions on taxiways intersecting Runways 2C-20C and 13-31 should be relocated further from the runway centerlines;
- Runways 2L and 2R have approach visibility minimums lower-than ½ statute mile, and thus their centerlines must be at least 500 feet from parallel taxiway centerlines. However, the Taxiway A centerline is only 400 feet from the Runway 2L centerline, and the Taxiway H centerline is only 400 feet from the Runway 2R centerline; and,
- The separations between each of the four runway centerlines and their parallel taxiways/taxilanes and to their aircraft parking areas are adequate.

Table 4-21 summarizes the D-IV and D-V taxiway/taxilane separation standards, in comparison with the existing conditions of all major taxiways and taxilanes at BNA. The key findings are:

- Separation between Taxiways B and M, Taxiways T1 and T2, and Taxiways L and J do not comply with the ADG-V requirement;
- Some objects fall within 160 feet of the centerlines of Taxiways T4 and H, which is less than adequate for ADG-V standards;
- The dual parallel taxilanes at the Concourse A apron and Concourse C apron have inadequate separation for ADG-V standards; and,
- Objects (buildings, fences, roads) fall within 112.5 feet of the centerlines of all major taxilanes (U, U3, Concourses A, B, and C), which is less than ADG-V standards.

When feasible, sufficient separation should be provided in these identified areas. However, some areas, such as Taxilanes U and U3, and Concourse C, are intended to mainly serve ADG-III traffic. For these areas, as long as the major aircraft served remain ADG-III, it is not necessary to increase separation to ADG-V standards.

Table 4-20. Runway Separation

Separation	D-IV	D-V	2L-20R	2C-20C	2R-20L	13-31
Runway Separation						
Parallel Runway Centerline	700′ for VFR; 3,000′ for IFR Approaches; 2,500′ for IFR Departures	1,200′ for VFR; 3,000′ for IFR Approaches; 2,300′ for IFR Departures	1,200′ from 2C-20C 5,855′ from 2R-20L	1,200′ from 2L-20R 4,655′ from 2R-20L	4,655′ from 2C-20C 5,855′ from 2L-20R	N/A
Holding Position	256′	256′	All above 256′	**Holding positions with <256′ separation: Twy N, Twy S3, Twy S5**	All above 256′	**Holding positions with <256′ separation: Twy L entrance to Rwy 13, Twy L1**
Parallel Twy/Txl Centerline	400′ for visibility minimums NO LESS THAN ½ statute mile; 500′ for visibility minimums LESS THAN ½ statute mile	400′ for visibility minimums NO LESS THAN ½ statute mile; 500′ for visibility minimums LESS THAN ½ statute mile	**Taxiway A is at 400′ from Runway 2L (visibility minimum at 600′)**	All at or above 400′	**Taxiway H is at 400′ from Runway 2R (visibility minimum at 600′**	All at or above 400′
Aircraft Parking Area	500	500	All above 500′	All above 500′	All above 500′	All above 500′

Notes:

*a. **Red text** denotes insufficiency based on both ADG-IV and ADG-V standards*

Table 4-21. Taxiway/Taxilane Separation

Taxiway Separation	Taxiway Centerline to Parallel Taxiway/Taxilane Centerline	Taxiway Centerline to Fixed or Moveable Object[a]	Taxilane Centerline to Parallel Taxilane Centerline	Taxilane Centerline to Fixed or Moveable Object
D-IV	215′	129.5′	198′	112.5′
D-V	267′	160′	245′	138′
Taxiway A	340′ from south cargo apron taxilane; 267′ from north cargo apron taxilane	Above 160′	N/A	N/A
Taxiway B	**225′ from Twy M**	Above 160′	N/A	N/A
Taxiway S	350′ from Twy T4	Above 160′	N/A	N/A
Taxiway S7	215′ from Twy S6	Above 160′	N/A	N/A
Taxiway T4	350′ from Twy S	**155′ from fence at Murfreesboro Pk Tunnel; 153′ from fence around Building 4203**	N/A	N/A
Taxiway H	N/A	**150′ from fence along Donelson Pk**	N/A	N/A
Taxiway K	365′ from MRO apron taxilane	Above 160′	N/A	N/A
Taxiway L	**251′ from Twy J**	Above 160′	N/A	N/A
Taxiway J	More than 370′ from terminal apron taxilane	Above 160′	N/A	N/A
Taxiway T1	**225′ from Twy T2**	Above 160′	N/A	N/A
Taxilane U	N/A	N/A	N/A	**108′ from Building 4263**
Taxilane U3	N/A	N/A	N/A	**108′ from Building 4265; 105′ from fence**
Concourse C Apron Taxilanes	N/A	N/A	**140′ ~ 198′ between the dual taxilanes**	**81′ from vehicle service road**
Concourse B Apron Taxilanes	N/A	N/A	N/A	**112.5′ from vehicle service road**
Concourse A Apron Taxilanes	N/A	N/A	**225′ between the dual taxilanes**	**112.5′ from vehicle service road**

Notes:

*b. **Orange text** denotes insufficiency based on ADG-V standards*

*c. **Red text** denotes insufficiency based on both ADG-IV and ADG-V standards*

4.2.6. Airfield Marking and Lighting

4.2.6.1. Airfield Markings

Part 139-certified airports, such as BNA, must provide and maintain, at a minimum, the following markings:

- Runway markings meeting the specifications for takeoff and landing minimums of each runway
- Taxiway centerlines
- Taxiway edge markings, as appropriate
- Holding position markings
- ILS critical area markings

Airport pavement markings at BNA are in accordance with FAA AC 150/5340-1L, *Standards for Airport Marking*. The markings are in good condition and refreshed as needed.

4.2.6.2. Airfield Lighting

Runway Lighting

Table 4-22 outlines the available runway lighting at each runway to provide clarity to pilots. The Runway Centerline Lighting Systems (RCLS) and the Touchdown Zone (TDZ) lights are required on runways with Category II and III approaches, and Category I approaches where visibility minimums are less than 2,400 feet RVR.

Table 4-22. Available Runway Lighting

Runway	Approach Lights	Centerline Lights	REIL
2L	ALSF 2	YES	NO
20R	MALSF	YES	NO
2C	MALSR	NO	YES
20C	NO	NO	YES
2R	ALSF 2	YES	NO
20L	MALSR	YES	NO
13	NO	NO	YES
31	NO	NO	YES

Taxiway Lighting

All BNA taxiways have edge lights. Like runway edge lighting, taxiway edge lighting delineates the taxiway's edge and provides guidance to pilots in darkness or restricted visibility conditions. These lights are blue, set at 200 foot intervals along the taxiway edges. Like the runway edge lights, they are classified according to their intensity and brightness. BNA's taxiways are equipped with Medium-

Intensity Taxiway Lighting (MITL) systems. In addition to taxiway edge lighting, Taxiway H and portions of Taxiways J and L (between Taxiways T6 and H) have centerline lighting.

4.2.7. Current Modifications of Standards (MOS)

Table 4-23 lists the current FAA-approved Modifications of Standards (MOS) for BNA's airfield components, which were in part based on the prior Master Plan evaluation of Group IV standards (which included the B757as the "design aircraft"). The airfield design standards review in this Master Plan evaluates the ability of the current airfield to meet Group V design standards associated with aircraft such as the B787.

Table 4-23. Current Approved Modifications of Standards

No.	Description	FAA Standard	Mitigation	Approval Date
1	Gradient of proposed Taxiway T-4 extension	1.5% gradient	Taxiway gradients will be addressed as pavement is overlaid or strengthened	May-93
2	Localizer siting criteria, Runway 2C	Only objects fixed by function may be located within an RSA	FAA to install frangible localizer antenna and declare "fixed by function"	Dec-93
3	Runway 2C-20C, 13-31, and 2R-20L shoulder widths	35-foot paved or stabilized shoulders	No modification, but runway shoulders to be addressed with future projects	Jul-04
4	Taxiway A, A-1, K2, I shoulder widths / C-1 fillet dimensions	35-foot paved or stabilized shoulders	Taxiway shoulders to be addressed in future projects	Jul-04
5	Taxiway A, B, I, R-4 Taxiway Safety Area transverse gradients	1.5% to 3% gradient	Taxiway Safety Area transverse gradients will be addressed as pavement is overlaid or strengthened	Jul-04
6	Runway Visibility Zone associated with intersection of extended Runway 2L and Runway 13	No objects permitted within RVZ	Modification was granted for future RVZ	Oct-04
7	Taxiway T-4 longitudinal grades between Taxiways Kilo and Runway 13-31	0.015	None	Jun-09

4.2.8. Navigational Aids

Navigational Aids (NAVAIDs) for an airport vary in sophistication. Typically, the degree of sophistication relates to the information provided to an approaching aircraft. The more sophisticated the NAVAID, the lower the landing minimums at an airport. For that reason, instrument approaches and the NAVAIDs that make up the ground-based equipment required to perform the approach procedure are divided into two categories: precision and non- precision.

A precision approach provides both horizontal and vertical guidance to pilots as their aircraft descends to land. A non-precision approach provides only horizontal guidance to the runway end. The types of NAVAIDs available at an airport play an important role in the use of the facility. Typically, pilots of corporate or commercial aircraft anticipate access to an airport in nearly all weather conditions. Therefore, it is incumbent upon an airport to have NAVAIDs and published approaches that allow for approaches to the airport during marginal and instrument flight conditions if it intends to attract or accommodate corporate or commercial aircraft.

Table 4-24 summarizes the Airport's existing navigational aids. The Airport maintains Category II (CAT II) and CAT III Instrument Landing Systems (ILS) for approaches to both Runways 2L and 2R. CAT I ILS approach aids provide precision instrument guidance to pilots on approach to each of the Airport's runways, with the exception of Runways 13 and 20C. An ILS consists of a localizer antenna (LOC) and a glide slope antenna (GS). Those two antennas, located in proximity to the runway, transmit vertical and horizontal information to ensure that the aircraft is on the correct approach path during Instrument Flight Rules (IFR).

Table 4-24. Approach Navaids at Each Runway

Runway	Approach Minimums	Approach Types
2L	600 RVR	ILS CAT II/III, LOC, RNAV/GPS
20R	¾ mile	ILS/LOC, RNAV/GPS
2C	½ mile	ILS/LOC, RNAV/GPS
20C	1 mile	RNAV/GPS
2R	600 RVR	ILS CAT II/III, LOC, RNAV/GPS
20L	½ mile	ILS/LOC, RNAV/GPS
13	1 mile	RNAV/GPS, VOR/DME
31	¾ mile	ILS/LOC, RNAV/GPS

Source: FAA Runway Instrument Approach Procedures.

4.2.9. Airfield Facility Requirements Summary

Airfield Capacity:

- BNA's Annual Service Volume was calculated to be 495,300 operations. The annual operations in 2017 were at 42% of ASV. BNA's forecast annual operations will reach above 60% ASV in 2037, which is the FAA's suggested trigger for airport sponsors to begin planning for capacity improvements.

Runway Length Requirements:

- A takeoff runway length of approximately 11,500 – 12,000 feet is needed to serve most potential international markets from Nashville, assuming the representative aircraft types evaluated are operating at a 100% payload at maximum takeoff weight (MTOW).

Runway Design Standards:

- In anticipation of increasing operations of D-V aircraft at BNA, various elements of the airfield need to be upgraded to meet the FAA D-V design standards, including runway blast pads, runway shoulders, taxiway shoulders, and taxiway intersection fillets.
- There are objects located within several object clearing surfaces, including ROFAs, TOFAs, and RPZs. It is recommended to clear the objects from these surfaces.
- Runway and taxiway separation standards for D-V are not met at several locations in the airfield and should be addressed through airfield reconfiguration, modification of standards, or maintaining Group IV standards for Group V-deficient areas.
- The Runway 13-31 declared distances as published on 5010 Airport Master Records do not accurately reflect the non-standard object clearing surfaces at BNA and should be corrected.

Marking and Lighting:

- The BNA markings meet the FAA design standards and are in good condition.
- The BNA runway and taxiway lighting meet the design standards.

4.3. Passenger Terminal Capacity and Requirements

The existing terminal building (**Figure 4-13**) is undergoing major improvement with the implementation of the $1.2 billion BNA Vision program. Significant physical changes are being made to the existing terminal building, including terminal lobby expansion, constructing a new and expanded passenger security screening checkpoint, expanding the number baggage claim devices, and adding a new International Arrivals Facility with six international ("T") gates between Concourses B and C; constructing a new Concourse D with six domestic gates with new dining and retail space; constructing a new central utility plant beyond the end of new Concourse D; and demolishing the existing Interim International Arrivals Building at the end of Concourse A.

This Section focuses on future facility requirements for the passenger terminal building once the BNA Vision program is complete, currently projected to be 2023 (**Figure 4-14**). The Section also includes a capacity analysis of BNA Vision facilities expected to be in place in 2023. Industry guidelines were used to assess the capacity of different functional areas in the terminal, and facility requirements and terminal space needs for each functional area were evaluated to accommodate projected demand for the planning periods presented in BNA Master Plan Chapter 3, Aviation Demand Forecasts.

Figure 4-13. Existing Terminal Building

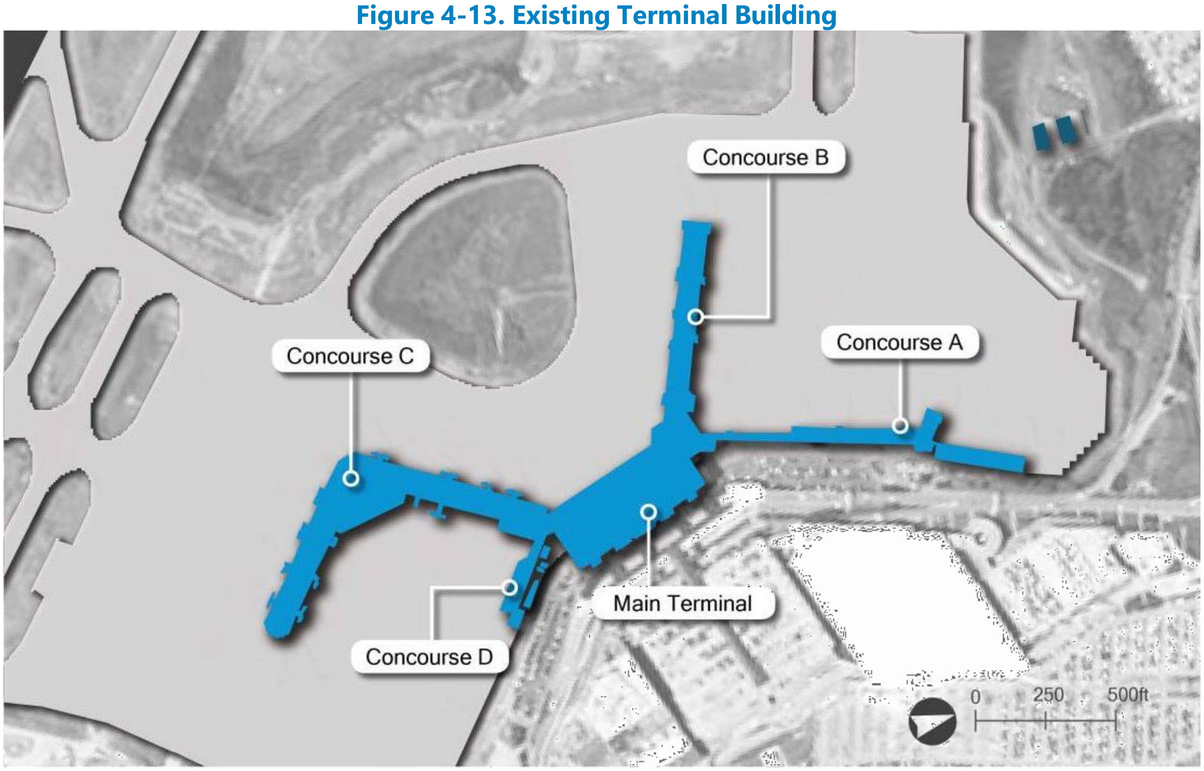
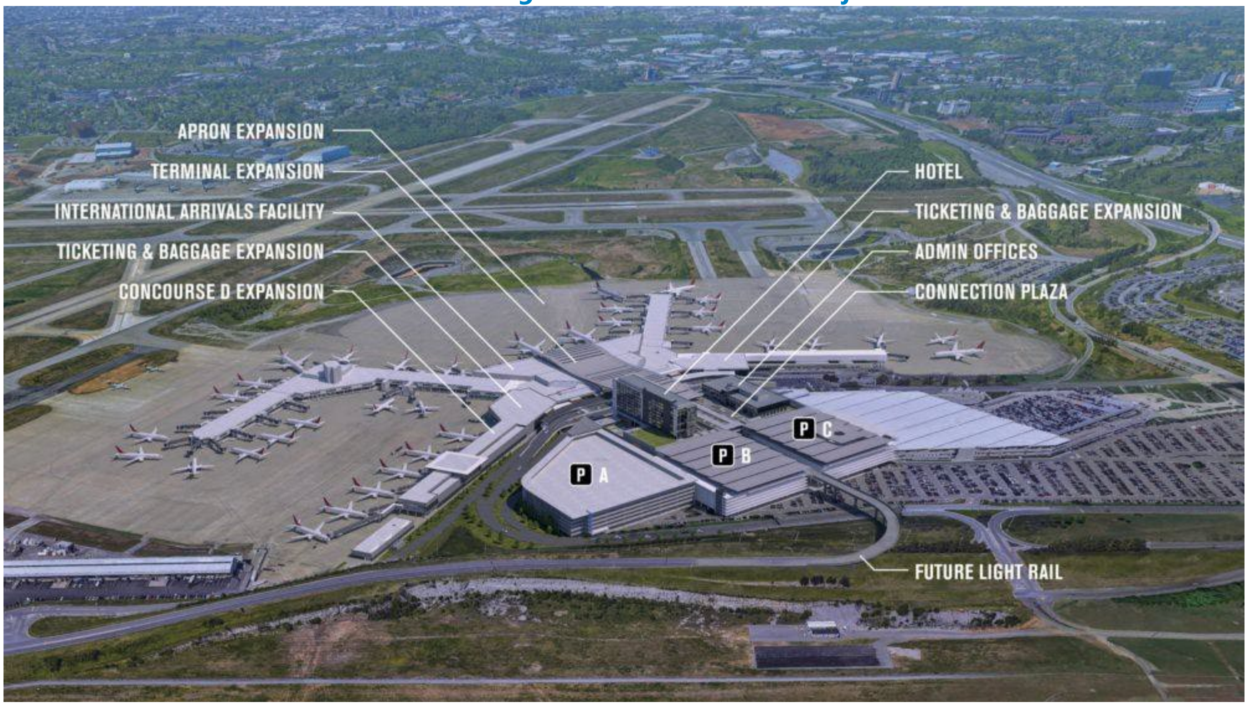


Figure 4-14. BNA Vision Projects



Source: BNA Vision.

The terminal facility is categorized into different functional areas for the analysis, as listed below.

Gates, Parking Positions, and Remain Overnight (RON) Parking Positions: facilities dedicated to aircraft parking and passenger loading and unloading between the terminal building and aircraft.

Check-in/Ticketing: The check-in/ticketing facilities are found in two areas - the ticketing hall and curbside check-in.

- **The ticketing hall:** consists of full-service and bag drop check-in counters, area for self-servicing kiosks, and space for baggage conveyers, passenger queuing, and circulation space.
- **Curbside Check-in**: The exterior area adjacent to the departures level drop-off curb where passengers can check bags before entering the building. Curbside check-in includes queue area, space for counters, and conveyors to transport bags to the baggage screening area and ultimately, the airline's outbound baggage makeup area.

Security Screening Checkpoint (SSCP): The SSCP continues to evolve with the addition of new programs intended to increase passenger throughput rates. The number of required SSCP lanes will always be determined by peak period demand; however, increased throughput rates may also require a slightly larger footprint for each screening lane.

Checked Baggage Inspection System (CBIS): CBIS typically refers to the specific systems and machines used in screening bags for explosives detection.

Baggage Makeup Area (BMU): The BMU area includes tug and cart circulation, cart staging, and the bag makeup devices and excess bag storage area. Cart staging and carousel capacity are the primary determining factor for this functional area and has been analyzed based on the peak bag demand per flight and standard number of carts used to make up a flight.

Baggage Claim (BC): BC area is the final functional area for arriving passengers before exiting the terminal building and proceeding toward the curb/ground transportation or parking. The BC area consists of general circulation, waiting area adjacent to the baggage claim device, active bag retrieval area, and the baggage claim devices.

International Arrivals Facilities - Federal Inspection Services (FIS): FIS facilities are required at all airports with international flights, except for most flights from Canada and a limited number of other airports with U.S. pre-clearance facilities and processes. Passengers arriving on pre-cleared international flights are treated the same as domestic arrivals.

Holdrooms: Holdrooms provide a waiting area for passengers prior to boarding an aircraft and include areas for an airline agent customer service podium, boarding queues, circulation, and other amenities.

Concessions: Concessions space planning is important to the overall terminal program because of its impact on airport revenues as well as passenger convenience/satisfaction. For master planning purposes, the primary goal is to identify existing and potential issues and recommend general programming needs based on industry guidelines.

Restrooms: The unique considerations of airport terminal restrooms include continuous availability and operation, changing passenger demographics, evolving customer expectations, and greater space requirements to accommodate luggage and operational/maintenance needs.

Support Functions: in addition to the major functions specified above, areas for several support functions are estimated in this section, including airport support (MNAA operations, maintenance, office space), airline support, mechanical/electrical/communications space, and other miscellaneous space needs.

Subsequent sections will focus on each area by first estimating the projected capacity of the terminal facilities at the time of BNA Vision completion, and then evaluating whether further improvements will be needed to accommodate future demand in each of these functional areas throughout the master planning period.

4.3.1. Methods, Assumptions, and Performance Specifications

Terminal facility capacity analysis and requirements were developed based on a series of assumptions and parameters. Many assumptions were developed during passenger surveys conducted at BNA in May 2018 and data collected specific to BNA airport. Other parameters were determined by identifying similarities with comparable airports and using terminal facility planning best practices and industry guidelines.

Facility requirements can vary dependent on the level of detail of planning assumptions. The key assumptions used in this analysis were derived from the following major sources:

- Several BNA-specific passenger processing parameters and passenger behaviors were determined based on on-site data collection surveys conducted in May 2018 and information provided in BNA Vision documents;

- Time and space standards as defined in the International Air Transport Association (IATA)'s Airport Development Reference Manual (ADRM) as well as the Airport Cooperative Research Program (ACRP) *Report 25, Airport Passenger Terminal Planning and Design Guidebook*, were both used as criteria and metrics;
- All assumptions were reviewed against the BNA Vision program to adjust for changing conditions and evolving stakeholder preferences;
- Transportation Security Administration (TSA) Checkpoint Requirements and Planning Guide (CRPG);
- Customs and Border Protection (CBP) *Airport Technical Design Standards Manual (ATDS)*; and,
- Airport Cooperative Research Program (ACRP) *Report 25 "Airport Passenger Terminal Planning and Design Guidebook."*

According to guidelines provided in the IATA ADRM, level of service (LOS) of many terminal facilities is dictated by two important variables: space and time – specifically queuing space and waiting time.

Figure 4-15 shows the LOS space-time diagram from IATA. The X-axis defines the amount of space available per occupant, whereas the Y axis denotes the maximum waiting time for passengers in queue. When both space and time fall within the optimum range, the facility is offering an acceptable LOS. Otherwise the facility could be either underprovided, or over-designed and require adjustments in either the time or space aspect. When planning for new or expanded facilities, typically the peak hour of the average day in the peak month (ADPM) is used for demand and the optimum LOS should be targeted for initial sizing. However, sometimes an airport sponsor might choose to accept facilities that operate at a lower LOS for short periods of time during very high demand peaks in order to be responsive to local parameters, capital/operational costs, and user needs. Considering the recent, rapid growth at BNA, this analysis identifies facilities that will provide the optimum LOS where possible, while accounting for flexibility to adjust for BNA-specific operations.

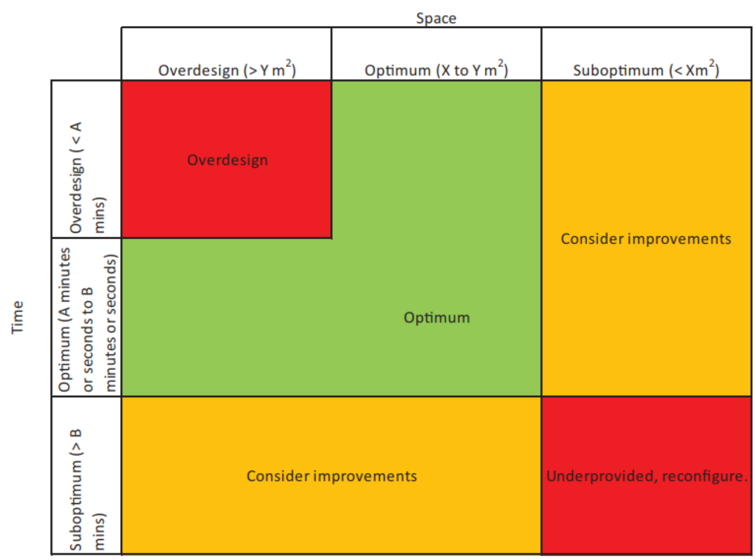


Figure 4-15. IATA LOS Space-Time Diagram

Table 4-25. IATA Level of Service Guidelinesshows the space and time LOS standards from IATA for each functional passenger processing area. This capacity and requirements analysis uses the upper bound numbers in the optimum ranges; that is, assumes higher waiting times (slower processing speeds) and larger square feet per passenger parameters.

Table 4-25. IATA Level of Service Guidelines

		SPACE GUIDELINES [sf/PAX]			MAXIMUM WAITING TIME GUIDELINES Economy Class [minutes]			MAXIMUM WAITING TIME GUIDELINES Business Class /First Class/Fast Track [minutes]			OTHER GUIDELINES & REMARKS		
		Over-Design	Optimum	Sub-Optimum	Over-Design	Optimum	Sub-Optimum	Over-Design	Optimum	Sub-Optimum	Over-Design	Optimum	Sub-Optimum
Public Departure Hall (well-wishers)		> 25.0	22.0 - 25.0	< 22.0	n/a			n/a			Optimum proportion of seated occupants: **15 - 20% ***		
Check-in	Self-Service Kiosk (Boarding Pass/Bag Tagging)	> 19.0	14.0 - 19.0	< 14.0	< 1.0	1.0 - 2.0	> 2.0	< 1.0	1.0 - 2.0	> 2.0			
	Bag Drop (queue width: 1.4m - 1.6m	> 19.0	14.0 - 19.0	< 14.0	< 1.0	1.0 - 5.0	> 5.0	< 1.0	1.0 - 3.0	> 3.0			
	Check-in Desk (queue width: 1.4m - 1.6m)	> 19.0	14.0 - 19.0	< 14.0	< 10.0	10.0 - 20.0	> 20.0	< 3.0	Business Class 3.0 - 5.0	> 5.0			
								< 1.0	First Class 1.0 - 3.0	> 3.0			
Security Control (queue with: 1.2m)		> 13.0	11.0 - 13.0	< 11.0	< 5.0	5.0 - 10.0	> 10.0	< 1.0	Fast Track 1.0 - 3.0	> 3.0			
Immigration Control - Outbound Passport Control (queue with: 1.2m)		> 13.0	11.0 - 13.0	< 11.0	< 5.0	5.0 - 10.0	> 10.0	< 1.0	Fast Track 1.0 - 3.0	> 3.0			
Gate Holdrooms/ Departure Lounges	Seating	> 18.0	16.0 - 18.0	< 16.0	n/a			n/a			Optimum proportion of seated occupants: **50 - 70% ***		
	Standing	> 13.0	11.0 - 13.0	< 11.0							Maximum Occupancy Rate: < 60.0%	60.0% - 70.0%	> 70.0%
Immigration Control - Inbound Passport Control (queue with: 1.2m)		> 13.0	11.0 - 13.0	< 11.0	< 5.0	5.0 - 10.0	> 10.0	< 1.0	Fast Track 1.0 - 5.0	> 5.0			
Baggage Claim	Narrowbody Aircraft	> 18.0	16.0 - 18.0	< 16.0	< 0.0	0.0 / 15.0	> 15.0	< 0.0	0.0 / 15.0	> 15.0	The first waiting time relates to "first passenger to first bag". The second waiting time relates to "last bag on belt" (counting from first bag delivery)**		
	Widebody Aircraft	> 18.0	16.0 - 18.0	< 16.0	< 0.0	0.0 / 25.0	> 25.0						
Customs Control		> 19.0	14.0 - 19.0	< 14.0	< 1.0	1.0 - 5.0	> 5.0	< 1.0	1.0 - 5.0	> 5.0	Waiting times refer to a procedure when 100% of the passengers are being checked by Customs		
Public Arrivals Hall (meeters-greeters)		> 25.0	22.0 - 25.0	< 22.0	n/a			n/a			Optimum proportion of seated occupants: **15 - 20% ***		

Source: IATA Airport Reference Development Manual (ADRM), 10th Edition

Future terminal requirements can, in part, be determined by identifying the number of peak hour passengers projected to flow through the terminal. Peak hour passenger volumes are derived from the aviation demand forecast, which also serves as the basis for development of design day flight schedules (DDFS) for future years. Peak hour enplanement and deplanement demand was approximated through a rolling 60-minute flow of arriving and departing passengers across the design day. **Table 4-26** provides a summary of peak hour enplanements and deplanements throughout the planning horizon.

Table 4-26. Peak Hour Enplanements and Deplanements

Year	Peak Hour Enplanements	Peak Hour Deplanements
2017	2,439	2,652
2022	3,118	3,391
2027	3,425	3,725
2032	3,752	4,080
2037	4,114	4,473

Source: Table 3-43, BNA Master Plan Update Chapter 3, Aviation Demand Forecasts.

Peak hour enplanements and deplanements include origin and destination (O&D) passengers as well as connecting passengers. According to BNA Master Plan Update Section 3.4.2.2, *Originating vs. Connecting Passengers*, this analysis assumes 12% connecting passengers, and 88% O&D passengers. For the purpose of projecting terminal facility requirements, peak departure and peak arrival demand profiles assume 100% O&D since the highest departure demand occurs early in the morning before current and projected airline schedules foresee passengers connecting from one flight to another; and the highest arrival demand occurs in the late evening when most passengers are ending their travel at BNA.

Since passenger activity is not evenly distributed during the peak hour, but more typically follows a curved distribution, the DDFS also helps with constructing a passenger show-up profile to understand how many passengers are processed through each facility during the peak 30 minutes. This indicator is referred to as the "peak 30 minute factor." Typically, more than half of peak hour passengers would show up during the peak-30 minutes, making the peak 30 minutes the real 'pressure point" for terminal facilities. BNA's peak 30 minute factor is roughly 68%, which means that among all peak hour passengers, 68% of them are processed during the peak 30 minutes. The peak 30 minute factor is a key consideration when estimating facility requirements for terminal core processors such as check-in, SSCP, and baggage claim.

4.3.2. Aircraft Gate Parking Positions and RON Parking

4.3.2.1. Contact Gate Requirements

Contact gate requirements for BNA were developed using the Design Day Flight Schedules (DDFSs) created as part of the Master Plan Update. The assumptions used in determining gate requirements included:

- Continued BNA gate assignment/use parameters
- Number of daily operations per gate limited to 8 or less per gate per airline
- Factors regarding gate reduction due to adjacencies – wide body to narrow body gate use
- Additional gates needed for use during construction phasing

Contact gate requirements for the planning horizons are shown in **Table 4-27**.

Table 4-27. Contact Gate Requirements

	2022 Dedicated gates	2027 Dedicated gates	2032 Dedicated gates	2037 Dedicated gates
Sub-Total	48	51	53	54
Added gates to reduce daily operations per gate to a maximum of 8.0				
	4	1	1	1
Sub-Total	52	55	57	58
Added gates to address adjacency and construction phasing needs				
Adjacency	2	2	2	2
Phasing	2	1	1	1
TOTAL	**56**	**58**	**60**	**61**

Source: TransSolutions and AECOM analysis.

While the design day flight schedules can be accommodated with a reduced numbers of gates, there would be little to no gate availability and flexibility for the airport and airlines during periodic flight delays or other-than-normal operations, such as temporary gate closures for construction. If the number of daily operations (turns) per gate per day were limited to a lower number for operational considerations, the gate requirements would increase and provide operational flexibility for the airport and airlines to allow, for example, longer buffer times between flight arrivals and departures if needed. In order to reduce the number of turns per gate per day to be more consistent with current and anticipated future activity, one additional gate was added for each of the following airlines: American (AA), Delta (DL), United (UA), and Southwest (WN).

For planning purposes, it was considered that during the peak gate demand, two wide body aircraft may occupy four narrow body positions, reducing the gate availability by two gates. As such, two gates were added to address this anticipated adjacency issue.

Finally, BNA will be in some stage of construction for many years as the BNA Vision plan is implemented and future improvements recommended as part of this Master Plan Update occur. During construction phasing, it is assumed that one to two gates would be needed as interim gates to relocate airlines temporarily during construction. As a more detailed phasing analysis is done, it may be determined that more construction phasing gates are required for relocated airlines.

Contact gate dimensional characteristics are determined by the planned fleet mix. For BNA, the majority of operations are projected to be Airplane Design Group (ADG) III. The largest ADG-III aircraft is the A321 NEO which has a 117.45-foot wingspan and fuselage length of 146 feet. Contact stands should also include:

- Wing clearance on both sides of the contact gate position can vary from 20- to 25-feet and would be split between the two adjacent positions
- Pushback tractor staging and maneuvering space forward of the aircraft nose, which can vary from 30- to 40-feet
- A buffer zone between the aircraft tail and a vehicle service road (VSR) or taxilane object free area (OFA) of roughly 5- to 10-feet
- The VSR can be located either adjacent to the concourse (referred to as a head-of-stand VSR) or behind the aircraft tail; the VSR is typically a two-way drive approximately 20- to 25-feet wide

Overall dimensions for an ADG-III contact gate position is 225-feet deep by approximately 145-feet wide. It is suggested that a 25-foot wide VSR should be provided between every grouping of five contact gates. Actual contact gate depth and width can vary based on site limitations and airline requirements.

4.3.2.2. Remain Overnight (RON) Requirements

Near the end of the evening when airline arrivals continue beyond the number of available gates and no departures are scheduled until the following day, these aircraft are considered RON aircraft at BNA. RON demand is defined by the DDFS prepared for BNA. RON aircraft parking is a key component of an airline's operation to ensure that the right aircraft is located at the correct airport to begin daily operations. Total RON parking consists of on-gate and off-gate aircraft parking positions. On-gate RON positions use a contact gate that may include a passenger boarding bridge. Off-gate RON positions are those that cannot be accommodated at a contact gate and must be parked remote to the concourse gate area. The number of off-gate RON positions is the total RON demand minus the number of contact gate aircraft parking positions.

Based on the DDFS created for the four planning horizons (2022, 2027, 2032, 2037), RON parking position requirements were developed. RON parking is a fluid aspect of terminal apron requirements and can vary based on the available gates to use for RON aircraft parking. Sometimes a gate used by an airline needs to remain vacant overnight and cannot be used for RON by another airline due to early morning scheduling of departures. Additionally, many airlines have preferential use agreements for gates that limit the use of the gate by other airlines. **Table 4-28** summarizes the off-gate RON aircraft parking requirements for the PALs.

Table 4-28. Remain Overnight Aircraft Parking Requirements Summary

	2022	2027	2032	2037
TOTAL	16	17	17	18

Source: AECOM Analysis.

If consideration is given to use of international gates as RON aircraft parking, it is possible the total RON requirements for each PAL could be reduced by 2 to 4 positions, and/or could allow RON parking by other carriers having overnight parking requirements in excess of the gates they lease. Late evening and early morning international arrival demand will determine the viability of using international gates for RON positions.

4.3.3. Check-In / Ticketing

The airline check-in process continues to evolve with technological advances such as added self-service facilities that provide convenience, efficiency, and more passenger control in the check-in process. As the technology evolves in the future, facility requirements for check-in facilities will inevitably evolve as well. The objective is to provide space flexible enough to respond to such evolution.

4.3.3.1. Key Assumptions

Table 4-29 summarizes the percentages of passengers using different check-in options by airlines. The data is presented based on two processes: the options for getting boarding passes; and the options for checking in bags.

Airlines typically provide four options for getting boarding passes:

1. Full service agent counters
2. Curbside
3. Self-servicing kiosks
4. Mobile/online

Among the four options, passengers can typically check in their bags at full-service agent counters or at curbside check-in facilities. With self-servicing kiosks and mobile/online boarding pass retrieval, passengers still need to proceed to a bag drop position to check in their bags. Therefore, in Error! Reference source not found., the percentages of passengers who used bag drop positions are reported separately from passengers who use the four options for getting boarding passes.

Table 4-29 also compares BNA check-in behaviors with survey results at other commercial airports across the country. The main observation is that the lack of kiosks with several airlines at the time of the May 2018 survey contributed to a lower kiosk percentage compared to other airports. The same comparison is observed with the bag drop facilities. Both the average numbers and the industry benchmark numbers are used in the analysis to provide an estimated range for check-in facility requirements.

Table 4-29. Check-in Options

Airlines	Options for Obtaining Boarding Passes					Bag Drop
	Agent Counters	Kiosks	Curbside	Mobile/Online	Total	
Southwest[1]	5%	32%	8%	55%	100%	36%
American[1]	13%	33%	8%	46%	100%	28%
Delta[1]	25%	31%	3%	41%	100%	53%
United[1]	17%	40%	0%	43%	100%	0%
Alaska[1]	25%	50%	0%	25%	100%	0%[a]
JetBlue[1]	12%	63%	0%	25%	100%	0%[a]
Frontier[1]	73%	0%	0%	27%	100%	0%[a]
Air Canada[1]	77%	0%	0%	23%	100%	0%[a]
Westjet[1]	44%	0%	0%	56%	100%	0%[a]
Boutique[1]	100%[b]	0%		0%	100%	
Contour[1]	100%[b]	0%	0%	0%	100%	0%[a]
New Carrier 1[2]	9.8%	49%	0%[a]	41%	100%	53.6%
New Carrier 2[2]	9.8%	49%	0%[a]	41%	100%	53.6%
New Carrier 3[2]	9.8%	49%	0%[a]	41%	100%	53.6%
New Carrier 4[2]	9.8%	49%	0%[a]	41%	100%	53.6%
New Carrier 5[2]	9.8%	49%	0%[a]	41%	100%	53.6%
Charter[2]	100%	0%[a]	0%[a]	0%	100%	0%[a]
Average	**38%**	**29%**	**1%**	**32%**	**100%**	**23%**
Industry Benchmark[3]	**38%**	**40%**	**1%**	**21%**	**100%**	**35%**

Data Sources:

1. *BNA Master Plan Update, Passenger Characteristics & Processing Times Data Collection DRAFT Report, June 2018*
2. *BNA Facilities Requirements Report, June 2017*
3. *Based on surveys conducted at other commercial airports*

Notes:

a. *Facility not provided at the time of the survey*
b. *Incomplete data points from the survey*

Table 4-30 summarizes average passenger check-in processing times based on the facility processor used. The information is from three sources. The primary source is the BNA survey data collected in May 2018 (*BNA Master Plan Update, Passenger Characteristics & Processing Times Data Collection DRAFT Report*, *June 2018*). The May 2018 data collection efforts did not capture complete data for some airlines such as the curbside information for American, United, JetBlue, and Frontier. For these airlines the information was derived from the June 2017 Facilities Requirements report. For the remaining airlines whose data is incomplete from either the 2017 or 2018 reports, the IATA reference processing times are used for a conservative analysis purpose.

Similarly, average processing time for each check-in option is calculated and benchmarked with survey data from other commercial airports. Both the agent counters and kiosks have generally faster processing rates at BNA compared to other airports. For a conservative analysis to allow for operational flexibility, both the average processing time and industry benchmark are used in this analysis to provide an estimated range for the facility requirements.

Table 4-30. Check-in Processing Times per Passenger (seconds)

Airlines	Agent Counters		Kiosks	Curbside	Bag Drop
	Economy	Premium			
Southwest[1]	102	114	84	90	30
American[1 2]	228	264	228	164	36
Delta[1]	96	72	96	78	72
United[1 2]	125	108	126	125	42
Alaska[3]	140	150	120	140	110
JetBlue[1 2 3]	132	150	72	108	90
Frontier[1 2 3]	78	150	80	108	44
Air Canada[1 3]	108	150	120	140	110
Westjet[1 3]	132	150	120	140	114
Boutique[1 3]	90	150	120	140	110
Contour[1 3]	90	150	120	140	110
New Carrier 1[3]	140	150	120	140	110
New Carrier 2[3]	140	150	120	140	110
New Carrier 3[3]	140	150	120	140	110
New Carrier 4[3]	140	150	120	140	110
New Carrier 5[3]	140	150	120	140	110
Charter[3]	140	150	120	140	110
Average	**127**	**148**	**118**	**130**	**90**
Industry Benchmark	**150**	**210**	**150**	**130**	**90**

Data Sources:
1. *BNA Master Plan Update, Passenger Characteristics & Processing Times Data Collection DRAFT Report, June 2018*
2. *BNA Facilities Requirements Report, June 2017*
3. *IATA Airport Reference Development Manual (ADRM), 10th Edition*

Based on IATA's ADRM, it is assumed that 85% of passengers use economy agent counters, and 15% of passengers use premium check-in counters. **Table 4-31** provides a simplified summary of the maximum waiting time from the IATA ADRM LOS guidelines for the check-in facilities.

Table 4-31. Maximum Waiting Time

Max Waiting Time in Queue for Optimum Services (Min)	
Check-in	
Economy Counter	20
Premium Counter	5
Self-Service Kiosks	2
Curbside	5
Bag Drop	3

In correlating peak hour enplanement data with specific airline facility capacity, each airline's requirements were estimated individually. However, where specific airline data was unavailable, an aggregate approach was taken for the facility requirements.

4.3.3.2. Check-In Capacity

BNA Vision will be expanding airline check-in facilities, and **Table 4-32** provides a summary of the total number of units for the different types of facilities after the expansion. Based on the processing time per passenger by airline for each type of facility and several other key assumptions to allow for demand variability, the number of passengers each airline's facility can process during the peak hour was evaluated and summarized in **Table 4-32**. The total number of passengers that the check-in facilities can process during the peak hour, not including mobile or online check-in passengers, is estimated to be approximately 3,880 when the BNA Vision ticketing expansion is fully completed.

Table 4-32. Check-in Facility Capacity

	Full Service[1]	Kiosks[1]	Curbside[1]	Bag Drop[1]	Peak Hour Passenger Capacity
Southwest	5	15	10	15	947
American	4	12	2	8	233
Delta	3	13	2	10	541
United	10	10	1	0	278
Alaska	1	6	0	1	151
JetBlue	1	4	0	2	166
Frontier	1	4	0	2	166
Air Canada	1	3	0	1	96
Westjet	2	0	0	2	61
Boutique	1	0	0	0	40
Contour	1	0	0	0	40
New Carrier 1	3	6	0	2	210
New Carrier 2	3	7	0	2	230
New Carrier 3	2	6	1	2	201
New Carrier 4	3	5	0	2	190
New Carrier 5	1	5	1	3	151
Charter	6	0	0	0	176
Total	**48**	**96**	**17**	**52**	**3,880[2]**

Notes:

1. *Information from Section 1.1, Ticketing & Security, BNA Vision Bridging Document*
2. *The capacity analysis focuses on how many passengers the on-site facilities are capable of processing. Therefore, this number only includes passengers processed through full service counters, kiosks, and curbside positions, as well as passengers who dropped their bags at the bag drop positions. This number does not include passengers who check in online or on their mobile devices and bypass any of the physical on-site check-in facilities, including bag drop positions*

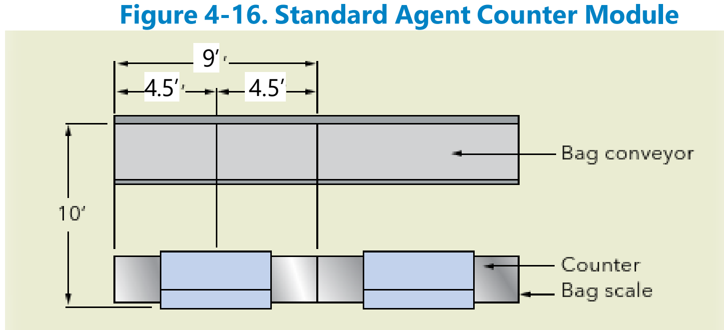
4.3.3.3. Check-In Facility Requirements

The facility requirements focus on both the number of units needed and the space required to accommodate these units.

The agent counters and the self-service kiosks can be configured in a variety of layouts. The modules used for this analysis are consistent with the layout proposed in the BNA Vision documents.

As shown on **Figure 4-16.** Standard Agent Counter Module, a standard agent counter module would be roughly 10 feet deep by 4.5 feet wide, each position occupying 45 square feet. This zone includes the counter, agent standing/sitting area, and the bag load conveyor. In addition to the counter itself, additional area for circulation between the counters and the queue areas must be provided for passengers to navigate around the counter areas. The typical depth for circulation is 11 feet based on the BNA Vision design. The curbside counters and bag drop counters are assumed to be configured in a similar module, consistent with the current facilities at BNA.

Figure 4-16. Standard Agent Counter Module

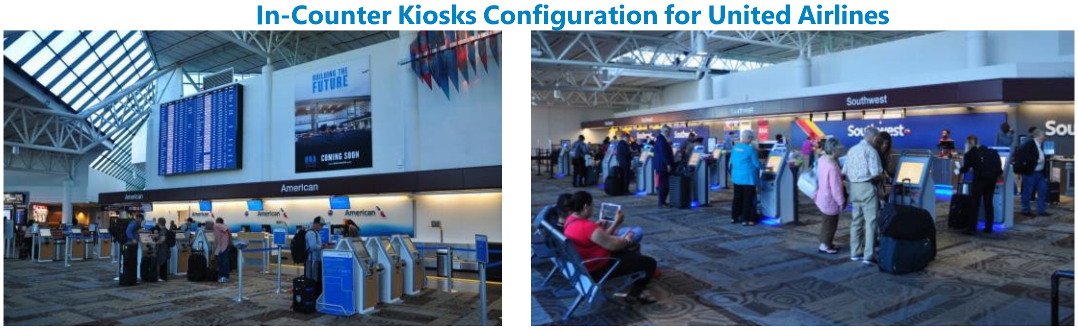


Self-service kiosks range in size and configuration as well as placement within the check-in lobby. Typically kiosks can be placed in two configurations:

- "In-line" or "in-counter" along the ticket counter line, such as the existing kiosk configuration for United Airlines, or
- Independent from the counters, in rows or clusters in the proximity of the airlines' full-service and bag drop agent positions, such as the existing Southwest or American Airlines kiosk configuration.

Although some airlines use a one-step process that incorporates in-counter kiosks to obtain boarding passes with the bag drop process using an agent, this analysis assumes the independent kiosks configuration used by Southwest and American Airlines in order to allow for the flexibility to accommodate the two-step bag tagging process that has increased in popularity. The two-step process uses kiosks for passengers to obtain boarding passes and baggage tags, and then passengers carry their bags to a bag drop counter position for agent processing. Each kiosk typically occupies two square feet of space. IATA recommends adding a factor of 3 to this space to accommodate passengers and their baggage when they operate in front of the kiosk. An additional 35% of circulation factor is also recommended by IATA between kiosks and passenger queueing area.

In-Counter Kiosks Configuration for United Airlines



Independent Kiosks Configuration for American Airlines and Southwest Airlines

Based on the processing time per passenger, the maximum allowable queue time, the passenger arrival profiles for the peak 30 minutes, and the space required for the check-in units, the check-in facility requirements were calculated. **Table 4-43** presents the requirements for agent counters, kiosks, curbside counters, and bag drop positions in terms of the number of units and the space required for these units. As indicated, the BNA Vision check-in expansion will provide sufficient area, kiosks, and curbside counter facilities. Although there is a projected deficiency in agent counter and bag drop positions, there is sufficient space in the check-in facilities to adjust the number of kiosks, curbside, agent counters, and bag drop positions to meet demand, if needed. Throughout the planning period, it is possible that facility deficiencies may resolve with passenger processing behavior and check-in protocol changes.

Table 4-33. Check-in Facility Requirements

Facility Type		Facility Requirements				
		Baseline	**2022**	**2027**	**2032**	**2037**
Units	Agent Counters	**48**	39~47	42~51	46~57	50~62
	Kiosks	**96**	40~67	43~74	46~81	51~89
	Bag Drop	**52**	26~41	29~44	32~48	35~53
	Curbside Counters		2	2	2	2
Areas						
	Indoor Counter Areas (s.f.) [2]		2,930 ~ 3,960	3,200~4,280	3,510~4,730	3,830~5,180
	Existing Queue, Circulation & Kiosks Areas (s.f.) [3]		12,480~15,620	13,710~17,100	15,020~18,780	16,400~20,560
	Curbside Counter Areas & Queue (s.f.)		540	540	560	560

Notes:

1. *Not including online/mobile/people who don't check bags*
2. *Agent counters and bag drop counters*
3. *Results rounded up to the nearest tenths*
4. *Red text indicates deficiencies*
5. *S.f. = square feet*

4.3.4. Security Checkpoint (SSCP)

After completing the check-in process, passengers proceed to the security screening checkpoints (SSCP). Security screening is generally regarded as a major "pressure point" in terminal facility planning for a number of reasons:

1. Unlike other areas which might only be used by a percentage of passengers (for instance some people might not check bags to bypass the ticketing facility), the SSCP is a function that must serve all passengers.
2. More airports are moving to a 100% security screening policy for employees. While some portion of the employee population will use passenger SSCP's, more airports are investigating dedicated employee SSCP's as an option to reduce the employee population using passenger SSCP's.
3. In contrast to other areas where technology and new processes expedite the flow of people, security screening technology steadily evolves with increasing complexity, and the ever changing screening protocols could increase the queue wait time as well as space requirements.

In developing requirements for the SSCP, an allowance should be provided to accommodate future changes to security screening equipment and processes.

The SSCP consists of a standard module set with either single or dual inspection lanes. The Transportation Security Administration (TSA) policy is that single or dual inspection lane configuration can be further enhanced for higher throughput rates by adjustments to include Automated Security

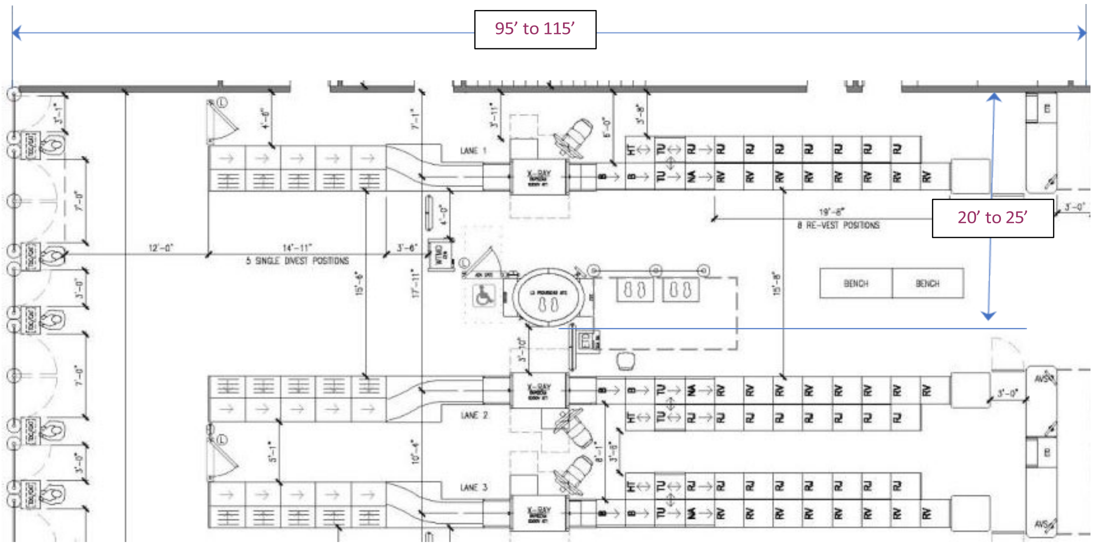
Lane (ASL) technology. Thus, requirements and planning for future SSCP's include allowances to install ASL configurations. A typical single lane module set consists of the following:

- Divesting area for multiple passengers
- X-Ray Unit
- Walk-Through Metal Detector for expedited screening (WTMD) and/or an Advanced Imaging Technology (AIT) unit for standard screening
- Passenger containment/holding area
- Composure area for multiple passengers
- A secondary screening area with Explosives Trace Detection (ETD), Bottle Liquid Scanner (BLS), Alternate Viewing Station (AVS), and passenger and carry-on bag inspection

A dual-lane module set is similar to a single-lane module set but with a second X-ray unit. The dual-lane module set increases the efficiency of the SSCP and is generally recommended. However, a single-lane module set is utilized when there are an odd number of lanes required per peak hour demand. The SSCP at BNA has mostly dual-lane modules in both the existing conditions and when BNA Vision projects are completed. The single- or dual-lane configuration can be assigned/configured as "Standard" for all passenger screening or "Pre-check" to screening passengers who have been approved for use of Pre-check lanes. While Pre-check lanes do not typically include AIT equipment, for flexibility AIT's should be provided for all SSCP lanes. ASL lane configurations can vary slightly depending on the equipment used for each lane. **Figure 4-17** shows a typical ASL configuration.

The TSA has pilot programs that are trying to speed up the screening checkpoint process and increase passenger throughput. The FLEX lane program is a recent pilot program to investigate various risk-based screening (RBS) processes and protocols aimed at enhancing the passenger experience at the checkpoint. As TSA further develops and refines their RBS programs FLEX, Pre-check and other programs will evolve into the standard checkpoint planning and design process with a goal of maximizing existing facilities and infrastructure. Other checkpoint lane processes such as CLEAR typically use established standard or Pre-check and CLEAR enrolled passengers essentially get priority processing to the next available document check officer. Known Crew Member (KCM) lanes are typically established at the egress point from the concourse or an access point into the secure area. The lanes are not typical security screening lanes in that they are essentially an identity and credential checkpoint with a podium. The requirement for KCM lanes varies considerably from airport to airport based on the airport configuration more than volume of people. At BNA it is anticipated that no more than 2 KCM lanes/access point will be required.

Figure 4-17. Automated Screening Lane (ASL) Typical Configuration



Source: TSA Checkpoint Requirements Planning Guide, 12/17/2018

Pre-Check lanes allow pre-approved travelers to leave on shoes, light outerwear and belts, laptops in the case, and 3-1-1 compliant liquids/gels bag in the carry-on luggage. Passengers and personnel that are screened through TSA Pre-Check lanes include the TSA Pre-Check passengers and Managed Inclusion (MI) passengers.

As of early 2019, BNA employees and crew members are processed through a dedicated dual-lane module in a separate screening area, instead of being mixed with passenger traffic in the main SSCP area. Future SSCP requirements will include a total number of lanes needed to process passengers and employees.

4.3.4.1. Key Assumptions

Based on BNA Vision, the baseline conditions for the SSCP after the planned expansion are as summarized in **Table 4-34.** SSCP Baseline Conditions

Table 4-34. SSCP Baseline Conditions

Type of Lanes	Number of Lanes	Queue Area (s.f.)
Pre-Check	4	
Premium	5	
Standard	12	7,125
ADA	3	
Total	**24**	

Source: BNA Vision.

The use of TSA Pre-Check is anticipated to increase based on recent registration statistics and the TSA's initiative in risk-based screening (RBS). RBS refers to the method that defines a passenger's credentials prior to the security screening process. TSA Pre-Check is an existing example of the RBS program that is intended to increase throughput rates for SSCP lanes which in turn would reduce the required number of lanes. Although there are few other RBS programs currently utilized (CLEAR, Flex, Known Crew Member), the TSA plans on expanding RBS in the future. The implementation of the TSA Pre-Check has effectively increased the processing rate at TSA Pre-Check checkpoints. Therefore, in order to estimate future SSCP requirements for BNA it is assumed that the current TSA Pre-Check utilization of 25% will gradually increase to approximately 40% in the 20-year planning horizon. **Table 4-35** summarizes the key assumptions for the SSCP facilities.

Table 4-35. SSCP Key Assumptions

Type of Lanes	Throughput (Pax/Hr/Lane)[1]	LOS Maximum Wait Times (mins)[2]	Split of Passengers[3]
Pre-Check	250	10	25%-40%
Premium	150	10	20%
Standard	150	15	30~45%
ADA	130	10	10%

Sources:

1. *BNA Vision Bridging Document, SSCP Requirements Studies*
2. *Generally accepted wait times by the TSA and comparable airports*
3. *BNA Facilities Requirements Report, June 2017*

Based on the BNA Vision SSCP layout, it is assumed that future crew and employee traffic will also use the main SSCP area. Therefore, an additional 3% is added to the overall peak hour passenger number to account for the extra traffic based on general industry observations. It is assumed that crew members and employees will typically use Pre-Check Lanes. The Alternatives chapter will examine options for additional or separate checkpoint lanes for the various new technologies and employee screening requirements.

The general planning area requirement for each SSCP lane is approximately 1,540 square feet per lane. This area includes the primary screening area (WMTD/AIT devices, conveyor belts, etc.), secondary screening area (ETD, BLS, etc.) and egress/composure area where passengers re-arrange their belongings before heading to gates. This area does not include the queue area for passengers. Based on IATA LOS standards, 13 square feet of queue area should be provided for each passenger in the queue for optimum design.

4.3.4.2. SSCP Capacity

Based on the number of post-BNA Vision lanes and the projected throughput for each lane, the capacity of the SSCP lanes is calculated and summarized in **Table 4-36**.

Table 4-36. SSCP Capacity

Type of Lanes	Number of Lanes	Throughput (Pax/Hr/Lane)	Capacity (Pax/Hr)
Pre-Check	4	250	1,000
Premium	5	150	750
Standard	12	150	1,800
ADA	3	130	390
Total	**24**	**n.a.**	**3,940**

Source: AECOM Analysis.

4.3.4.3. SSCP Facility Requirements

Table 4-37 provides the estimated facility requirements for each type of SSCP lane, as well as the total requirements. In summary, due to the fast growth projected at BNA during the planning horizon, additional lanes may be required by 2037. Before 2037, the total number of SSCP lanes is sufficient but a portion of the standard lanes should be re-designated as Pre-check and premium lanes to serve the increasing percentage of passengers using these two types of lanes.

Table 4-37. SSCP Facility Requirements - Number of Lanes

Type of Lanes	Number of Lanes	Number of Lanes Required[1]			
	Baseline	**2022**	**2027**	**2032**	**2037**
Pre-Check	4	4	5	7	8
Premium	5	5	5	6	6
Standard	12	9	8	8	8
ADA	3	3	3	3	3
Total	**24**	**21**	**21**	**24**	**25**

Notes:

1. *The number of security screening lanes includes a correction factor for demand variability and is based on the maximum waiting time allowed*
2. *Red text indicates deficiencies*

Table 4-38 shows the total areas required for the screening area and queue area, in comparison to the areas provided based on the BNA Vision program. A larger queue area than designed in BNA Vision is required to accommodate the number of queuing passengers during the peak periods.

Table 4-38. SSCP Facility Requirements – Area Square Footage

Area	Existing Area	Area Required[2]			
	Baseline	2022	2027	2032	2037
Screening Area	35,527	32,370	32,370	37,000	38,540
Queue Area[1]	7,125	8,940	9,690	10,500	11,370
Total Area	**42,652**	**41,310**	**42,060**	**47,490**	**49,900**

Notes:
1. *Queue space includes a correction factor for the maximum number of passengers in the security queue at any one time and is based on the maximum waiting time allowed*
2. *Numbers are rounded up to the tenths*
3. *Red text indicates deficiencies*

It is also noted that the throughput per lane (passengers/hour/lane) is based on BNA Vision design parameters and benchmarked by on-site data collection results. It is anticipated that the processing rate has the potential to increase in the future with technological advances as well as new processing protocols. However, the number of SSCP lanes is very heavily dependent on the actual throughput capacity of each lane. Should future lane physical configuration or TSA protocols not produce the estimated throughput, additional lanes above the forecast presented may be necessary.

4.3.5. Checked Baggage Inspection System (CBIS)

The CBIS is the total bag screening system that centers around Explosive Detection Systems (EDS) machines. EDS machines are characterized by the throughput capacity achieved. These machines have remained relatively large but technological advances have increased the effectiveness, speed, and reliability of the bag screening process. In general, as throughput rates increase, fewer EDS machines should be required; but increased throughput rates could also result in upstream and downstream baggage processing congestion if bag belt speeds are not able to be adjusted simultaneously with reducing the number of EDS machines.

4.3.5.1. Key Assumptions

The CBIS at BNA are divided into two areas – the north CBIS in the main terminal, and south CBIS in Concourse C. This analysis assumes maintaining the two separate CBIS areas. Although BNA Vision does not propose any expansion of the CBIS facility, the CBIS systems are currently being reviewed in a separate study, since baggage throughput rates are not currently achieving their rated capacity. For this Master Plan analysis, the post-BNA Vision baseline conditions for the number of existing EDS machines remain the same as the existing conditions in 2019. **Table 4-39** provides a summary of the number of screening facilities at each level.

Table 4-39. CBIS Baseline Conditions

CBIS Area	Number of EDS Machines[1]	Areas (Square Feet)
North CBIS (Main Terminal)	4	13,640
South CBIS (Concourse C)	4	12,820
Total	**8**	**26,460**

Sources:
1. *Data from BNA Vision Bridging Document, page 10, Arrivals Level Plan*

The assumptions for each level of the screening activities are summarized in Error! Reference source not found.. The general planning area requirement for a CBIS is assumed to be approximately 4,250 square feet per EDS machine. This assumption includes 4,000 square feet for the EDS machine, checked baggage reconciliation area, and indexing conveyor system, as well as 250 square feet on average for the additional space required for TSA break rooms and mechanical space.

Table 4-40. CBIS Key Assumptions

Key Input Factor	Unit	Assumption
Average Bags per Passenger **who checked bags**[1]	Bags	0.73
Passenger Group Size[1]	Passengers	1.5
% of Groups without a checked bag[2]	%	36.6%
% of Total bags that are over-odd/sized bags & too large for EDS[2]	%	2%
TSA Surge Factor		1.1
EDS Throughput Rate[3]	Bags/hour/machine	500
Area required per EDS Screening Unit[4]	Square feet	4,250

Sources:
1. *BNA Master Plan Update, Passenger Characteristics & Processing Times Data Collection DRAFT Report, June 2018*
2. *BNA Facilities Requirements Report, June 2017*
3. *Estimated rated capacity of EDS machines from BNA Maintenance and Operations staff members*
4. *Industry general planning area requirements per EDS machine*

4.3.5.2. CBIS Capacity

Typically when a CBIS facility is designed, one extra EDS machine is provided in addition to the required number of machines to allow for positive redundancy in case of machine breakdown. This redundant machine is typically not used during normal conditions and only activated when the airport experiences unusual high traffic volumes. However, the existing two CBIS areas at BNA are experiencing less throughput than the EDS rated capacity of 500 bags per hour; thus, it is likely that all four EDS machines in both the Main and Concourse C CBIS areas are being used, rather than one EDS machine in each area being held in reserve. Recent observed throughput rates have been in the 360 bags per hour range. For this Master Plan, two separate calculations for determining facility requirements were prepared to account for the rated throughput and the observed throughput.

The first analysis assumes that one of the four in-line systems at each CBIS area is the redundant machine, and therefore the total active in-line systems under normal conditions are only six, instead of eight. Given that each machine has a rated throughput of 500 bags per hour, the total throughput rate for the six machines would be 3,000 bags per hour. Using this methodology, and after accounting for factors such as the oversize/irregular-shape bags, the TSA baggage surge factor during the peak 10 minutes, and the average bags per passenger, it is conservatively estimated through the ACRP Report 25 Baggage Screening model that the CBIS areas at BNA have **a peak hour capacity of processing approximately 3,800 passengers who check their bags**.

For the second analysis, it was assumed that all four EDS machines in each CBIS area are being used to meet baggage demand due to observed throughputs of 360 bags per hour. At 360 bags per hour, the throughput rate for the eight (8) EDS machines would be 2,880 bags per hour; however, this would not allow one EDS machine to be held in reserve for redundancy and maintenance practices. Using the same factors as described above, the CBIS in the second analysis would have a peak hour capacity of processing approximately 3,600 passengers who check their bags.

4.3.5.3. CBIS Facility Requirements

The requirements for each level of screening facilities and the associated areas were determined based on projected peak hour baggage demand and throughput rates. **Table 4-41** depicts the peak hour enplanements, peak hour bags to be screened, and the facility requirements, assuming that the EDS machines can achieve their rated throughput of 500 bags per hour, and assuming that the TSA's "n+1" configuration can be achieved in keeping one EDS machine in reserve and separate from the CBIS available capacity for redundancy and maintenance needs. A separate calculation is made to identify the number of EDS machines required if the baggage processing rate can only achieve the 360 bags per hour.

Table 4-41. CBIS Facility Requirements

	Baseline	Facility Requirements			
	2017	2022	2027	2032	2037
Peak Hour Enplanements	2,439	3,118	3,425	3,752	4,114
Number of Bags to process during Peak Hour	1,134	2,174	2,389	2,617	2,869
	Baseline	2022	2027	2032	2037
Number of Bags to process in Level 1	n.a.	2,331	2,549	2,781	3,038
EDS machines required @500 bags per hour	6	5	6	6	7
EDS machines required @360 bags per hour[2]	8	8	9	9	10
CBIS Area Required[1]	26,460	21,250	25,500	25,500	29,750

Notes:

1. *Red text indicates deficiencies*
2. *Machines needed include the n+1 configuration.*

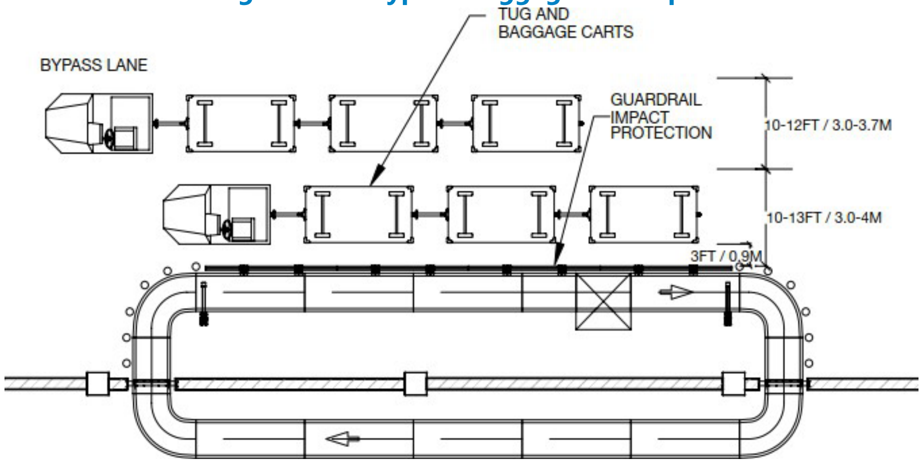
Using the "peak hour enplanement" and "Number of Bags to process during Peak Hour" information from **Table 4-41**, a calculation was made to determine the number of EDS machines needed in the event that the baggage processing throughout rates remain at the currently observed level of 360 bags per hour. Currently, all eight EDS machines are needed to process peak hour baggage. **Table 4-41** indicates that, if baggage screening throughput cannot achieve the rated capacity of 500 bags per hour, the number of EDS machines needed would exceed current capacity by 2027.

4.3.6. Baggage Makeup (BMU)

Once bags clear the screening process, they are sorted to the appropriate airline outbound baggage makeup (BMU) area through conveyor belts. The BMU area includes the bag makeup devices, baggage cart staging area, and tug/cart circulation area. **Figure 4-18** depicts an effective baggage makeup device and its surrounding areas. The most effective baggage makeup areas have the capability of allowing airline baggage carts to stage at the carousel to load baggage onto their carts, while providing area for cart bypass or storage in close proximity to, but not blocking other cart train movements.

Similar to CBIS, BMU at BNA is divided into two locations - the north area under the Main Terminal and the south area under Concourse C, each connected to their respective CBIS system. At BNA, the Main (north) BMU area has four carousels for airlines to process their outbound baggage. Two of the carousels are dedicated to individual airlines (American, Delta), whereas the third and fourth carousels provides baggage makeup capability for all remaining airlines except Southwest, which is currently the sole user of the south (Concourse C) BMU. The practice of multiple airlines sharing one BMU carousel in the north BMU creates a less effective operating condition reducing the efficiency of the available area, and potentially jeopardizing the airport's ability to accommodate new or expanded air service. BMU configurations and expansion options will be evaluated in the Alternatives section.

Figure 4-18. Typical Baggage Makeup Device



Source: Airport Cooperative Research Program (ACRP) Report 25, "Airport Passenger Terminal Planning and Design Guidebook"

4.3.6.1. Key Assumptions

The demand for BMU area is primarily driven by the number of peak period departing flights, peak bag demand per flight, and the required number of carts to accommodate bag demand. Domestic and international flights are treated separately in this analysis because typically international flights are operated on widebody aircraft with more passengers and more checked bags, whereas domestic flights carry fewer passengers and a lower percentage of checked bags.

In the post-BNA Vision baseline condition, the north BMU area is 25,747 square feet and processes both domestic and international flights. The south BMU area is 28,508 square feet and processes domestic flights only.

Table 4-43 documents the key assumptions for the BMU analysis.

Table 4-42. BMU Key Assumptions

	Domestic Flights	International Flights
Load Factor[1]	82.6%	82.9%
Seats[2]	200	300
Checked bag per pax[3]	0.73	1
Bags per cart[4]	40	

Sources:
1. *BNA Master Plan Update 2018: Aviation Demand Forecasts Report*
2. *Conservative estimates about number of seats based on typical seat configurations on narrowbody and widebody aircraft*
3. *BNA Master Plan Update, Passenger Characteristics & Processing Times Data Collection DRAFT Report, June 2018*
4. *Airport Cooperative Research Program (ACRP) Report 25 "Airport Passenger Terminal Planning and Design Guidebook"*

Based on the key assumptions, the number of carts needed per flight is estimated for domestic and international flights as summarized in **Table 4-43.**

Table 4-43. Number of Carts Required per Flight

	Domestic Flights	International Flights
Average Passengers per Flight	165	249
Average Bags per Flight	121	249
Carts Required to serve each Flight	4	7

Source: AECOM Analysis.

The typical configuration requires an average area of approximately 620 square feet per baggage cart[2], which includes the makeup device, the work aisle for operators to load bags, the baggage train staging area by the device, bypass lanes, and additional baggage train circulation. However, at BNA, there is no bypass lane capability in the north (Main) BMU rooms for any of the four carousels, limiting the ability for cart storage and cart train circulation.

4.3.6.2. BMU Capacity

Based on the available square footage at each BMU area, the number of carts required to serve each flight, and the area required for each cart, it is estimated that:

- The north BMU area has a capacity to serve 9 domestic flights and one international flight simultaneously, which translates to a capacity of approximately 1,750 passengers.
- The south BMU area has a capacity to serve 12 domestic flights simultaneously, translating to 1,900 passengers.
- The total capacity of the baseline BMU facilities at BNA is 21 domestic flights, one international flight, and 3,650 passengers being processed at the same time.

[2] Area calculated based on standards provided in Airport Cooperative Research Program (ACRP) *Report 25 "Airport Passenger Terminal Planning and Design Guidebook"*

4.3.6.3. BMU Facility Requirements

Based on the peak hour enplanements and peak hour departure schedule, the facility requirements are estimated and summarized in **Table 4-44**.

Table 4-44. BMU Facility Requirements

		Facility Requirements			
	Baseline	2022	2027	2032	2037
Peak Hour Domestic Departures[1]	-	33	34	36	38
Peak Hour International Departures[1 (a)]	-	1	1	1	1
Total Carts at BMU area simultaneously	-	126	129	136	144
Total Area	**54,255**	**78,120**	**79,980**	**84,320**	**89,280**

Sources:
1. *BNA DDFS*

Note:
a. *Based on the DDFS, there is no international flight during the peak hour. This analysis takes a conservative approach to add in one international flight during the peak hour for estimation.*
b. *Red text indicates deficiencies.*

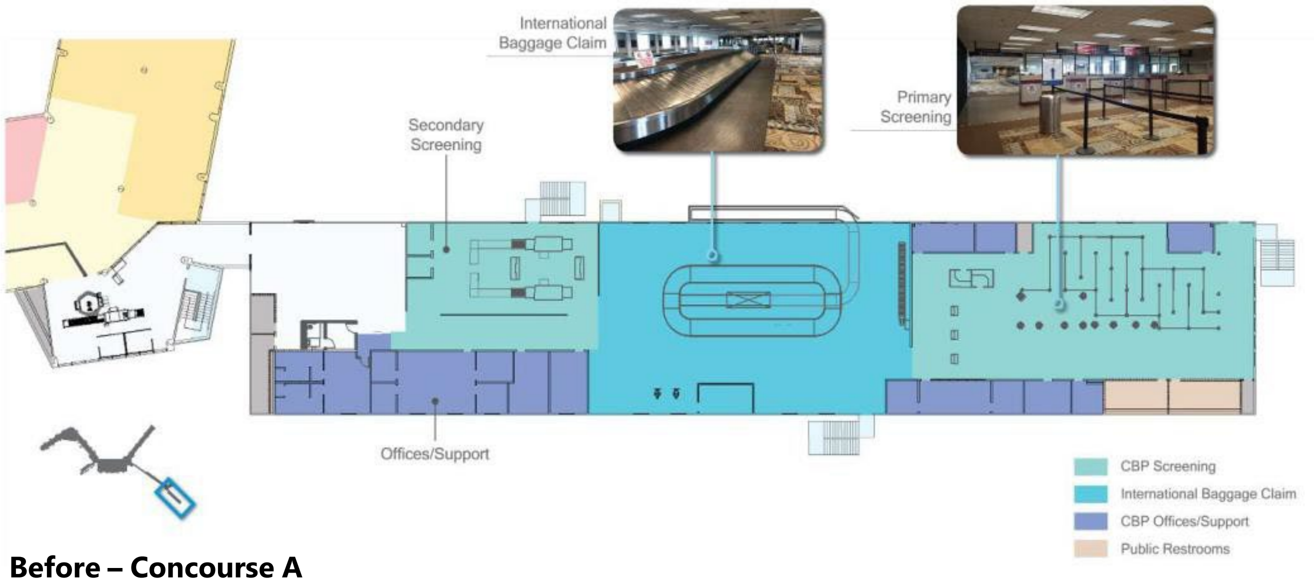
The existing BMU facilities, with an estimated total capacity to process 21 peak period departures, will require expansion in the near term (2022) to meet the required projected demand for 34 peak period departures. Through the planning period it is anticipated that an additional 34,000 square feet of BMU will be required.

4.3.7. Baggage Claim

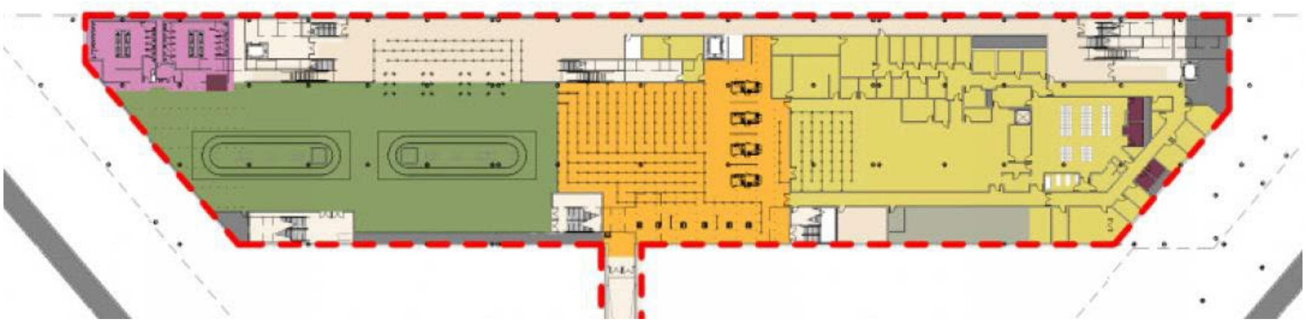
At the completion of BNA Vision, the baseline condition maintains the eight (8) existing baggage claim devices (although there are provisions to add presentation length, if needed), and an additional four (4) units are provided in the expanded domestic baggage claim hall. All of the baggage claim devices will be flat plate units designed in a "T" shape configuration. These units are manually fed from the secure baggage tug lanes on the same level.

As of early 2019 one baggage claim device is provided in the International Arrivals Building in Concourse A on Level 3, the Departures Level, as shown in **Figure 4-19**. However the BNA Vision baseline condition provides two baggage claim devices in the newly expanded international arrivals facility on Level 1 – below grade at the new central terminal area.

Figure 4-19. FIS before and after BNA Vision



Before – Concourse A



After – Main Terminal

4.3.7.1. Key Assumptions

Requirements for the baggage claim area were based on the peak period flight arrivals, first and last bag show-up on the claim device, and the number of bags per passenger. **Table 4-45** documents the key assumptions in this analysis.

Table 4-45. Bag Claim Key Assumptions

	Domestic Flights	International Flights
Load Factor[1]	82.6%	82.9%
Seats[2]	200	300
Ratio of Terminating Passenger[1]	88%	88%
Checked bag per pax[3]	0.73	1
Passengers Per Group[3]	1.5	
Percentage of Additional Passengers at the Claim[4]	30%	
Average Claim Device Occupancy Time[5]	20 ~ 25 mins	30 ~ 45 mins

Sources:
1. *BNA Master Plan Update 2018:Aviation Demand Forecasts Report*
2. *Conservative estimates about number of seats based on typical seat configurations on narrowbody and widebody aircraft*
3. *BNA Master Plan Update, Passenger Characteristics & Processing Times Data Collection DRAFT Report, June 2018*
4. *Airport Cooperative Research Program (ACRP) Report 25 "Airport Passenger Terminal Planning and Design Guidebook"*
5. *Typical observation in the industry and at BNA*

Typically, a flight will substantially clear (90 percent or more of bags and passengers have left the bag claim area) a bag claim device in 20 to 25 minutes for narrowbody aircraft (Boeing 737 and Airbus A320). Smaller aircraft will clear slightly quicker and widebody aircraft will take more time to clear the device. Typically an international flight or widebody aircraft will take 45 minutes. Based on site observations, airlines occasionally unload bags for multiple flights currently onto one claim device. Planning for the BNA Vision program assumed that it would be necessary in the future to change the use of the baggage claim devices from preferential use to common use in order to process the number of simultaneous peak period arrivals.

The Master Plan DDFS was used to identify peak hour flight arrivals used for bag claim requirements. The peak period for domestic arrivals and international arrivals are not coincidental and use separate baggage claim areas. The international baggage claim requirements will be discussed as part of the Federal Inspection Station (FIS) facility requirements.

4.3.7.2. Baggage Claim Capacity

Based on the assumption that each domestic baggage claim device will serve on average 2.5 to 3 flights during one hour, and all the domestic flights are performed on narrowbody aircraft at BNA, it is estimated that the twelve (12) baggage claim devices in the domestic baggage claim hall have a total capacity of serving between 4,360 to 5,230 terminating passengers. The projected 4,473 peak hour deplanements would indicate that the presentation length of the 12 devices would be adequate to accommodate the demand; however, there are 38 projected peak hour arrivals in 2037. Using the assumption of 3 arrivals per hour per device yields a requirement for 12.67 (13) devices needed by 2037.

Based on the assumption that each international baggage claim device will serve on average 1.5 to 2 flights during one hour, it is estimated that the two baggage claim devices in the international baggage claim hall have a total capacity of serving approximately a range of 570 to 870 terminating passengers.

4.3.7.3. Baggage Claim Facility Requirements

The resulting requirements for baggage claim devices and linear frontage are estimated based on peak hour deplaning passengers and arrival flights, as summarized in **Table 4-46**.

Table 4-46. Bag Claim Facility Requirements

		Facility Requirements			
	Baseline	2022	2027	2032	2037
Domestic Baggage Claim					
Peak Hour Domestic Deplanements[1 2 (a)]	-	3,391	3,725	4,080	4,473
Peak Hour Domestic Arrivals[1 2]	-	33	34	36	38
Estimated Passengers at Claim Devices During Peak 20 Minutes	-	824	905	992	1,087
Required Linear Frontage of the Claim Devices (feet)	**1,752**	1,236	1,358	1,487	1,631
Required Number of Claim Devices[(b)]	**12**	**11**	**12**	**12**	**13**

Sources:
1. *BNA Master Plan Update 2018: Aviation Demand Forecasts Report*
2. *DDFS*

Notes:
a. *Based on the DDFS, there is no international arriving flight during the peak hour. Therefore, the peak hour deplanements are all domestic passengers.*
b. *Based on the assumption that each domestic flight typically takes 20 minutes to clear the device.*
c. *The peak hour for international arrivals is not in the same peak hour with the domestic arrivals.*
d. *Based on the assumption that each international flight typically takes 30 minutes to clear the device.*
e. *Red text denotes deficiencies*

The requirements show that both domestic and international baggage claim devices have sufficient linear frontage to accommodate passengers waiting alongside the devices during the peak periods. However, if device sharing is not allowed between different flights (which means baggage from one flight must be totally cleared from a device before the next flight could occupy the device), the domestic baggage claim hall would need to install one additional baggage claim device by 2037.

It is recommended that sharing devices be allowed during the peak periods given that the linear frontage provided in the baseline condition is much higher than the required linear frontage, and that no additional claim devices are required in the domestic baggage claim hall to meet demand in the planning horizon.

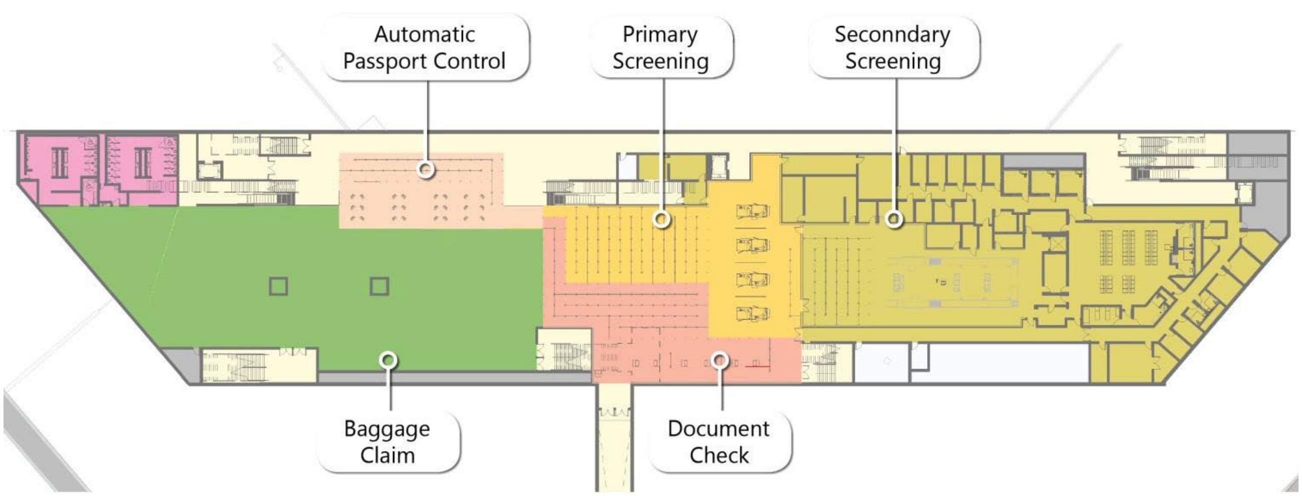
While it is typical for many of the airlines to use the same bag claim devices continually based on gates locations and operations, it is imperative that the baggage claim devices be available as common use facilities. A key assumption for BNA carried into this Master Plan analysis is that the baggage claim hall is completely common use.

The staging and queuing area in the baggage claim hall is key to the passenger experience. The staging and queueing area is defined as all the space allocated to the claim area, less the space the claim devices use and any offices, restrooms or cross circulation corridors. As indicated in the BNA Vision Facility Requirements Report, a LOS C goal was assumed in the baggage claim hall using 14 square feet per passenger. The baggage claim hall staging and queueing area is approximately 55,200 square feet. Based on the projected demand levels and anticipated meeter/greeter ratio, approximately 3,950 peak hour deplanements can be accommodated in the baggage claim hall staging and queuing area. Theoretically, this area should be adequate through 2027. Options will be evaluated in the alternatives phase to expand the staging and queuing areas to meet projected future demand.

4.3.8. Federal Inspection Services (FIS)

The Interim International Arrivals Building at Concourse A as of early 2019 is configured in a more traditional flow, in which passengers are processed through primary inspection counters first, proceed to collect their bags, and then exit the FIS or go through additional inspection at the secondary screening area. Comparatively, the new international arrival facility centrally located at the Main Terminal is designed with the most current Customs and Border Protection (CBP) design standard known as a "bag-first" process, in which the baggage collection and the primary inspection are reversed in order. **Figure 4-20** shows the different areas in the new BNA Vision FIS facility.

Figure 4-20. FIS Facility

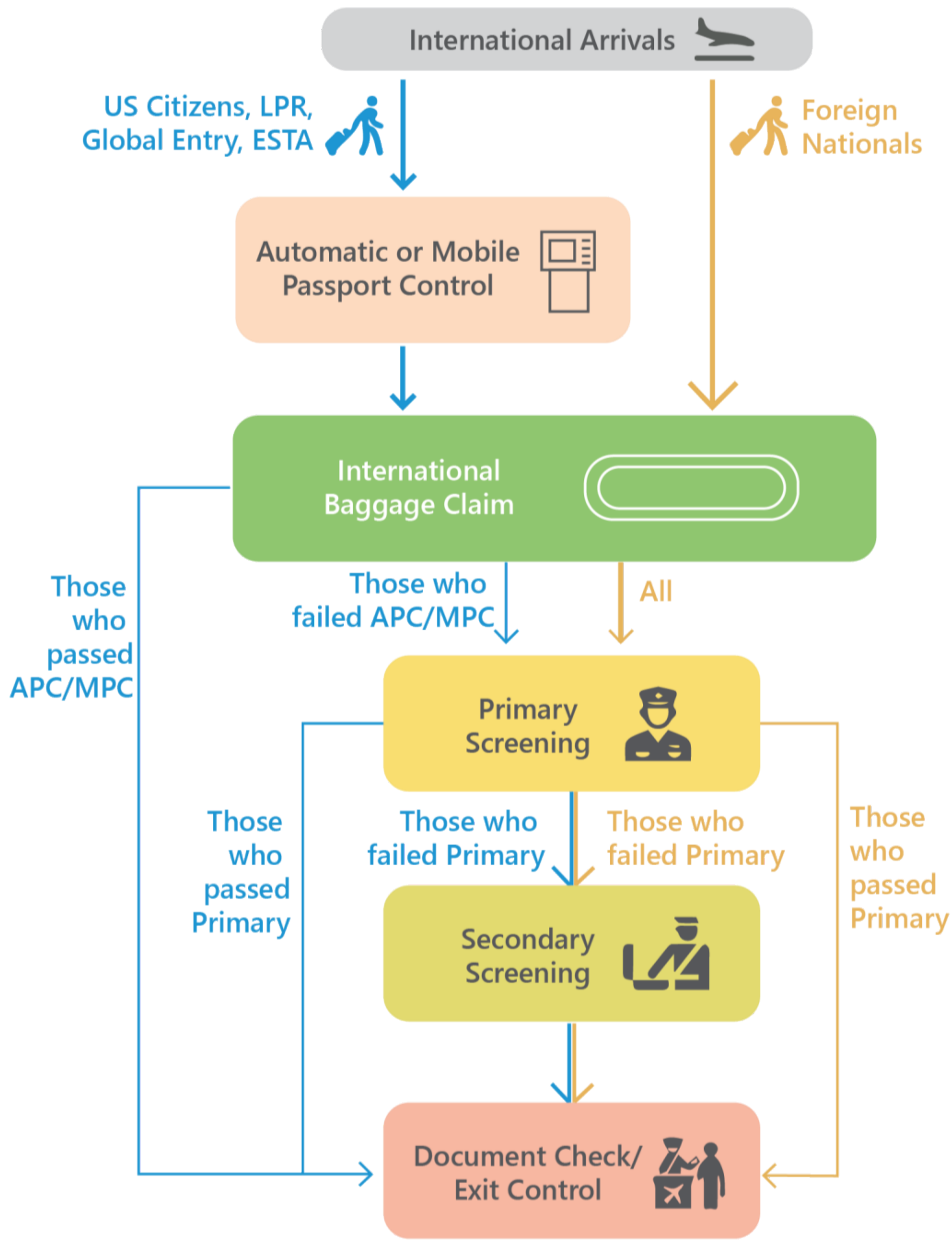


The general processing steps in the bag-first flow are depicted in **Figure 4-21** and explained as follows. The analysis model is established upon this processing procedure.

1. U.S. citizen, lawful permanent residents (LPR), Global Entry holders, and ESTA holders[3] go through the Automatic Passport Control (APC) kiosks first before collecting their bags from the claim devices. Those who fail to pass the APCs must enter a dedicated queue in the Primary Screening area to meet with a Passport Control agent from CBP; whereas those who passed the APCs proceed directly to the Document Check Podiums before exiting.
2. Mobile Passport Control (MPC) allows eligible passengers to use an online application form prior to arriving at a U.S. port of entry in lieu of using an Automated Passport Control kiosk in the FIS facility. The passenger path taken for MPC users is similar to those using an APC kiosk and is shown on **Figure 4-21**.
3. Foreign nationals cannot be processed through APC kiosks. Thus, they are directed to collect their bags first, and then proceed to the Primary Screening area to meet with the Passport Control agents.
4. Those who clear the inspection at Primary Screening can proceed to the Document Check Podiums before exiting the FIS.
5. A random number of passengers in the Primary Screening area could be directed to the Secondary Screening area for additional inspection of their documents and baggage.
6. Those who clear the Secondary Screening Area can then proceed to the Document Check Podiums and exit the FIS.

[3] The Electronic System for Travel Authorization (ESTA) is an automated system that determines the eligibility of visitors to travel to the United States under the Visa Waiver Program (VWP).

Figure 4-21. Bag-First Process



4.3.8.1. Key Assumptions

The baseline conditions for all the processing steps are summarized in **Table 4-47.** FIS Baseline Conditions

Table 4-47. FIS Baseline Conditions

	Number of Units[1]	Processing Area (s.f.)[2]	Queue Area (s.f.)[2]
Automatic Passport Control (APC)	24	1,580	980
Baggage Claim	2	13,240	n.a.
Primary Screening	8	2,870	2,340
Secondary Screening	2	2,760	1,430
Document Check Podiums	6	1,960	2,060

Sources:
1. *BNA Vision Bridging Document*
2. *BNA Vision Floor Plan Measurements*

Based on the bag-first processing flow explained in the previous section, several key assumptions are summarized in **Table 4-48** and used as input in the analysis. The key input factors include the percentage of passengers being processed through each step, the processing time per passenger, the area required for each processing unit, and the queue space required for each waiting passenger.

Table 4-48. FIS Key Assumptions

Key Input Factor	Unit	Assumption
APC Kiosk		
Percentage of Passengers Using APCs[1]	%	72%
Processing Time[1]	Seconds per passenger	123
Area required for one self-service APC[3]	Square feet	60
Queue Space (with no carts)[4]	Square feet per passenger	10.8
Primary Screening – Passport Control Desk		
Percentage of Passengers Going to Primary Screening[1]	%	42.4%
Processing Time[2]	Seconds per passenger	72
Area required for one booth[3]	Square feet	660
Queue Space (high percentage with carts) [4]	Square feet per passenger	21.5
Secondary Screening		
Percentage of Passengers Going to Secondary Screening[2]	%	10%
Processing Time[2]	Seconds per passenger	150
Area required for one X-ray Lane[3]	Square feet	680
Queue Space (high percentage with carts) [4]	Square feet per passenger	21.5
Exit Document Check Podium		
Percentage of Passengers Going Through Podium[1]	%	57.6%
Processing Time[1]	Seconds per passenger	24
Area required for one podium[3]	Square feet	230
Queue Space (high percentage with carts) [4]	Square feet per passenger	21.5

Sources:
1. *BNA Facilities Requirements Report, June 2017*
2. *Industry observations at other commercial airports*
3. *BNA Vision Floor Plan Dimensions. Circulation around the devices is included*
4. *IATA Airport Reference Development Manual (ADRM), 10th Edition*

4.3.8.2. FIS Capacity

Based on the number of units provided at each step, the processing time per passengers by each step, and several other key assumptions to allow for demand variability, the number of passengers the FIS facility can process during the peak hour were evaluated and summarized in **Table 4-49**. The total number of passengers that the FIS facilities can process during the peak hour is estimated to be approximately 800 when the BNA Vision International Arrivals Facility (IAF) is open for service.

Table 4-49. FIS Capacity

	Number of Units[1]	Number of Passengers Processed During Peak Hour[2]
Automatic Passport Control (APC)	24	610
Baggage Claim	2	875
Primary Screening	8	350
Secondary Screening	2	40
Document Check Podiums	6	610
Entire FIS Facility	n.a.	800

Sources:
1. *BNA Vision Bridging Document*
2. *AECOM Analysis*

4.3.8.3. FIS Facility Requirements

Based on the future DDFS, all international flights are projected to arrive during the same hour in the late afternoon in 30-minutes intervals. **Table 4-50** shows the projected number of international arrivals during the peak 30 minutes and the peak hour.

Table 4-50. DDFS - Peak Hour International Arrivals

		Peak Hour Flights			
Year	Baseline	2022	2027	2032	2037
Peak 30-Minutes International Arrivals	1	1	2	2	2
Peak Hour International Arrivals	1	1	2	2	2

Source: BNA DDFS

This analysis first seeks to accommodate international arriving passengers during the peak 30 minutes, given that the CBP has the capacity to clear these passengers during the 30 minutes and proceed to clear the next arriving flight. In case of flight delays, it is possible that all flights could be arriving during the same 30 minutes. Therefore, this analysis also seeks to accommodate all projected international arrivals in the peak 30 minutes to avoid congestion in the FIS hall caused by flight delays.

Table 4-51 summarizes the facility requirements as the number of flights increase during the peak 30 minutes. The processing area includes the area occupied by the APC units, CBP officers, and the circulation area surrounding them. This analysis indicates that number of APC processing units at each step is capable of handling two flights arriving during the same half hour, but additional units and processing areas would be required if three flights arrive during the same half hour. In contrast, the queue areas provided in the BNA Vision plan are larger than required even with three flights arriving during the same hour, especially in the Secondary Screening and Exit Document Check area. Therefore, the FIS facility as designed in BNA Vision provides flexibility to allow for possibly expanding the number of APC processing units into the available queue space.

Table 4-51. FIS Facility Requirements

	Baseline Conditions	Number of International Arrivals during Peak 30-Mins 1	2	3
APC				
Number of Units	24	11	22	33
Processing Area (s.f.)	1,580	800	1,600	2,390
Queue Area (s.f.)	980	460	920	1,370
Primary Screening				
Number of Units	8	4	8	12
Processing Area (s.f.)	2,870	1,320	2,640	3,960
Queue Area (s.f.)	2,340	540	1,080	1,610
Secondary Screening				
Number of Units	2	1	2	3
Processing Area (s.f.)	2,760	1,360	2,710	4,070
Queue Area (s.f.)	1,430	50	90	130
Exit Document Check Podium				
Number of Units	6	3	5	7
Processing Area (s.f.)	1,960	960	1,600	2,240
Queue Area (s.f.)	2,060	270	540	800
Baggage Claim				
Number of Units	2	1	2	3
Linear Frontage	330	101	310	446
Processing Area (s.f.)	13,240	4,060	12,420	17,900

Notes:

a. Red text indicates deficiency.

4.3.9. Holdrooms

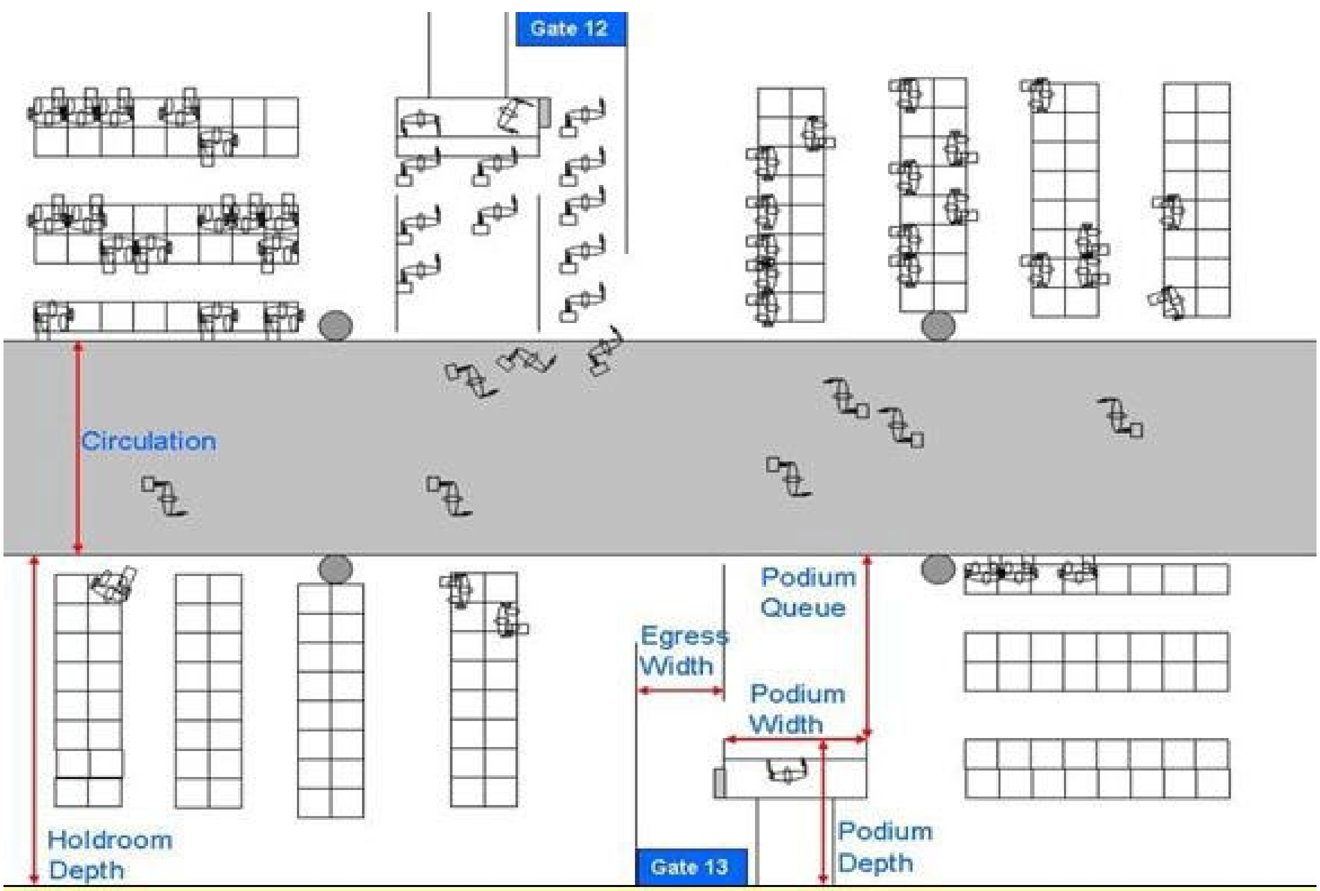
The holdrooms provide a waiting area for passengers prior to boarding an aircraft as well as airline agent customer service podium, boarding queues, circulation, and other amenities. The holdroom requirements in this analysis are based on the analytical approach provided in ACRP Report 25 which estimates the size of the holdrooms as a function of the dimension of different elements in the holdroom, the split of seated and standing passengers, allowance for amenities, and holdroom sharing conditions between adjacent gates.

The ACRP Report 25 method is based on an open-area gate concept (similar to BNA) which means holdrooms for adjacent gates are not blocked by walls and also have contiguous space with adjacent concessions space. Holdrooms in such an open environment typically require less space because passengers have the flexibility to seat themselves in the areas at adjacent gates or in the concession areas, as long as they can monitor the boarding process from their seated location. Based on the open-area layout, the holdroom analysis for BNA is performed by gate areas instead of gate-by-gate. Most of the gate areas include two or more gates.

4.3.9.1. Key Assumptions

Figure 4-22 shows a typical layout of holdrooms, which consists of passenger seating areas, gate podium area and queue space, boarding area in front of the gates, and general circulation area. Error! Reference source not found. provides a summary of the key assumptions used in this analysis based on this typical layout. This analysis estimates the size required for each gate area, based on the number of gates/flights each gate area serves concurrently, the number of passengers boarding these flights, the space needed to accommodate each seated/standing passenger, the space needed for the podium, and the space needed for the boarding lanes.

Figure 4-22. Typical Holdroom Layout



Source: Airport Cooperative Research Program (ACRP) Report 25 "Airport Passenger Terminal Planning and Design Guidebook"

Two additional factors are considered in this analysis:

- Many modern holdrooms provide additional space within the gate areas for children's play areas, work areas, or electronics charging stations. A small allowance is added to the space requirement to provide such amenities.
- In the open-gate layout, many holdrooms are often shared between two or more gates, which provide greater flexibility of use. A reduction factor is applied to account for this flexibility.

Table 4-52. Holdrooms Key Assumptions

Key Input Factor	Unit	Assumption
Typical Seats (Narrowbody) – Domestic[1]	Seats	200
Typical Seats (Widebody) – International[1]	Seats	300
Load Factor (Narrowbody) – Domestic[2]	%	82.6%
Load Factor (Widebody) – International[2]	%	82.9%
Percentage of Seated Passengers in the Holdroom[3]	%	70%
Percentage of Standing Passengers in the Holdroom[3]	%	10%
Required Space per Seated Passenger[4]	Square feet	18.3
Required Space per Standing Passenger[4]	Square feet	12.9
Podium Area		
Podium Width/Position[5]	Feet	12
Depth of Podium to back wall[5]	Feet	12
Podium Queue Depth[5]	Feet	14~18
Area per Podium Position[5]	Square feet	312~360
Boarding Lanes		
Boarding Corridor Width[5]	Feet	10
Depth of Holdroom[5]	Feet	26~30
Boarding/ Egress Corridor per Bridge (sq. ft.) [5]	Square feet	260 ~300
Additional Factors		
Allowance for Amenities (Increase)[6]	%	5%
Holdroom Sharing Factor (Decrease)[6]	%	15%

Sources:
1. *Conservative estimates about number of seats based on typical seat configurations on narrowbody and widebody aircraft*
2. *BNA Master Plan Update 2018: Aviation Demand Forecasts Report*
3. *BNA Vision Bridging Document, Aircraft Holdroom Sizing Studies.*
4. *IATA Airport Reference Development Manual (ADRM), 10th Edition*
5. *BNA Vision Floor Plan Measurements*
6. *Airport Cooperative Research Program (ACRP) Report 25 "Airport Passenger Terminal Planning and Design Guidebook"*

4.3.9.2. Holdroom Capacity

Table 4-53 shows the capacity of each holdroom in terms of number of passengers to accommodate and number of flights to serve concurrently. The analysis indicates that except for the newly designed D gates and T gates, most of the holdrooms are too small to concurrently serve all the gates in each gate area. For these holdrooms it is important to avoid scheduling flights at all the gates in the same gate area concurrently.

Additional relievers to stretch holdroom capacity could be reconfiguring the holdrooms for narrower boarding lanes, smaller podium area, and tighter seating areas. However such reconfigurations will inevitably compromise the level of service.

Table 4-53. Holdroom Capacity

Gate Areas	Baseline Conditions - Area Size (s.f.)	Number of Passengers Each Area can Accommodate Concurrently	Number of Flights Each Area can Accommodate Concurrently[a]	Total Gates on Plan
Concourse A			Narrowbody	
Gate A5, A6	5,730	354	2	7
Gate A3, A4	2,728	117	1[b]	
Gate A1, A2	3,250	158	1	
Concourse B			Narrowbody	
Gate B3, B5	8,059	539	3	10
Gate B7	2,052	113	1[b]	
Gate B9, B11, B13, B12, B10	7,123	314	2	
B6, B8	3,730	195	1	
Concourse C			Narrowbody	
Gate C4	2,988	184	1	19
Gate C7, C9	4,731	269	2[c]	
Gate C6, C8	4,770	271	2[c]	
Gate, C10, C11, C12, C13, C14	10,696	581	3	
Gate C15, C17	3,631	181	1	
Gate C16, C18	4,828	275	2[c]	
Gate C19, C20, C21, C22, C25	10,114	535	3	
Concourse D			Narrowbody	
Gate D1, D2, D3	9,787	617	3	6
Gate D4, D5, D6	10,264	655	4	
Main Terminal			Narrowbody (Widebody)	
Gate T1, T2, T3, T4, T5, T6	22,160	1,396	8(6)	6 (3)

Notes:

a. *The numbers accounted for load factors on each flight*
b. *The gate area is very tight to accommodate all the passengers on one narrowbody flight*
c. *The gate area is very tight to accommodate all the passengers on two narrowbody flights concurrently*
d. *Red text indicates deficiencies.*

4.3.9.3. Holdroom Space Requirements

The holdroom space requirements analysis was performed to determine expansion required to maintain the optimal level of service in the holdrooms, if the airport were to provide unconstrained operational flexibility to schedule flights at all gates at any time. **Table 4-54** and **Figure 4-23** summarize the total area required for each gate area. Similar to the capacity analysis, except for the newly designed D gates and T gates, most of the gate areas are undersized and would require expansion or other innovative solutions in order to serve all projected gate demand. Any additional gates and/or new concourse(s) proposed for the Master Plan will also be subject to the same design criteria so that holdrooms are sufficiently sized to allow for unconstrained operational flexibility.

Table 4-54. Holdroom Facility Requirements

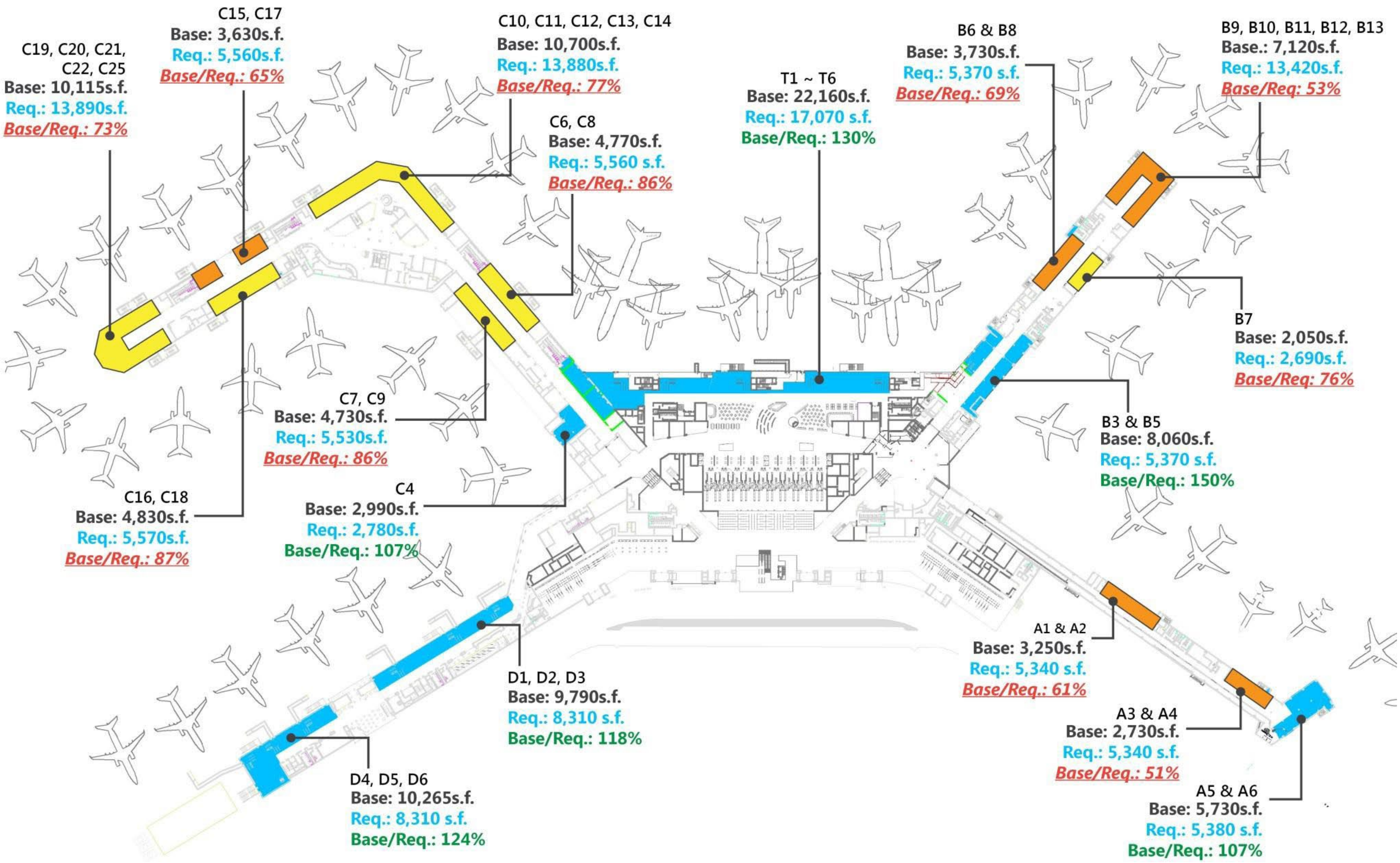
Gate Areas	Baseline Conditions - Area Size (s.f.)	Adjusted Seated & Standing Area (s.f.)	Boarding Lane (s.f.)	Podium Area (s.f.)	Total Area (s.f.) [a]	Baseline Area/ Total Area
Concourse A						
Gate A5, A6	5,730	4,158	555	666	5,380	107%
Gate A3, A4	2,728	4,158	535	642	5,340	51%
Gate A1, A2	3,250	4,158	535	642	5,340	61%
Concourse B						
Gate B3, B5	8,059	4,158	550	660	5,370	150%
Gate B7	2,052	2,079	275	330	2,690	76%
Gate B9,B11,B13,B12,B10	7,123	10,395	1375	1650	13,420	53%
B6,B8	3,730	4,158	550	660	5,370	69%
Concourse C						
Gate C4	2,988	2,079	315	378	2,780	107%
Gate C7, C9	4,731	4,158	621	745	5,530	86%
Gate C6, C8	4,770	4,158	636	763	5,560	86%
Gate, C10, C11, C12, C13, C14	10,696	10,395	1581	1897	13,880	77%
Gate C15,C17	3,631	4,158	633	760	5,560	65%
Gate C16,C18	4,828	4,158	641	769	5,570	87%
Gate C19,C20,C21,C22,C25	10,114	10,395	1,587	1,904	13,890	73%
Concourse D						
Gate D1, D2, D3	9,787	6,237	941	1129	8,310	118%
Gate D4,D5, D6	10,264	6,237	941	1129	8,310	124%
Main Terminal						
Gate T1,T2,T3, T4, T5, T6 (Widebody Configuration)	22,160	9,389	1214	1080	11,690	190%
Gate T1,T2,T3, T4, T5, T6 (Narrowbody Configuration)	22,160	12,474	2428	2160	17,070	130%

Notes:

a. Numbers rounded up to the nearest tenths.

b. Red text indicates facility deficiencies.

Figure 4-23. Holdroom Facility Requirements



4.3.10. Concessions

Concessions space planning is important to the overall terminal program because of its impact on airport revenues as well as passenger convenience/satisfaction. Concessions programs are such a specialized aspect of terminal facility needs, that a more refined detailed analysis is typically conducted by a firm specializing in concessions programming and planning. For master planning purposes, the primary goal is to identify existing and potential issues and recommend general programming needs based on industry guidelines. This section evaluates the overall concession space throughout the entire terminal complex and how it is allotted.

4.3.10.1. Key Assumptions

Concessions are provided both prior to and after the SSCP (pre-security and post-security). The total concessions area in the baseline condition amounts to 123,273 square feet according to the BNA Vision floor plans. The standard metrics recommended for benchmarking concession space are based on annual enplanements, in multiples of one thousand. IATA specifies that the typical concession spaces (per 1,000 enplaned passengers) should range from 8.6 square feet to 16.1 square feet.

It is also assumed that the types of concessions at BNA will be split as indicated in **Table 4-55**. The breakdown percentage is based on general concession planning parameters identified in the IATA ADRM as well as local characteristics at BNA.

Table 4-55. Concession Type Split

Type of Concession	Percentage
Duty-Free	5%
Specialty Retail, Duty Paid	35%
Convenience Retail	10%
Food and Beverage	45%
Personal or Business Services	5%
Total	**100%**

4.3.10.2. Concessions Capacity

Table 4-56 summarizes the range of concessions capacity in terms of annual enplanements and total passengers, based on the varying concessions space requirements per 1,000 enplaned passengers. Given the 123,273 square feet of concessions space throughout the passenger terminal, the annual total passenger capacity ranges from 15.3 MAP to 28.7 MAP, depending on the space provided per 1,000 enplaned passengers.

Table 4-56. Concession Capacity

	8.6 SF/1,000 Enplaned Pax	12.4 SF/1,000 Enplaned Pax	16.1 SF/1,000 Enplaned Pax
Existing/Proposed Area (sf)		123,273	
Annual Enplaned Passengers Capacity	14,334,070	9,981,619	7,656,708
Annual Total Passenger Capacity	28.7 MAP	20.0 MAP	15.3 MAP

Source: AECOM Analysis.

4.3.10.3. Concessions Facility Requirements

For the purposes of this concessions requirements analysis, the midpoint of the IATA ADRM recommended range was used to evaluate concessions facility requirements. Based on the assumption of providing 12.4 square feet for every 1,000 enplaned passengers, **Table 4-57** summarizes the facility requirements for total concessions area, as well as a breakdown for the space required for each type of concessions. The total concessions area will become deficient beyond 2027 and could be expanded.

Table 4-57. Concession Facility Requirements

		Future Number of Flights			
	Baseline	2022	2027	2032	2037
Annual Enplaned Passengers[1]	7,076,371 (2017)	9,047,142	9,938,318	10,886,036	11,935,070
Total Required Area for Concessions (s.f.)[(a)]	123,273	112,200	123,250	135,000	148,010
Concession Space Split					
Duty-Free	n.a.	5,610	6,170	6,750	7,410
Specialty Retail, Duty Paid	n.a.	39,270	43,140	47,250	51,810
Convenience Retail	n.a.	11,220	12,330	13,500	14,810
Food and Beverage	n.a.	50,490	55,470	60,750	66,610
Personal or Business Services	n.a.	5,610	6,170	6,750	7,410

Source:
1. *BNA Master Plan Update 2018: Aviation Demand Forecasts Report*

Notes:
a. *Numbers rounded up to the nearest tenths.*
b. *Red text indicates facility deficiency.*

4.3.11. Restrooms

Often the customer comments that airports receive relate to the convenience, location, design, and cleanliness of public restrooms in the terminal. According to the ACRP Report 130, *Guidebook for Airport Terminal Restroom Planning & Design*, the unique considerations of airport terminal restrooms include continuous availability and operation, changing passenger demographics, evolving customer expectations, and greater space requirements to accommodate luggage and operational/maintenance needs. As part of the BNA Vision program, an extensive analysis was conducted of restrooms to determine fixture count requirements and optimum location. The BNA Vision analysis was used as the basis for the Master Plan restroom requirements analysis.

4.3.11.1. Key Assumptions

Public restrooms at BNA are located both before and after security. Each public restroom module consists of a male, female, and family/assisted facility. The module should be located so that maximum walking distance is 250-feet or essentially 500-feet between modules. Restroom modules range in size from 1,500 square feet to 2,200 square feet depending on the number of fixtures to be accommodated. **Table 4-58** provides a baseline condition inventory of the restroom facilities provided at BNA in terms of number of fixtures and modules in different terminal areas.

Table 4-58. Restroom Baseline Conditions

	Number of Modules	Total Male Fixtures	Total Female Fixtures
Secure Area			
Concourse A	2	25	28
Concourse B	3	26	22
Concourse C	4	52	70
Concourse D	3	20	24
Main Terminal	2	18	20
FIS Facility	1	10	12
Non-secure Area			
Departures Floor	4	37	29
Arrivals Floor	4	25	32

Source: BNA Vision CAD floor plans

The capacity and facility requirements analysis for the public restrooms is performed in accordance with the methodologies and guidelines in the ACRP Report 130, *Guidebook for Airport Terminal Restroom Planning & Design*. **Table 4-59** summarizes the key assumptions used in this analysis. Also the following principles are followed in the calculation:

- The restroom requirements for the secure area are based on the number of enplaning and deplaning passengers.
- The restroom requirements for the non-secure area account for the additional needs from well-wishers who send off enplaning passengers and the meeters/greeters who wait for the deplaning passengers.
- For the non-secure area, one male fixture should be provided per 70 peak hour passengers for the first 400 passengers, and one male fixture per 200 peak hour passengers in excess of 400 passengers.
- A female increase factor is applied to the analysis as recommended in the ACRP report.

Table 4-59. Restroom Key Assumptions

Key Input Factor	Unit	Assumption
Typical Seats (Narrowbody) – Domestic[1]	Seats	200
Typical Seats (Widebody) – International[1]	Seats	300
Load Factor (Narrowbody) – Domestic[2]	%	82.6%
Load Factor (Widebody) – International[2]	%	82.9%
Percentage of Male Passengers[3]	%	50%
Percentage of Passengers during Peak 20 minutes[3]	%	50%
Percentage of Passengers Using Restroom[3]	%	50%
Female Increase Factor[3]	n.a.	1.5
Increase Factor for Well-Wishers[3]	%	20%

Key Input Factor	Unit	Assumption
Increase Factor for Meeters & Greeters[3]	%	30%

Sources:
1. *Conservative estimates about number of seats based on typical seat configurations on narrow body and wide body aircraft*
2. *BNA Master Plan Update 2018: Demand Forecast Report*
3. *ACRP Report 130, Guidebook for Airport Terminal Restroom Planning & Design*

4.3.11.2. Public Restroom Capacity

Based on the methodology specified in ACRP Report 130, the number of passengers that the restrooms in each terminal area could accommodate during the peak 20 minutes was estimated and summarized in **Table 4-60**.

Table 4-60. Public Restroom Baseline Inventory

	Total Male Fixtures	Total Female Fixtures	Passengers Accommodated During the Peak 20-Minutes[(a) (b)]
Secure Area			
Concourse A	25	28	650
Concourse B	26	22	676
Concourse C	52	70	1,352
Concourse D	20	24	520
Main Terminal	18	20	468
FIS Facility	10	12	260
Non-secure Area			
Departures Floor	37	29	1,387
Arrivals Floor	25	32	819

Notes:
a. *The numbers only account for passengers who have the need to use the restroom facility during the peak 20 minutes.*
b. *The total number of passengers for the secure area and non-secure are not provided because the peak 20-minutes happen at different times during the day in different terminal areas.*

4.3.11.3. Public Restroom Facility Requirements

This restroom requirements analysis for the secure-side facilities is based on a conservative scenario assuming all gates are occupied by flights during the same hour. This scenario would result in the maximum number of passengers in the concourses and secure portion of the terminal. **Table 4-61** summarizes the number of fixtures required for each concourse, the FIS and the post-security screening portion of the terminal.

Overall, the public restrooms post-security screening and the FIS meet and exceed the facility requirements in terms of total number of fixtures. And, each restroom module is well within the maximum 250-foot walking distance criteria. Any new restroom modules added in the alternative's analysis should be sized and located using the same criteria.

Table 4-61. Public Restroom Facility Requirements in Secure Area

	Number of Gates	Total Seats	Total Passengers (a)	Peak 20-minute Passengers(b)	Peak 20-min Passengers Using Restrooms(c)	Required Male's Fixtures	Required Female's Fixtures
Concourse A	7	1,400	1,157	579	290	12	18
Concourse B	10	2,000	1,652	826	413	16	24
Concourse C	19	3,800	3,139	1,570	785	31	47
Concourse D	6	1,200	992	496	248	10	15
Main Terminal	6 (NB)	1,200	992	496	248	10	15
FIS	3 (WB)	900	747	374	187	8	12

Notes:

a. *After accounting for load factors*
b. *Assuming 50% of peak hour passengers concentrate in the peak-20 minute*
c. *Assuming 50% of passengers use the restrooms*

Table 4-62 summarizes the number of fixtures required in the non-secure area based on the peak hour enplanements for the departures level and peak hour deplanements for the arrivals level. It is noteworthy that the number of female's fixtures provided on the departures level is lower than that of male's fixtures, which will result in a deficiency based on projected activity levels. The arrivals level will observe deficiency in both male's and female's fixtures. In the baseline condition, all the non-secure restrooms are also within the maximum walking distance from one another. Some smaller modules only have three fixtures per gender. The non-secure restrooms need to be expanded to accommodate the projected future demand and also meet the minimum fixtures per module requirements.

Table 4-62. Public Restroom Facility Requirements in Non-Secure Area

	Baseline Conditions	2022	2027	2032	2037
Departures					
Peak Hour Enplanements	n.a	3,118	3,425	3,752	4,114
Design Demand (after accounting for well-wishers)	n.a	4,054	4,453	4,878	5,349
Required Male's Fixtures(a)	25	24	26	29	31
Required Female's Fixtures(b)	32	36	39	44	47
Arrivals					
Peak Hour Deplanements	n.a	3,391	3,725	4,080	4,473
Design Demand (after accounting for Meeters/Greeters)	n.a	4,070	4,470	4,896	5,368
Required Male's Fixtures(a)	37	25	27	29	31
Required Female's Fixtures(b)	29	38	41	44	47

Notes:

a. *1 fixture per 70 peak hour passengers for first 400 passengers + 1 fixture per 200 peak hour passengers in excess of 400 passengers*
b. *Accounting for the female increase factor of 1.5.*
c. *Red text denotes deficiencies*

4.3.12. Supporting Functions

4.3.12.1. Airport Support

This functional category includes a number of spaces such as administrative offices, Welcome Centers/Information desks, United Service Organizations (USO), Airport Operations and Maintenance, etc. **Table 4-63** provides the baseline conditions for the airport support areas. Based on discussions with airports, these spaces are typically increased by 15% to 20% over the entire planning period. **Table 4-64** summarizes the required area for airport support functions in a range based on 15% to 20% over the planning period.

Table 4-63. Airport Support Baseline Conditions

Baseline Airport Support Areas	Non-Secure Area (s.f.)	Secure Area (s.f.)	Total (s.f)
Level 1 – Ground Transportation	99	5,761	5,860
Level 2 – Arrivals	2,764	15,677	18,441
Level 3 – Departures	8,076	4,346	12,422

Source: AECOM Analysis.

Table 4-64. Airport Support Facility Requirements

Required Airport Support Areas	Non-Secure Area (s.f.)	Secure Area (s.f.)	Total (s.f)
Level 1 – Ground Transportation	120 ~ 150	6,630 ~ 7,960	6,740 ~ 8,090
Level 2 – Arrivals	3,180 ~ 3,820	18,030 ~ 21,640	21,210 ~ 25,460
Level 3 – Departures	9,290 ~ 11,150	5,000 ~ 6,000	14,290 ~ 17,150

Source: AECOM Analysis.

4.3.12.2. Airline Support

Airline support areas are typically airline operations spaces associated with gate operations, pilot lounges, operations and administrative space, janitorial spaces, etc. Airlines vary significantly in terms of the way they operate and thus the amount of space they need. For a master plan level analysis, a per-gate square footage factor is used to estimate how much additional airline support space is needed when the number of gates increases.

Table 4-65 summarizes the airline support areas in the baseline condition. Due to the nature of airline support operations, all the areas are post-security, and the majority of the airline support areas are on the arrivals/apron level to support apron activities of servicing the aircraft.

Table 4-65. Airline Support Baseline Conditions

Baseline Airline Support Areas	Secure Area (s.f.)
Level 1 – Ground Transportation	363
Level 2 – Arrivals	63,711
Level 3 – Departures	3,965
Total	**68,039**

Source: AECOM Analysis.

The baseline condition provides 48 gates in total; therefore the airline support areas at BNA are approximately 1,420 square feet per gate. **Table 4-66** shows the growth requirement in airline support space as the number of gates increases through the planning horizon.

Table 4-66. Airline Support Facility Requirements

Year	Baseline Conditions	2022	2027	2032	2037
Number of Gates (Low Range)	48	48	51	53	54
Number of Gates (High Range)		56	58	60	61
Required Airline Support Areas (Low Range)	68,039	68,160	72,420	75,260	76,680
Required Airline Support Areas (High Range)		79,520	82,360	85,200	86,620

Source: AECOM Analysis.

4.3.12.3. Mechanical/Communications/Electrical

Mechanical, electrical, plumbing (MEP) and communications functional areas in a Master Plan are typically calculated based on the percentage of total building functional spaces. The functional areas include rooms for air distribution systems and controls, electrical panel closets, plumbing chases, and communications equipment rooms and closets. At macro level programming and planning the requirement for the functional spaces for BNA ranges from 10% to 15% of total building functional requirements. Additional functional areas required should include, as a guide, an allowance for up to 15% to account for MEP and communications areas.

4.3.12.4. Other Miscellaneous Space Needs

Similar to MEP and communications functional areas, other miscellaneous space needs are represented as a percentage of total building functional spaces. The category accounts for building structure, vertical circulation, and allowances for design variations. This category of spaces and requirements associated can vary dramatically and typically is provided during more detailed terminal programming stages. At this macro level of planning for BNA, the following range of percentages was assumed:

- Building structure, 8% to 12%
- Vertical circulation, 9% to 13%
- Allowance for design variations, 5% to 7%

Additional functional areas required should include, as a guide, an allowance for the upper range of these categories to account for building structure, vertical circulation, and design variations.

4.3.13. Terminal Facility Requirements Summary

- Check-In Facilities:
    - Adjust allocation of check-in methods throughout the planning period to maximize available terminal space (i.e. use of more self-serve kiosks and bag drop positions might lessen need for additional full-service counter positions to avoid ticketing expansions)
- SSCP:
    - Meet TSA checkpoint design standards to maximize throughput
    - Enlarge the queue area
    - Add one additional lane by 2037
    - Convert some standard lanes to Pre-check lanes to absorb increasing demand from projected pre-check passengers
- CBIS:
    - One additional EDS machine by 2037 and enlarged CBIS area
- BMU:
    - Requires expansion by 2022
- Domestic Baggage Claim:
    - Requires one additional claim devices by 2037
- FIS:
    - The new IAF has the capacity to process two international arrivals during the peak 30-mins, but all functional areas would require expansion IF the number of peak hour arrivals reach 3
- Holdrooms:
    - Most of Concourse A, B, and C holdrooms require expansion; BNA Vision "T" gates and Concourse D gates have sufficient holdrooms. Any additional gates should be designed with adequate holdroom space
- Concessions:
    - Concessions areas require expansion by 2032
- Restrooms:
    - Restrooms in the secure area are adequate, whereas those in the non-secure area (departures hall and domestic baggage claim) require expansion in both male and female fixtures
- Supporting functions:
    - Airport support and airline support require expansion to support the growing demand from other functional areas

4.4. Landside Capacity & Requirements

This Section presents requirements for key on-Airport ground access and parking facilities and describes data sources, assumptions, and key elements of the methodology. Facilities addressed in this chapter include on-airport roadways, terminal curbsides, commercial ground transportation and public transit facilities, public and employee parking, and rental car facilities. Requirements are based on a capacity analysis of existing facilities (as of October 2018) and capacity estimates determined in 2016 and 2017 as part of BNA Vision planning and programming efforts.

The data used in the BNA Vision analyses has been updated to reflect more recent passenger activity as described Chapter 3, *Aviation Demand Forecasts* (the Forecast). For facilities not specifically addressed in BNA Vision, such as valet and employee parking, requirements are based on conditions observed in 2018 and early 2019. Facility requirements correspond to the following planning activity levels:

- Baseline (2017 activity): 7.1 million annual enplaned passengers (MEP)
- Updated Baseline (2018 activity): 8.0 million MEP
- Planning Activity Level (PAL) 1 (2022): 9.05 MEP
- PAL 2 (2027): 9.9 MEP
- PAL 3 (2032): 10.9 MEP
- PAL 4 (2037): 11.9 MEP

4.4.1. Data Sources

Data collected, assembled, and used for the analysis of ground access and parking requirements include:

- Monthly passenger enplanements from January 2010 through October 2018
- Hourly parking occupancy data for October 2017 and October 2018 for the Terminal Garage, Terminal Lot A, Economy Lot B, and Economy Lot C
- Hourly vehicle pickups and drop-offs for Valet Parking facility for October 2018
- Daily Valet Parking and BNA Express overnight vehicle counts for October 2018 and October 2017

- Transportation Network Company (TNC) pickup and drop-off transaction records for August 2018, monthly pickup volumes for October 2014 through October 2018, and monthly drop-off volumes for December 2014 to October 2018
- Monthly taxicab pickup volumes for October 2014 through October 2018
- Monthly rental car contracts and rental days for January 2010 through September 2018
- Surveys of rental car operators regarding existing and anticipated future facility needs and fleet size and operating characteristics
- Peak accumulation counts for the Employee Parking Lot in summer and winter 2018/2019
- Hourly entry and exit volumes for employees parking in the Employee Parking Lot and Economy Lot C for July through November 2018
- Number of employee access cards and associated spaces in each employee parking facility in the fall of 2018

In addition, the analysis of facility requirements incorporated data and findings developed as part of the BNA Vision Plan, including the following:

- *Basis of Design Report, Terminal Area Parking Garage*, prepared by Atkins and Walker Consultants
- *Technical Memorandum: Analysis of Landside Roadway System Configurations to Compliment the Donelson Pike Realignment Project*, prepared by Atkins
- *June 2018 Parking Demand Analysis*, prepared by Walker Consultants
- *Roadway Analyses, Curbside Analyses, and Ground Transportation Center Program*, prepared by Inter*VISTAS* in September 2017

4.4.2. Activity Growth/Mode Share Assumptions

Traditionally, airport master plans have projected ground transportation and parking facility requirements by assuming that demand would change in direct proportion with changes in originating and terminating passengers. This Master Plan, however, cannot rely solely on that traditional approach. Since the introduction of Transportation Network Company (TNC) services at the Airport in 2014, passenger use of TNCs has increased significantly while demand (on a per-passenger basis) for public parking, rental cars, and taxicabs has declined. Given the increasing trend in TNC popularity, it is projected that airport passengers will rely less on public parking, rental cars, and taxicabs in favor of TNCs and other technologies that are expected to reduce demand for traditional airport access and parking. While the specific timing and impact of these emerging technologies on facility planning cannot be predicted, activity growth assumptions presented in this Section project continued growth in total demand for public parking facilities, but at a declining rate in demand for public parking, rental cars, and taxicabs *on a per passenger basis*.

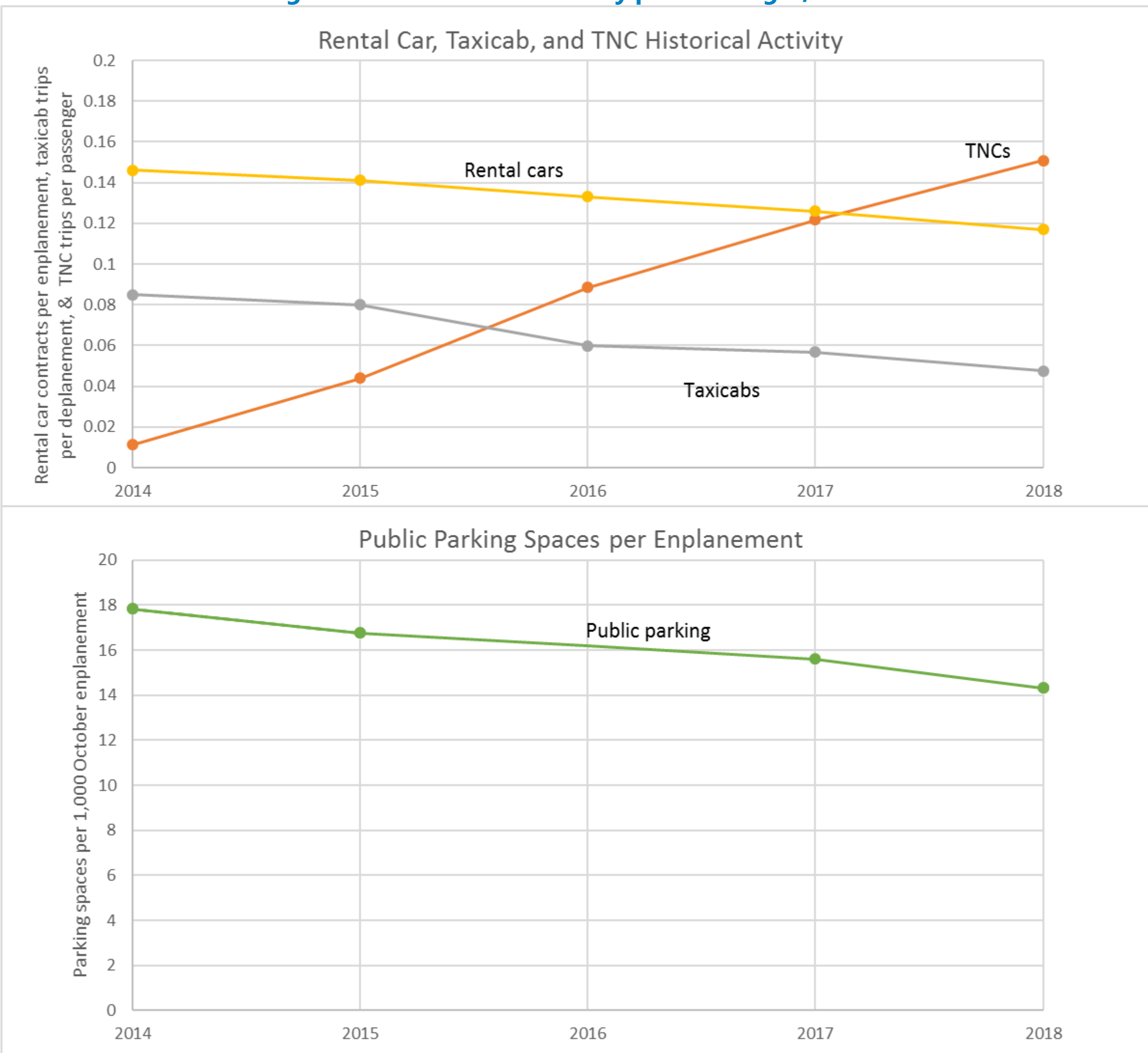
It is also expected that demand for public parking, rental car, and taxicab facilities could be affected by emerging technology improvements such as "car sharing" and "autonomous vehicles". Car sharing is a trend that relies on peer-to-peer car sharing (i.e., Turo) and/or subscription-based shared fleets (such as ZipCar), and less on personally-owned automobiles. Customers of these services would likely choose a vehicle near their point of origin within the region (i.e., home or business), drive to the airport, and drop the vehicle off at a designated location on or near the airport. Upon their return, they would pick up a vehicle at the designated location on or near the airport and drive it to a location near their destination within the region.

Through the planning period, a share of vehicles in the general fleet will likely be autonomous. While it may take several years for these vehicles to comprise a significant share of the fleet, it appears likely that over time, they could reduce demand for airport parking and/or rental cars due to their ability to travel unoccupied to off-airport locations. In the event they cannot (or are not permitted to) travel unoccupied, it appears likely that the early adopters of autonomous vehicles will be TNCs (due to goals of reducing driver costs), rental car companies (due to rapid fleet turnover), and car-sharing services (due to ability to disperse higher vehicle costs among multiple subscribers). Given that TNCs and rental car companies serve significant shares of airport customers, autonomous vehicles are likely to either reduce demand for airport parking and rental cars by themselves or increase the popularity of other services that, in turn, would reduce demand for airport parking and rental cars.

4.4.2.1. Recent Historical Trends

Figure 4-24 summarizes historical demand levels, on a per-passenger basis, for rental cars, taxicabs, TNCs, and public parking for the month of October in 2014 through 2018. The rental car values reflect the number of contracts per enplaning passenger; taxicab values reflect the number of pickups per deplaning passenger; and TNC values reflect total drop-offs and pickups per total passengers. The public parking values reflect the ratio of the number of occupied spaces during a typical busy day to the monthly enplanements, expressed as a number of spaces per 1,000 monthly enplaning passengers.

Figure 4-24. Historical Activity per Passenger, Selected Modes



Source: InterVISTAS, from data provided by MNAA.

As shown, since their introduction in 2014, TNC trips per passenger have increased steadily from near 0 in 2014 to over 0.15 in 2018. Over the same period, rental car transactions per enplanement have decreased by 0.146 to 0.117 (a 20% reduction); taxicab trips per deplanement have decreased from 0.085 to 0.048 (a 44% reduction); and public parking spaces per 1,000 monthly enplanements have decreased from 17.8 to 14.3 (a 20% reduction). The reduction in rental car, taxicab, and public parking demand appears to be predominantly due to increased use of TNCs, as they appear to have also attracted customers who previously used other modes, but reductions in public parking could also be due to recent changes in the mix of resident versus visiting passengers.

4.4.2.2. Future Mode Share Projections

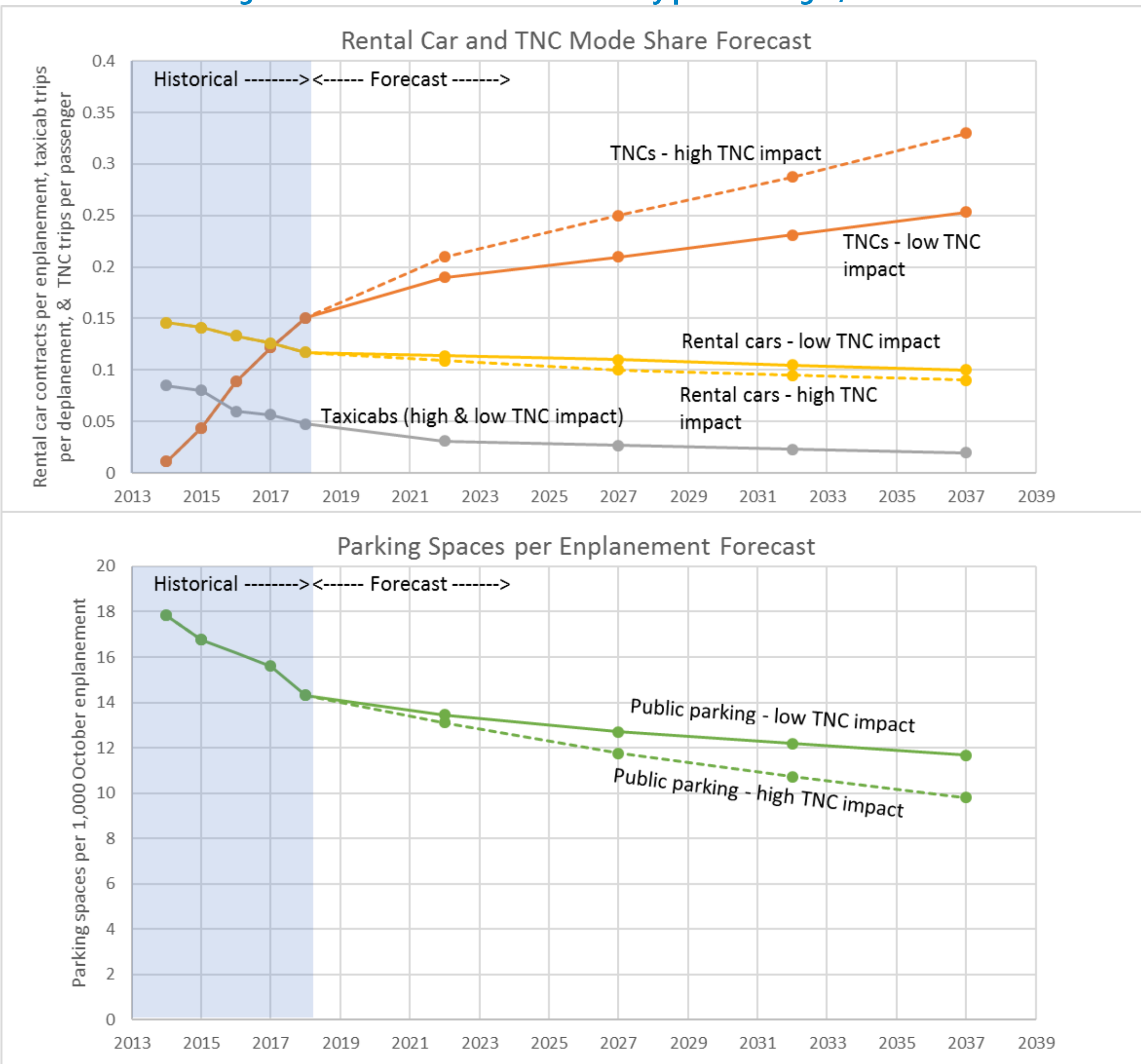
Given the significant and sudden change in passenger mode choice at the Airport since 2014, it is difficult to estimate how behavior will continue to evolve through the Master Plan planning horizon, especially considering significant BNA Vision construction disruptions affecting close-in garage parking supply and terminal area circulation. To capture that uncertainty, potential outcomes for TNCs, public parking, rental cars, and taxicabs were established for two scenarios, as shown on **Figure 4-25**, **Table 4-67** and **Table 4-68**: "high TNC impact" and "low TNC impact." For purposes of these projections, the "TNCs" activity growth assumptions capture existing TNC services as well as future services such as car sharing and the influence of connected/autonomous vehicles. It is recognized, however, that the future split between TNCs and the new services is unknown. Therefore, for planning purposes, it is assumed that the new services operate similar to TNCs.

The recent and ongoing significant changes in mode shares at the Airport and at other U.S. airports provide an uncertain basis for the projection of future passenger behavior. Therefore, the values shown on **Figure 4-25**, **Table 4-67** and **Table 4-68** are based substantially on professional judgement, informed by observations at other U.S. airports where TNC mode shares appear to be stabilizing, and do not reflect a mode share forecast model.

TNCs

In general, both scenarios assume that airline passenger willingness to use TNCs will continue to increase, though at slightly lower growth rates than observed since 2014. Through 2022, the TNC growth rate is assumed to predominantly comprise a continued market share increase at the expense of other access modes as the TNC market continues to mature. Under the "high TNC impact" scenario, TNC trips per passenger are expected to increase from 0.15 in 2018 to 0.22 in 2022. Under the "low TNC impact" scenario, TNC trips per passenger are expected to increase to 0.19 by 2022. After 2022, the growth rate assumes that the TNC market is mature, but the TNC share of activity continues to increase due to the increasing influence of car sharing services and connected/autonomous vehicles. The difference between the "high" and "low" TNC impact scenarios reflects uncertainty regarding (a) the extent to which the TNC market at the Airport is approaching maturity and (b) the future adoption rate of car sharing services and connected/autonomous vehicles. By 2037, the "high TNC impact" scenario assumes 0.33 TNC trips per passenger and the "low TNC impact" scenario assumes 0.25 TNC trips per passenger.

Figure 4-25. Estimated Future Activity per Passenger, Selected Modes



Source: InterVISTAS.

Rental Cars

Under both "High TNC Impact" and "Low TNC Impact" scenarios described above, rental car transactions per passenger are assumed to decrease, but at a substantially reduced rate compared with recent years. This is predominantly due to rental car company observations that the number of one-day rentals (which are more susceptible to becoming TNC trips) at the Airport has substantially decreased while longer-duration rentals have remained relatively steady. This qualitative observation is consistent with rental car contract and rental day data that indicates that the average number of days per rental has increased from 3.46 days in 2014 to 3.65 days in 2018. Therefore, the companies believe that while TNCs have impacted passenger use of rental cars, the remaining rental car customers are less likely to become TNC customers due to longer rental durations. The rental car values shown on **Table 4-67** and **Table 4-68** assume a slight continued decrease in rental car activity per passenger at the Airport and a small difference in the "low" and "high" TNC impact scenarios. Rental car contracts per passenger are expected to decline from 0.117 in 2018 to between 0.09 ("high TNC impact" scenario) and 0.10 ("low TNC impact" scenario) by 2037.

Table 4-67. Future Demand Multipliers due to Passenger Growth and Mode Changes

"High TNC Impact" Scenario	2018	2022	2027	2032	2037
Annual enplanements	8,000,000	9,047,142	9,938,318	10,886,036	11,935,070
Peak hour enplanements	2,757	3,118	3,425	3,752	4,114
Peak hour deplanements	2,999	3,391	3,725	4,080	4,473
TNCs					
Trips per passenger	0.151	0.21	0.25	0.29	0.33
Multiplier due to passenger increase	1	1.13	1.24	1.36	1.49
Multiplier due to mode change	1	1.39	1.66	1.91	2.19
Combined multiplier	*1*	*1.58*	*2.06*	*2.59*	*3.27*
Rental cars					
Contracts per enplanement	0.117	0.109	0.100	0.095	0.090
Multiplier due to passenger increase	1	1.13	1.24	1.36	1.49
Multiplier due to mode change	1	0.93	0.85	0.81	0.77
Combined multiplier	*1*	*1.05*	*1.06*	*1.10*	*1.15*
Public parking					
Occupied spaces per 1,000 monthly enplanements	14.17	12.98	11.75	10.73	9.80
Multiplier due to passenger increase	1	1.13	1.24	1.36	1.49
Multiplier due to mode change	1	0.92	0.83	0.76	0.70

"High TNC Impact" Scenario	2018	2022	2027	2032	2037
Combined multiplier	*1*	*1.043*	*1.037*	*1.037*	*1.038*
Taxicabs					
Trips per deplanement	0.048	0.031	0.027	0.023	0.020
Multiplier due to passenger increase	1	1.13	1.24	1.36	1.49
Multiplier due to mode change	1	0.66	0.56	0.48	0.42
Combined multiplier	*1*	*0.74*	*0.70*	*0.66*	*0.62*

Source: InterVISTAS, from data provided by MNAA.

Table 4-68. Future Demand Multipliers due to Passenger Growth and Mode Changes

"Low TNC Impact" Scenario	2018	2022	2027	2032	2037
Annual enplanements	8,000,000	9,047,142	9,938,318	10,886,036	11,935,070
Peak hour enplanements	2,757	3,118	3,425	3,752	4,114
Peak hour deplanements	2,999	3,391	3,725	4,080	4,473
TNCs					
Trips per passenger	0.151	0.19	0.21	0.23	0.25
Multiplier due to passenger increase	1	1.13	1.24	1.36	1.49
Multiplier due to mode change	1	1.26	1.39	1.53	1.68
Combined multiplier	*1*	*1.43*	*1.73*	*2.08*	*2.51*
Rental cars					
Contracts per enplanement	0.117	0.114	0.110	0.105	0.100
Multiplier due to passenger increase	1	1.13	1.24	1.36	1.49
Multiplier due to mode change	1	0.97	0.94	0.90	0.85
Combined multiplier	*1*	*1.10*	*1.17*	*1.22*	*1.28*
Public parking					
Occupied spaces per 1,000 monthly enplanements	14.06	13.45	12.72	12.19	11.67
Multiplier due to passenger increase	1	1.13	1.24	1.36	1.49
Multiplier due to mode change	1	0.96	0.90	0.87	0.83
Combined multiplier	*1*	*1.081*	*1.120*	*1.178*	*1.237*
Taxicabs					
Trips per deplanement	0.048	0.031	0.027	0.023	0.020
Multiplier due to passenger increase	1	1.13	1.24	1.36	1.49
Multiplier due to mode change	1	0.66	0.56	0.48	0.42
Combined multiplier	*1*	*0.74*	*0.70*	*0.66*	*0.62*

Source: InterVISTAS, from data provided by MNAA.

Taxicabs

Taxicab trips per passenger are expected to continue to decline through the planning period, though the rate of decrease is expected to be lower than observed since 2014 (most of the decrease occurred from 2015 to 2016 with a much lower rate occurring after 2016). Given the relatively low share of taxicab activity, it is assumed that the "high" and "low" TNC impact scenarios would be substantially similar. Taxicab trips per deplanement are expected to decline from 0.048 in 2018 to 0.020 by 2037.

Public Parking

For purposes of assessing the impact of TNCs and predicting future parking demands, parking demand is expressed in terms of occupied spaces per 1,000 monthly enplanements. Through 2037, the pattern of future parking demand substantially mirrors that of TNC activity growth. In 2018, during typical busy periods of the Airport's busy month for parking (October), there were approximately 10,860 occupied public parking spaces. When compared with the October 2018 monthly enplanements (approximately 771,000), parking demand can be expressed as 14.09 occupied spaces per 1,000 monthly enplanements. Under the "high TNC impact" scenario, this ratio is expected to reduce to 12.99 by 2022 and 9.80 by 2037. Under the "low TNC impact" scenario, this ratio is expected to reduce to 13.46 by 2022 and 11.67 by 2037.

Use in Facility Requirements Estimates

The future activity levels and corresponding facility requirements described in this section are expressed in terms of trips per passenger or occupied spaces per passenger, but are calculated based on monthly passenger volumes, as per the Forecast. While a range of requirements has been prepared reflecting the "high" and "low" TNC impact scenarios described above, the requirements presented in this chapter reflect the side of that range that would result in the greatest facility capacity need for a given facility type.

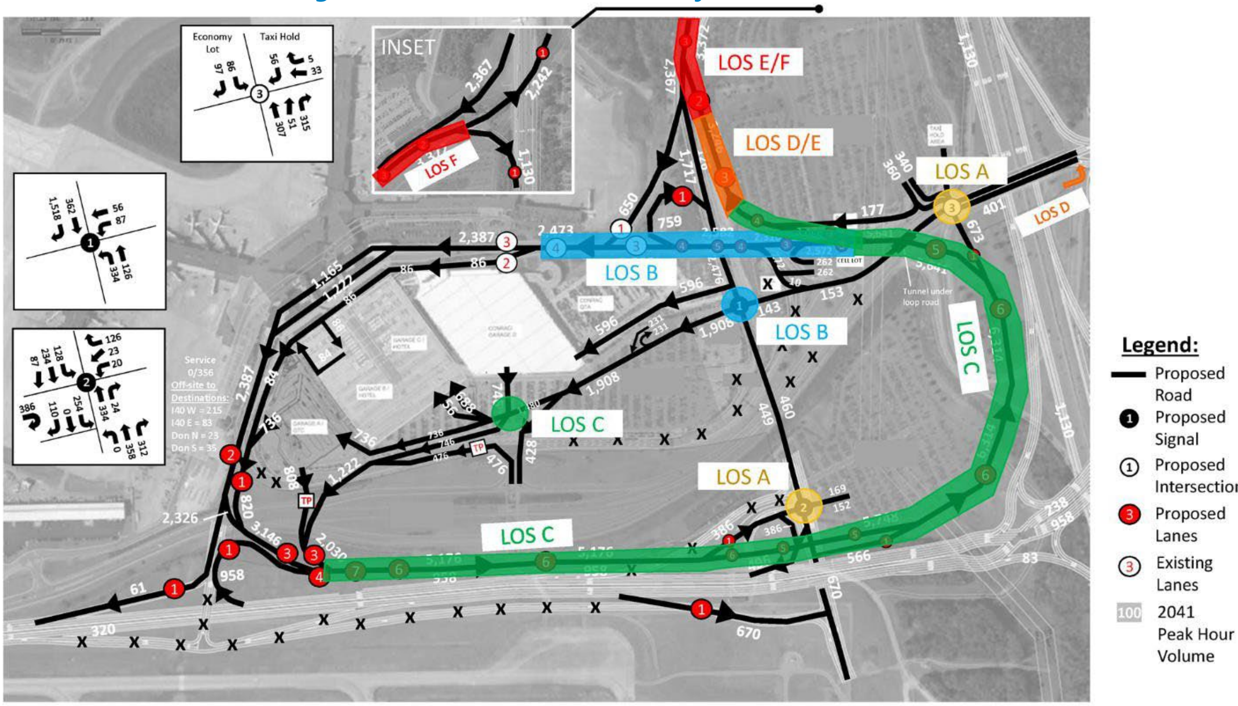
4.4.3. Roadways

From 2018 through 2023, the Airport will be implementing improvements to the on-airport roadways. The roadway network will be under construction as the Airport implements the Terminal Access Roadway Improvements (TARI) project, which accommodates reconstruction of parking facilities and the realignment of Donelson Pike. The Tennessee Department of Transportation (TDOT) will be relocating Donelson Pike and reconfiguring the interchange between Donelson Pike and Interstate 40. Roadway facility requirements in this Section reflect the completed roadway network. This section projects peak hour traffic for the on-Airport roadway network and identifies associated lane requirements. Two recent efforts have estimated roadway capacity – a roadway microsimulation prepared for BNA Vision, and an independent assessment by the Master Plan team.

4.4.3.1. Roadway Microsimulation Results (Prepared by Others)

As part of the BNA Vision planning and design process, the BNA Vision Team developed a CORSIM microsimulation model to evaluate future conditions on the roadways. The model results for 2041 peak hour volumes are shown on **Figure 4-26**. In general, the microsimulation determined that the on-Airport roadways would operate satisfactorily upon completion of TARI improvements, with the exception of the roadways exiting from and toward I-40. Additional lanes entering the airport from, and exiting the airport to I-40 were proposed to TDOT; however, the additional lanes were not accepted for programming into future TDOT capital budgets.

Figure 4-26. BNA Vision Roadway Microsimulation Results



Source: Atkins.

4.4.3.2. Independent Assessment of On-Airport Roadways

A volume-to-capacity ratio analysis was prepared independently by the Master Plan Team. As part of the TARI project, MNAA developed peak hour traffic volumes for the on-Airport roadway network for 2041 and assumed that in 2041, the Airport would be serving 13,277,000 annual enplanements. To estimate volumes for the Master Plan forecast years, these 2041 volumes were used to reflect each forecast year's annual enplanement levels. For example, in 2027, the Airport is expected to serve 9.9 million annual enplanements, so 2027 roadway volumes reflect the 2041 volumes multiplied by a factor of 0.756 (9.9 divided by 13.277). Because the peak hour volumes were based on analyses prepared as part of the TARI project, no range was established reflecting a "high" versus "low" TNC impact scenario.

For each roadway link identified in the 2041 network, the projected peak hour volume was compared to the assumed hourly link capacity to determine, based on the volume/capacity ratio, whether an acceptable level of service would be provided. Hourly link capacity was identified using Airport Cooperative Research Program (ACRP) Report 40, which provides hourly roadway capacities based on the assumed roadway free-flow speed. The ACRP Report 40 values, which do not address roadways with free-flow speeds below 25 miles per hour, were extrapolated to estimate the hourly capacity of a roadways with free-flow speeds of 15 and 20 miles per hour. Capacity values were generally reduced by an additional 10% to reflect the presence of many drivers who would likely be unfamiliar with the roadways network (at many U.S. airports that accommodate a large visitor population, a high proportion of those passengers may use the Airport only once or twice per year). **Table 4-69** summarizes the assumed roadway hourly capacities and **Table 4-70** summarizes the level-of-service associated with ranges of calculated volume/capacity ratios.

Table 4-69. Assumed Roadway Capacities

Roadway free flow speed (miles per hour)	Hourly capacity (vehicles per hour)
15	820
20	970
25	1,125
30	1,305
35	1,440
40	1,575
45	1,710
50	1,800

Note: Assumes 10% capacity reduction related to infrequent users.
Source: Airport Cooperative Research Program (ACRP) Report 40, Table 4-1.

Table 4-70. Level-of-Service Associated with Volume/Capacity Ratios

Volume / capacity ratio (a)	Level-of-service
Up to 0.26	A
0.26 to 0.42	B
0.42 to 0.60	C
0.60 to 0.80	D
0.80 to 1.0	E
Greater than 1.0	F

(a) Volume / capacity ratios shown are for roadways with a 30 – 35 miles per hour posted speed. Ratio ranges vary slightly for other speeds.
Source: Airport Cooperative Research Program (ACRP) Report 40, Table 4-1.

Figure 4-27 depicts the roadway network following completion of the TARI project and identifies the key roadway links used in this requirements analysis. **Table 4-71** and **Table 4-72** summarize, for each roadway link and each forecast year (roadway link identifiers shown in **Table 4-71** and **Table 4-72** correspond with those on **Figure 4-27)**:

- Assumed free-flow speed (provided by the Airport) and corresponding per-lane capacity;
- Assumed number of lanes and corresponding total roadway capacity;
- Peak hour volumes;
- Volume/capacity ratio and corresponding LOS; and
- For roadways operating at LOS D or poorer, the number of roadway lanes required to achieve LOS C or better. For on-Airport roadways, facility requirements reflect a desire to achieve LOS "C" during the design hour. LOS C represents conditions where traffic flows smoothly during peak periods but vehicles travel close together and individual motorists find it more difficult to change lanes without other motorists' cooperation in providing a gap. This LOS threshold (and corresponding volume/capacity ratio) reflects a more-stringent standard than may be used for typical urban transportation planning because for roadways used by airline passengers, the potential result of congestion can be more critical: a passenger may miss their flight.

The results of the independent analysis indicates that there could be on-airport roadway deficiencies should traffic evolve differently than predicted in the CORSIM microsimulation. As shown in **Figure 4-27** and detailed in **Table 4-71** and **Table 4-72**, eleven (11) roadway links could be expected to operate at LOS D or poorer by 2037, including four (4) which could experience LOS D prior to 2022 (links E, F, R, and X).

- **Link A, *Airport entrance from eastbound I-40*.** This two-lane link is expected to operate at LOS D through 2032. A third lane would be required to achieve LOS C through 2032 and a fourth would be required to achieve LOS C through 2037.

- **Link C, *Terminal approach*.** This four-lane roadway is expected to operate at LOS D by 2032. A fifth lane would achieve LOS C through 2037.

- **Link E, *Terminal-area exit to the north*.** This three-lane roadway is expected to operate at LOS D prior to 2022. A fourth lane would achieve LOS C through 2032 and a fifth lane would be required to achieve LOS C prior to 2037.

- **Link F, *Terminal-area entrance from southbound Donelson Pike.*** This one-lane roadway is expected to operate at LOS D prior to 2022. A second lane would achieve LOS C through 2037.

- **Link G, *Terminal loop, northbound (excludes lane added from Link F).*** This five-lane roadway is expected to operate at LOS D by 2032. A sixth lane would achieve LOS C through 2037.

- **Link H, *Terminal loop, northbound, after exit to Donelson Pike (includes lane added from Link F).*** This five-lane roadway is expected to operate at LOS D by 2027. A sixth lane would achieve LOS C through 2032 and a seventh lane would achieve LOS C by 2037.

- **Link M, *Terminal loop, westbound.*** This six-lane roadway is expected to operate at LOS C or better through 2022. A seventh lane would be required to achieve LOS C through 2032 and an eighth would be required prior to 2037.

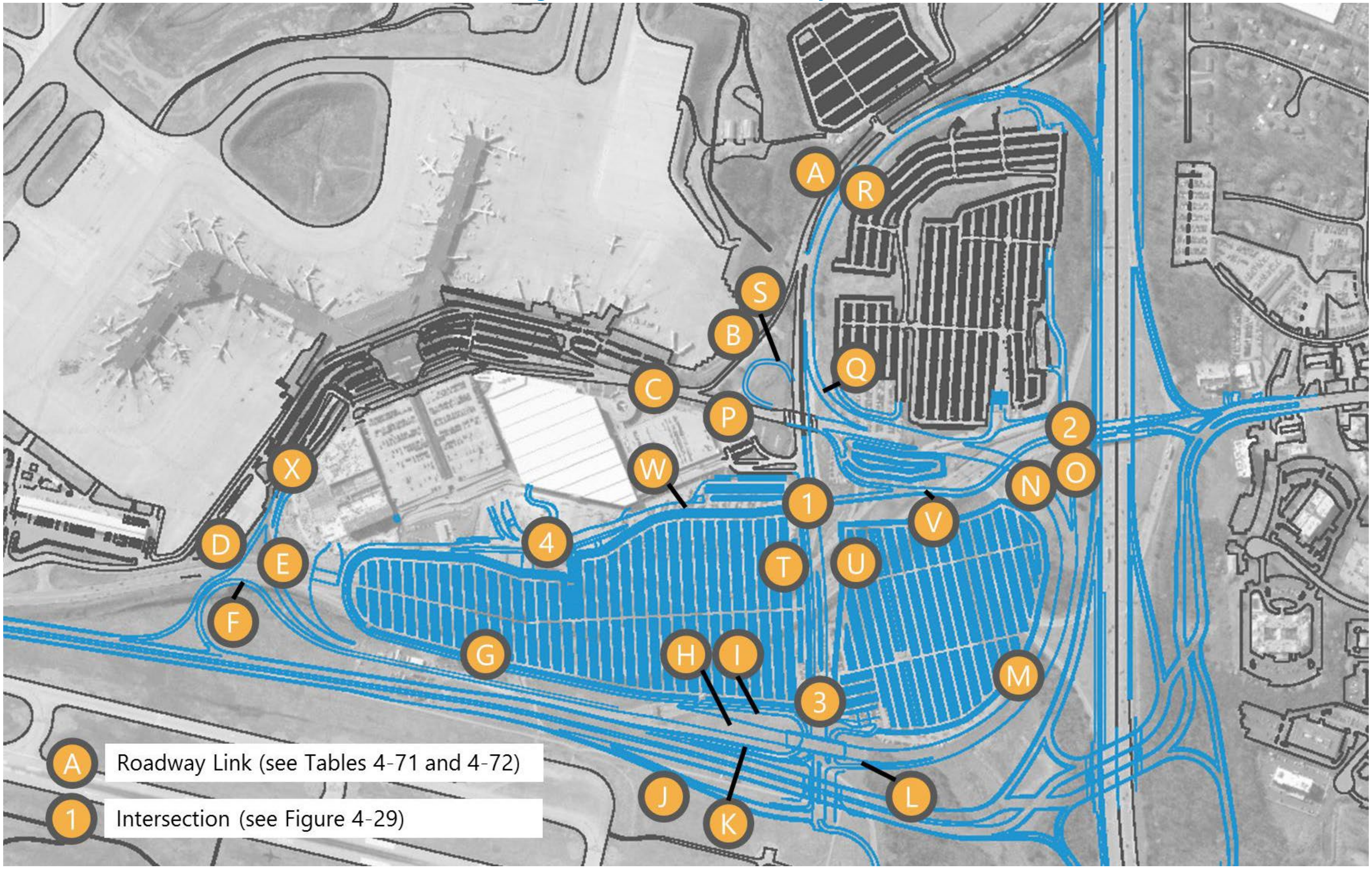
- **Link N, *Terminal loop, southbound.*** This five-lane roadway is expected to operate at LOS C or better through 2022. A sixth lane would achieve LOS C through 2032 and a seventh would be required prior to 2037.

- **Link Q, *Terminal loop exit to I-40.*** This three-lane roadway is expected to operate a LOS C or better through 2022. A fourth lane would be required by 2027 to achieve LOS C or better through 2037.

- **Link R, *Airport exit to I-40.*** At its narrowest point, this one-lane roadway is expected to operate at LOS F by 2022. LOS C would be achieved through 2037 with two additional lanes.

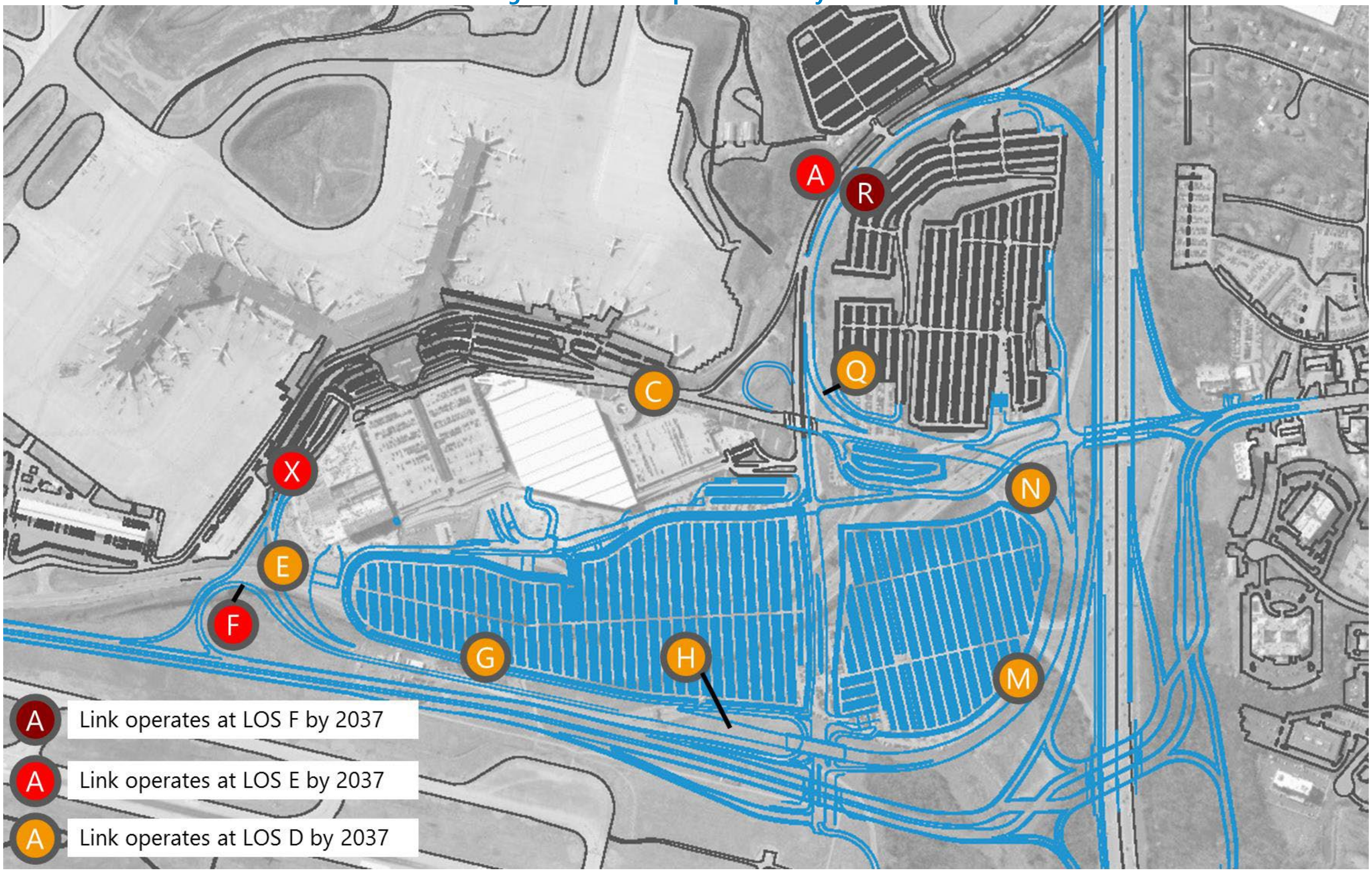
- **Link X, *Curbside exit.*** This two-lane roadway is expected to operate at LOS D by 2022. A third lane would achieve LOS C through 2037.

Figure 4-27. Assumed Roadway Network



Source: InterVISTAS, from base map provided by AECOM.

Figure 4-28. Anticipated Roadway Deficiencies



Source: InterVISTAS, from base map provided by AECOM.

Table 4-71. Roadway Volumes and Requirements, 2022 and 2027

						2022 (9.0 million annual enplanements) [(a)]				2027 (9.9 million annual enplanements)			
	Link identifier and description (see Figure 4-27)	**Assumed speed (miles per hour) (b)**	**Per-lane capacity (c)**	**Current or planned lane count**	**Assumed capacity (vehicles per hour)**	**Volume**	**Volume / capacity ratio**	**LOS**	**Lanes required to achieve LOS C or better**	**Volume**	**Volume / capacity ratio**	**LOS**	**Lanes required to achieve LOS C or better**
A	Eastbound Terminal Drive (entrance from eastbound I-40)	25	1,125	2	2,250	1,615	0.72	D	3	1,770	0.79	D	3
B	Entrance to terminal area from eastbound Terminal Drive	20	970	1	970	445	0.46	C		485	0.50	C	
C	Terminal approach	15	819	4	3,276	1,685	0.51	C		1,850	0.56	C	
D	Terminal-area exit to southbound Donelson Pike	25	1,125	1	1,125	40	0.04	A		45	0.04	A	
E	Terminal-area exit to north	30	1,305	3	3,915	2,145	0.55	C		2,355	0.60	D	4
F	Terminal-area entrance from southbound Donelson Pike	20	970	1	970	655	0.67	D	2	715	0.74	D	2
G	Terminal loop northbound	30	1,305	5	6,525	3,525	0.54	C		3,875	0.59	C	
H	Terminal loop northbound, after exit to Donelson Pike	30	1,305	5	6,525	3,915	0.60	C		4,305	0.66	D	6

						2022 (9.0 million annual enplanements) [a]				2027 (9.9 million annual enplanements)			
Link identifier and description (see Figure 4-27)		Assumed speed (miles per hour) (b)	Per-lane capacity (c)	Current or planned lane count	Assumed capacity (vehicles per hour)	Volume	Volume / capacity ratio	LOS	Lanes required to achieve LOS C or better	Volume	Volume / capacity ratio	LOS	Lanes required to achieve LOS C or better
I	Exit to southbound Donelson Pike	25	1,125	1	1,125	265	0.24	A		290	0.26	A	
J	Exit from northbound Donelson Pike	25	1,125	1	1,125	455	0.40	B		500	0.44	C	
K	On-ramp to southbound Donelson Pike	25	1,125	1	1,125	340	0.30	B		370	0.33	B	
L	On-ramp to terminal loop roadway	25	1,125	1	1,125	385	0.34	B		425	0.38	B	
M	Terminal loop westbound	30	1,305	6	7,830	4,300	0.55	C		4,725	0.60	D	7
N	Terminal loop southbound	30	1,305	5	6,525	3,845	0.59	C		4,220	0.65	D	6
O	Terminal loop exit to Economy Lot C and hotels	25	1,125	1	1,125	460	0.41	B		505	0.45	C	
P	Terminal approach, north of Terminal Drive	30	1,305	3	3,915	1,240	0.32	B		1,365	0.35	B	
Q	Terminal loop exit to I-40	30	1,305	3	3,915	2,210	0.56	C		2,430	0.62	D	4
R	Airport exit to I-40	40	1,750 (d)	1	1,750	2,300	1.31	F	3	2,525	1.44	F	3

Link identifier and description (see Figure 4-27)		Assumed speed (miles per hour) (b)	Per-lane capacity (c)	Current or planned lane count	Assumed capacity (vehicles per hour)	2022 (9.0 million annual enplanements) [(a)] Volume	Volume / capacity ratio	LOS	Lanes required to achieve LOS C or better	2027 (9.9 million annual enplanements) Volume	Volume / capacity ratio	LOS	Lanes required to achieve LOS C or better
S	Terminal loop exit to eastbound Terminal Drive	20	972	3	2,916	515	0.18	A		570	0.20	A	
T	Eastbound Terminal Drive in infield area	30	1,305	3	3,915	305	0.08	A		335	0.09	A	
U	Westbound Terminal Drive in infield area	30	1,305	3	3,915	110	0.03	A		120	0.03	A	
V	Southbound approach to Terminal Drive	25	1,125	1	1,125	105	0.09	A		115	0.10	A	
W	GTC and Garage access road	25	1,125	3	3,375	1,300	0.39	B		1,430	0.42	C	
X	Curbside exit	30	1,305	2	2,610	1,625	0.62	D	3	1,785	0.68	D	3

Note: Volumes are based on Terminal Access Roadway Improvements (TARI) Basis of Design Report, 35% Level, January 29, 2019, which provided peak hour volumes associated with 13.277 million annual enplanements. Volumes for 2022, 2027, 2032, and 2037 were estimated by applying the ratio of the forecast annual enplanements to13.277 million.

(a) Roadway configuration in 2022 may be changing periodically due to ongoing construction. Volumes are hypothetical as they assume construction is complete.
(b) Reflects lowest speed portion of the link.
(c) Based on ACRP 40, extrapolated for speeds below 25 mph
(d) Assumes no capacity reduction; a driver's only remaining decision is eastbound versus westbound I-40.

Source: InterVISTAS, from traffic volumes provided by Atkins.

Table 4-72. Roadway Volumes and Requirements, 2032 and 2037

					2032 (10.9 million annual enplanements)				2037 (11.9 million annual enplanements)			
Link identifier and description (see Figure 4-27)	**Assumed speed (miles per hour) (a)**	**Per-lane capacity (b)**	**Current or planned lane count**	**Assumed capacity (vehicles per hour)**	**Volume**	**Volume / capacity ratio**	**LOS**	**Lanes required to achieve LOS C or better**	**Volume**	**Volume / capacity ratio**	**LOS**	**Lanes required to achieve LOS C or better**
A Eastbound Terminal Drive (entrance from eastbound I-40)	25	1,125	2	2,250	1,940	0.86	E	3	2,130	0.95	E	4
B Entrance to terminal area from eastbound Terminal Drive	20	970	1	970	535	0.55	C		585	0.60	C	
C Terminal approach	15	819	4	3,276	2,030	0.62	D	5	2,225	0.68	D	5
D Terminal-area exit to southbound Donelson Pike	25	1,125	1	1,125	50	0.04	A		55	0.05	A	
E Terminal-area exit to north	30	1,305	3	3,915	2,580	0.66	D	4	2,830	0.72	E	4
F Terminal-area entrance from southbound Donelson Pike	20	970	1	970	785	0.81	E	2	860	0.88	E	2
G Terminal loop northbound	30	1,305	5	6,525	4,245	0.65	D	6	4,655	0.71	D	6

					2032 (10.9 million annual enplanements)				2037 (11.9 million annual enplanements)			
Link identifier and description (see Figure 4-27)	**Assumed speed (miles per hour) (a)**	**Per-lane capacity (b)**	**Current or planned lane count**	**Assumed capacity (vehicles per hour)**	**Volume**	**Volume / capacity ratio**	**LOS**	**Lanes required to achieve LOS C or better**	**Volume**	**Volume / capacity ratio**	**LOS**	**Lanes required to achieve LOS C or better**
H Terminal loop northbound, after exit to Donelson Pike	30	1,305	5	6,525	4,715	0.72	D	6	5,165	0.79	D	7
I Exit to southbound Donelson Pike	25	1,125	1	1,125	315	0.28	B		345	0.31	B	
J Exit from northbound Donelson Pike	25	1,125	1	1,125	550	0.49	C		600	0.53	C	
K On-ramp to southbound Donelson Pike	25	1,125	1	1,125	405	0.36	B		445	0.40	C	
L On-ramp to terminal loop roadway	25	1,125	1	1,125	465	0.41	B		510	0.45	C	
M Terminal loop westbound	30	1,305	6	7,830	5,175	0.66	D	7	5,675	0.72	D	7
N Terminal loop southbound	30	1,305	5	6,525	4,625	0.71	D	6	5,070	0.78	D	7
O Terminal loop exit to Economy Lot C and hotels	25	1,125	1	1,125	550	0.49	C		605	0.54	C	

Link identifier and description (see Figure 4-27)		Assumed speed (miles per hour) (a)	Per-lane capacity (b)	Current or planned lane count	Assumed capacity (vehicles per hour)	2032 (10.9 million annual enplanements) Volume	2032 Volume / capacity ratio	2032 LOS	2032 Lanes required to achieve LOS C or better	2037 (11.9 million annual enplanements) Volume	2037 Volume / capacity ratio	2037 LOS	2037 Lanes required to achieve LOS C or better
P	Terminal approach, north of Terminal Drive	30	1,305	3	3,915	1,495	0.38	C		1,640	0.42	C	
Q	Terminal loop exit to I-40	30	1,305	3	3,915	2,660	0.68	D	4	2,920	0.75	D	4
R	Airport exit to I-40	40	1,750 (c)	1	1,750	2,765	1.58	F	3	3,030	1.73	F	3
S	Terminal loop exit to eastbound Terminal Drive	20	972	3	2,916	620	0.21	A		680	0.23	A	
T	Eastbound Terminal Drive in infield area	30	1,305	3	3,915	370	0.09	A		405	0.10	A	
U	Westbound Terminal Drive in infield area	30	1,305	3	3,915	130	0.03	A		145	0.04	A	
V	Southbound approach to Terminal Drive	25	1,125	1	1,125	125	0.11	A		140	0.12	A	
W	GTC and Garage access road	25	1,125	3	3,375	1,565	0.46	C		1,715	0.51	C	
X	Curbside exit	30	1,305	2	2,610	1,955	0.75	D	3	2,145	0.82	E	3

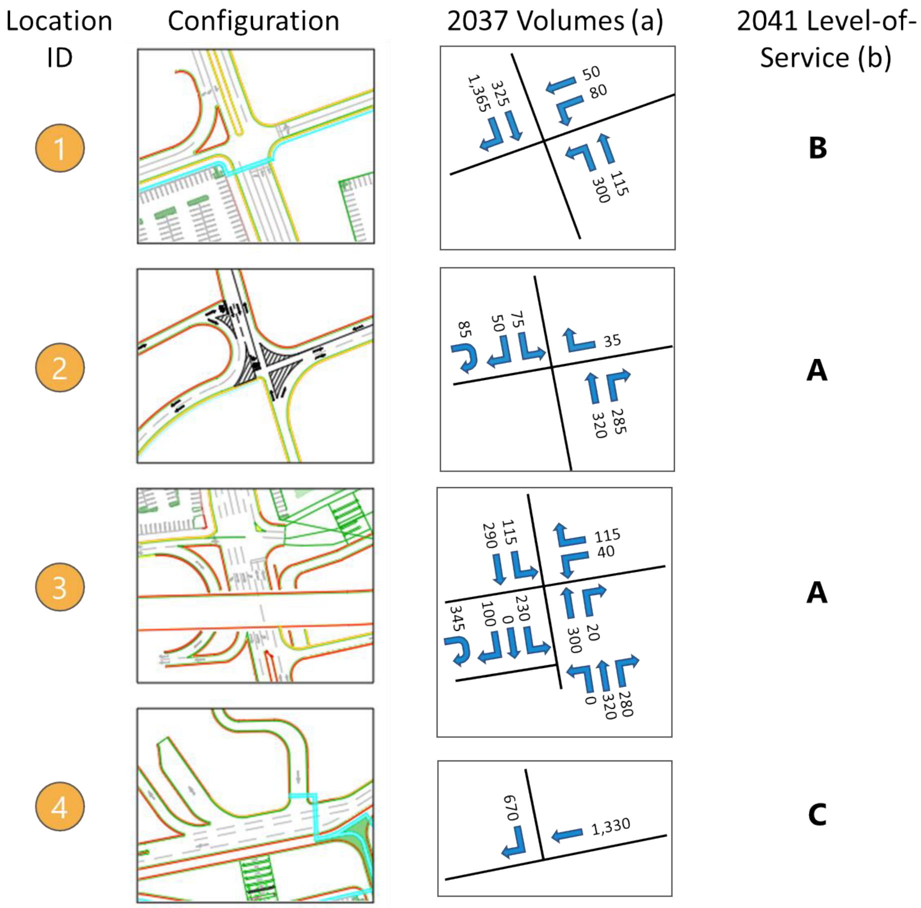
Note: Volumes are based on Terminal Access Roadway Improvements (TARI) Basis of Design Report, 35% Level, January 29, 2019, which provided peak hour volumes associated with 13.277 million

					2032 (10.9 million annual enplanements)				2037 (11.9 million annual enplanements)			
Link identifier and description (see Figure 4-27)	Assumed speed (miles per hour) (a)	Per-lane capacity (b)	Current or planned lane count	Assumed capacity (vehicles per hour)	Volume	Volume / capacity ratio	LOS	Lanes required to achieve LOS C or better	Volume	Volume / capacity ratio	LOS	Lanes required to achieve LOS C or better

annual enplanements. Volumes for 2022, 2027, 2032, and 2037 were estimated by applying the ratio of the forecast annual enplanements to13.277 million.
(a) Reflects lowest speed portion of the link.
(b) Based on ACRP 40, extrapolated for speeds below 25 mph
(c) Assumes no capacity reduction; a driver's only remaining decision is eastbound versus westbound I-40.
Source: InterVISTAS, from traffic volumes provided by Atkins.

Figure 4-27 also identifies four on-airport intersections. Analysis of these intersections was conducted as part of the TARI project and the results are provided on **Figure 4-29**, which provides the intersection configuration, 2037 peak hour turning movement volumes, and the TARI project 2041 LOS analysis results. As shown, each intersection is expected to operate at LOS C or better through 2041 (13,277,000 annual enplanements), which assumed higher activity levels than the Master Plan's 2037 planning horizon.

Figure 4-29. Intersection Configurations, Volumes and Expected Level of Service



The ramps entering the Airport from eastbound I-40 and exiting the Airport to westbound and eastbound I-40 are expected to serve the majority of peak hour traffic entering and exiting the terminal area. These ramps, shown on **Figure 4-30** are one lane each. As shown on **Table 4-73**, the Airport entrance from eastbound I-40 is expected to operate at LOS F by 2022. This ramp would need a second lane to achieve LOS C or better through 2027 and a third lane to achieve LOS C or better through 2037. The Airport exit to westbound I-40 is expected to operate at LOS E by 2022 and would need a second lane to achieve LOS C or better through 2037. After completion of the Donelson Pike relocation project, the future Airport exit to eastbound I-40 is expected to operate at LOS C or better through 2037.

Figure 4-30. Key I-40 Airport Access Ramps

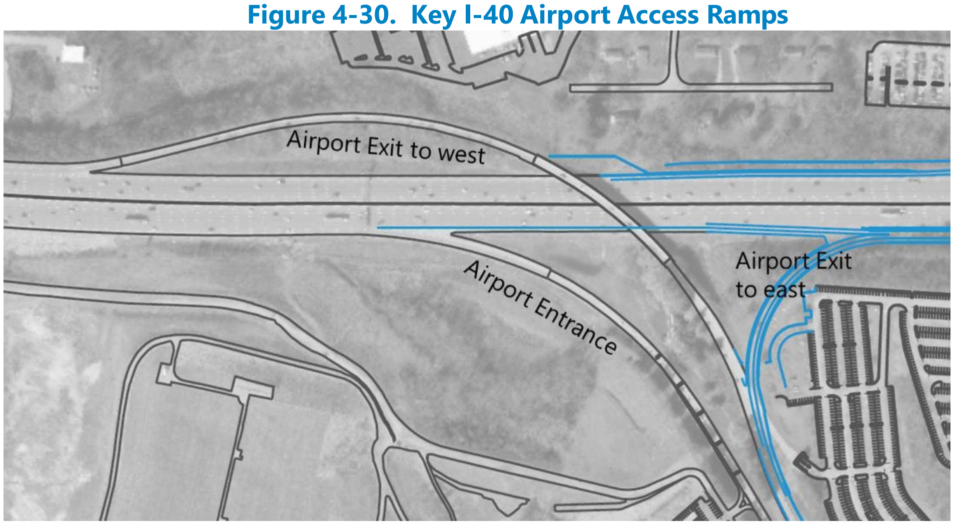


Table 4-73. Roadway Volumes and Requirements, Key I-40 Access Ramps

					2022 (9.0 Million Annual Enplanements)				2027 (9.9 Million Annual Enplanements)			
Roadway Link (see Figure 4-30)	**Assumed Speed (Miles Per Hour) (a)**	**Per-Lane Capacity (b)**	**Current or Planned Lane Count**	**Assumed Capacity (Vehicles Per Hour)**	**Volume**	**Volume / Capacity Ratio**	**LOS**	**Lanes Required to Achieve LOS C or Better**	**Volume**	**Volume/ Capacity Ratio**	**LOS**	**Lanes Required to Achieve LOS C or Better**
Airport entrance from eastbound I-40	40	1,575	1	1,575	1,615	1.03	F	2	1,770	1.12	F	2
Airport exit to westbound I-40	40	1,750	1	1,750	1,530	0.87	E	2	1,680	0.96	E	2
Airport exit to eastbound I-40	40	1,750	1	1,750	770	0.44	C		845	0.48	C	
					2032 (10.9 Million Annual Enplanements)				**2037 (11.9 Million Annual Enplanements)**			
Airport entrance from eastbound I-40	40	1,575	1	1,575	1,940	1.23	F	3	2,130	1.35	F	3
Airport exit to westbound I-40	40	1,750	1	1,750	1,840	1.05	F	2	2,015	1.15	F	2
Airport exit to eastbound I-40	40	1,750	1	1,750	925	0.53	C		1,015	0.58	C	

Note: Volumes are based on Terminal Access Roadway Improvements (TARI) Basis of Design Report, 35% Level, January 29, 2019, which provided peak hour volumes associated with 13.277 million annual enplanements. Volumes for 2022, 2027, 2032, and 2037 were estimated by applying the ratio of the forecast annual enplanements to13.277 million.

(a) Reflects lowest speed portion of the link. Airport exit to westbound I-40 is assumed to not have capacity reduction as drivers would no longer be facing any potential decisions.
(b) Based on ACRP 40.
Source: InterVISTAS, from traffic volumes provided by Atkins.

4.4.4. Curbsides, Commercial Ground Transportation, and Public Transit

This section summarizes existing and future use of curbside facilities and presents curbside facility requirements through the planning period for both the high-TNC impact condition and the low-TNC impact condition, as applicable.

Curbside facility requirements are based on providing level-of-service (LOS) C or better during the 'design hour' identified for the facility. LOS, as defined in Airport Cooperative Research Program (ACRP) Report 40, *Airport Curbside and Terminal Area Roadway Operations*, is based on two factors. The first factor is curbside utilization, which indicates the ability of the curbside to accommodate existing or projected requirements for vehicles loading or unloading at the curbside by comparing the required length of loading or unloading area with the available curbside length. The required length for loading or unloading incorporates factors that reflect peaks within the peak hour as well as likely non-uniform distribution of demand across the curbside, such as demand levels near terminal doorways or certain airlines.

The second factor is the volume to capacity (v/c) ratio of the curbside roadway. A v/c ratio of 1.00 would indicate that the roadway is operating at its capacity; thus, a v/c ratio of approximately 0.60 would indicate a LOS C. **Table 4-74** summarizes the curbside utilization ratio associated with LOS A through F. Additionally, because the curbside utilization value impacts the curbside roadway capacity value used in the v/c ratio, **Table 4-74** also provides the assumed curbside roadway capacity associated with each curbside utilization LOS threshold.

Table 4-74. Curbside Utilization Level of Service Ratios

	Airport curbside levels of service					
Assumes double-parking is permitted	A	B	C	D	E	F
Curbside utilization ratio (a)	0.90	1.10	1.30	1.70	2.00	> 2.00
Curbside roadway capacity (vehicles per hour)						
4- lane roadways (Departures Level – inner curb)	2,830	2,790	2,680	2,220	1,800	Up to 1,800
3-lane roadways (Departures Level – outer curb; and Arrivals Level – middle curb)	2,200	1,950	1,580	860	750	Up to 750
Assumes double-parking is prohibited	A	B	C	D	E	F
Curbside utilization ratio (a)	0.70	0.85	1.00	1.20	1.35	> 1.35
Curbside roadway capacity (vehicles per hour)						
2-lane roadways (Arrivals Level – outer curb) (b)	880	780	630	340	300	Up to 300

(a) The ratio between the calculated curbside demand and the available effective curbside length.
(b) Capacity is assumed to be 40% of the capacity of a 3-lane curbside roadway.
Source: Airport Cooperative Research Program Report 40, Table 5-2.

Table 4-75 summarizes the v/c ratio associated with each curbside roadway LOS threshold.

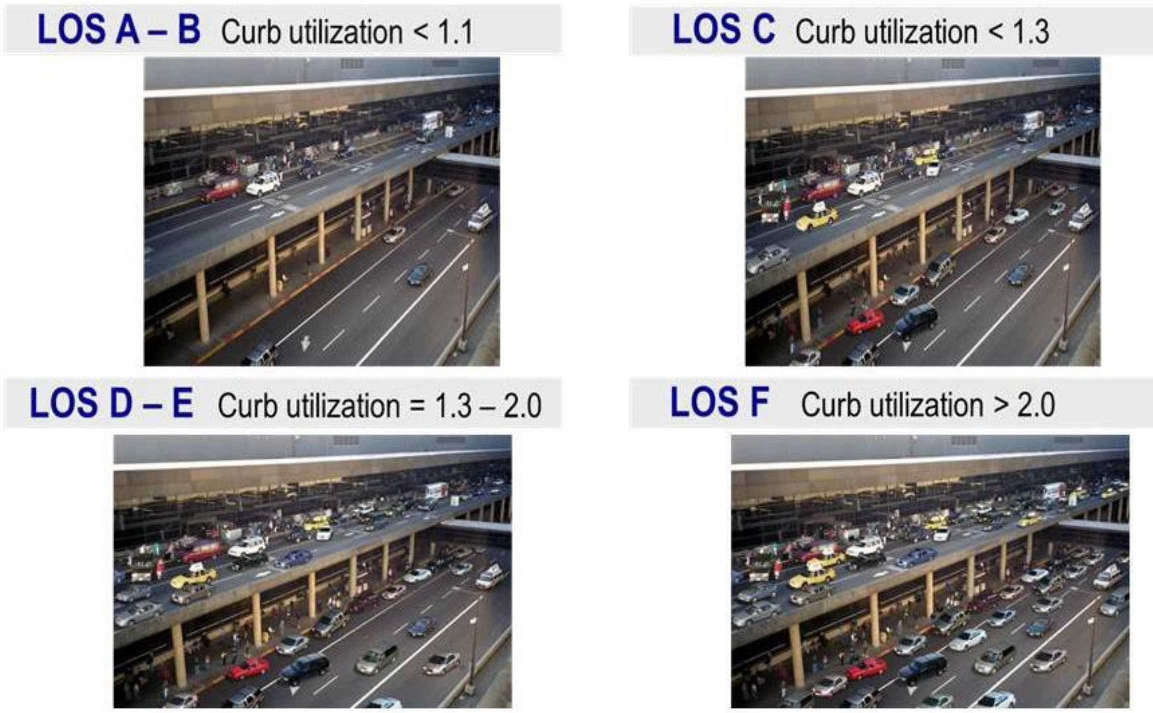
Table 4-75. Curbside Roadway Level of Service Ratios

	Airport curbside levels of service					
	A	B	C	D	E	F
Maximum through lane volume/capacity ratio	0.25	0.40	0.60	0.80	1.00	>1.00

Source: Airport Cooperative Research Program Report 40, Table 5-2.

Figure 4-31 depicts representative curbside conditions associated with each LOS.

Figure 4-31. Curbside Level of Service Depictions



Source: Airport Cooperative Research Program Report 40.

The goal of the curbside facility requirements analysis is to identify, for each planning horizon, the number of loading and/or unloading vehicles requiring accommodation during the 'design hour" for each curbside. For curbsides where vehicles park in a linear fashion, such as at BNA, curbside requirements are also typically provided in linear feet of curbside frontage parallel to a functioning terminal building and assume some amount of double-parking.

4.4.4.1. Methodology

Curbside facility requirements are calculated by one of two methods depending on the operating characteristics of the mode.

- **Vehicles operating on an on-demand basis** (e.g., private vehicles, taxicabs, TNCs). Design hour vehicle volumes are combined with the assumed dwell times to determine the average number of vehicles simultaneously picking up and/or dropping off passengers. This average value is then adjusted to reflect the 95th percentile number of vehicles expected to simultaneously pick up and/or drop off passengers during the design hour. Using the 95th percentile number accounts for uneven distribution of traffic volumes during the peak hour (i.e., peaks within the peak) as well as likely uneven distribution of demand along the face of the curbside. This 95th percentile value is then multiplied by the average vehicle length to estimate the length of occupied linear curb, which is then divided by 1.3 to account for a level of double-parking consistent with industry standards for level-of-service C for curbside roadways.

- **Vehicles operating on a scheduled basis** (e.g., scheduled vans, selected courtesy shuttles, and public transit). Vehicle volumes are combined with assumed dwell times to determine the average number of vehicles simultaneously picking up and/or dropping off passengers. Due to the scheduled nature of these vehicles, there is a low likelihood of peaking within the hour. Thus, requirements for scheduled vans, buses, and public transit reflect the average number of vehicles expected to be loading and/or unloading simultaneously. Because courtesy vehicles requirements reflect the operations of multiple operators that may operate on different schedules, requirements are calculated in the same manner as for on-demand vehicles.

4.4.4.2. Dwell Times and Vehicle Lengths

Table 4-76 summarizes the dwell times and vehicle lengths assumed for each mode. The dwell time values are based on (a) April 2017 dwell time surveys conducted at the Airport as part of BNA Vision, and (b) for modes not surveyed in April 2017, industry standards that can be achieved depending on policies enforced by the Airport. The vehicle lengths are those typically used in the industry and include the distance between the front of a vehicle and the front of the vehicle immediately in front or behind. The future curbside requirements assume that these values remain unchanged through the planning period.

Table 4-76. Curbside Vehicle Dwell Times and Lengths

	Dwell time (minutes)		Vehicle length
	Passenger	Passenger	
Private vehicles (a)	1.5	1.2	25
TNCs (b)	0.8	1.2	25
Taxicabs (b)	2.0	1.0	25
Limousines (b)	1.5	10.0	25
Shared ride vans and scheduled	1.5	10.0	30
Off-airport parking shuttle (b)	1.5	3.0	30
Hotel shuttle (b)	2.0	5.0	30
Scheduled buses (b)	6.0	10.0	60
Public transit (c, d)	1.0	1.0	60
Employee parking shuttle (d)	1.5	1.5	60
Charter buses (b)	10.0	10.0	60

4.4.4.3. Base Year Activity

The BNA Vision project included analysis of automatic traffic counts, vehicle classifications surveys, and dwell time surveys. These data were substantially collected in 2016 and 2017 and the BNA Vision project used March 2016 as a basis for establishing design day requirements. To incorporate the significant shift in mode share that was occurring in 2016 and 2017, the BNA Vision project conducted April 2017 vehicle classification surveys and applied them to the March 2016 peak hour volumes. For this Master Plan, those data were supplemented with evaluations of TNC activity during busy periods in 2017 and 2018, and taxicab activity during busy periods in 2017.

Table 4-77 and **Table 4-78** summarize the 2016 peak hour volumes identified in BNA Vision for the Departures Level and Arrivals Level, respectively.

Table 4-77. Peak Hour Curbside and Ground Transportation Volumes, Departures Level, BNA Vision

	April 2017 survey					March 2016 peak hour volumes		March 2016 volumes, assuming April 2017 distribution	
	Volumes		Distribution						
	Inner curb	Outer curb	Inner curb	Outer curb	Total	Inner curb	Outer curb	Inner curb	Outer curb
Departures level – on demand vehicles:									
Private vehicles	377	12	66.5%	2.1%	68.6%	495	0	444	14
TNCs	18	125	3.2%	22.0%	25.2%	0	48	21	147
Taxicabs	0	27	0.0%	4.8%	4.8%	0	115	0	32
Limousines	0	8	0.0%	1.4%	1.4%	0	10	0	9
Total	395	172	69.7%	30.3%	100.0	495	173	465	203
Departures level – scheduled/infrequent vehicles:									
Scheduled and	0	5				0	4	0	5
Off-airport parking	0	57				0	55	0	55
Hotel shuttle	0	27				0	34	0	34
Scheduled bus	0	1				0	0	0	1
Charter bus	0	2				0	0	0	2
Airport parking	0	40				0	40	0	40
Employee parking	0	31				0	31	0	31
Total	0	163				0	164	0	168

(a) Includes shuttles for Terminal Lot A, Economy B, Economy C, and BNA Express.

Table 4-78. Peak Hour Curbside and Ground Transportation Volumes, Arrivals and Ground Transportation Level, BNA Vision

March 2016 peak hour volumes			
Arrivals level:	Inner curb	Middle curb	Outer curb
Private vehicles	0	659	0
Airport parking shuttles (a)	30	0	0
Parking Shuttle - BNA Express	0	0	10
Off-airport parking shuttle	0	0	57
Hotel shuttle	0	0	33
Scheduled and shared-ride vans	0	0	14
Total	30	659	114
Ground Transportation Level:	Level 1 roadway	Garage roadway	
TNCs	0	101	
Taxicabs	116	0	
Limousines	0	36	
Scheduled bus	2	0	
Public transit	2	0	
Charter bus	4	0	
Total	124	137	

(a) Includes shuttles for Terminal Lot A, Economy B, and Economy C.

Source: BNA Vision.

4.4.4.4. Future Volumes

Table 4-79 summarizes future peak hour volumes for vehicles using the Departures Level curbsides. Volumes assume the “high TNC impact” scenario, and are assumed to increase as follows:

- **TNCs.** TNC volumes are assumed to increase at the rates shown in **Table 4-79**, which predict that due to passenger growth and mode shifts, TNC peak hour volumes will increase (compared with 2018 volumes) 58% by 2022, 106% by 2027, 159% by 2032, and 227% by 2037. Based on observations that despite the increase in TNC activity from March 2016 to March 2017, the ratio of Departures Level peak hour trips to monthly passengers remained constant, indicating that the growth in TNCs was due to customers switching from other curbside modes (as opposed to public parking, rental cars, and off-Airport parking). Therefore, it is assumed that the growth in TNC hourly traffic is due to passengers switching from taxicabs and private vehicles.

- **Taxicabs**. Taxicab volumes are assumed to decrease at the rates shown in **Table 4-79**, which predict that due to passenger growth and mode shifts, taxicab peak hour volumes will decrease (compared with 2018 volumes) 26% by 2022, 30% by 2027, 34% by 2032, and 38% by 2037. This rate reflects the growth in activity due to passenger growth as well as the reduced market share that taxis serve. Trips lost due to decreased market share are assumed to have shifted to TNCs.

- **Private vehicles.** Private vehicle volumes are assumed to increase at the same rate as hourly passengers (the rates are shown in **Table 4-79**, but volumes are subsequently reduced as it is assumed that the TNC volume increases due to changes in market share (as opposed to passenger growth) come from passengers who otherwise would have used private vehicles and taxicabs.

- **Limousines and charter buses.** Volumes are assumed to increase at the same rate as hourly passengers.

- **Scheduled and shared-ride vans.** By late 2018, shared-ride van service at the Airport had ceased and scheduled van service had reduced to a single operator providing service to and from Chattanooga. Therefore, future volumes were assumed to be one trip per hour.

- **Scheduled buses and airport parking shuttles.** These vehicles are assumed to operate on a schedule and thus, volumes are assumed to be constant during peak periods.

- **Employee parking shuttle.** These vehicles are assumed to operate at 100% capacity during existing peak periods and thus volumes are expected to increase at the same rate as growth in employee parking requirements, which are summarized below in **Table 4-93**.

- **Off-Airport parking and hotel shuttles.** These vehicles are assumed to operate on a schedule during peak periods. Therefore, volumes will increase only with the introduction of new hotels and/or off-Airport parking facilities. To reflect the introduction of new facilities, peak hour volumes are assumed to be constant through 2022. Beyond 2022, peak hour volumes are assumed to increase at 50% the growth rate in hourly passengers.

Table 4-79. Future Peak Hour Volumes, Departures Level

	2016 (see Table 4-77)	2018 (a)	2022	2027	2032	2037
Annual enplanements (b)	6,489,739	8,000,000	9,047,142	9,938,318	10,886,036	11,935,070
Peak hour enplanements (b)	2,439	2,757	3,118	3,425	3,752	4,114
Activity multipliers, applied to 2018 volumes (see Table 4-68)						
Private vehicles, limousines, charter buses		1	1.131	1.242	1.361	1.492
TNCs		1	1.575	2.060	2.592	3.265
Taxicabs		1	0.742	0.700	0.658	0.620
Private vehicles						
Volume based on passenger growth	458	565	639	702	769	843
Volume shifted to TNCs	n/a	n/a	(107)	(203)	(310)	(451)
Total	**458**	**565**	**532**	**499**	**459**	**392**
TNCs						
Volume based on passenger growth	168	271	306	336	368	404
Volume shifted from private vehicles	n/a	n/a	107	203	310	451
Volume shifted from taxicabs	n/a	n/a	13	18	23	29
Total	**168**	**271**	**426**	**557**	**701**	**883**
Taxicabs						
Volume based on passenger growth	32	33	37	41	45	49
Volume shifted to TNCs	n/a	n/a	(13)	(18)	(23)	(29)
Total	**32**	**33**	**24**	**23**	**22**	**20**
Limousines	9	12	13	14	16	17
Scheduled and shared-ride vans (c, d)	5	1	1	1	1	1
Off-airport parking shuttle (e)	55	55	55	58	60	63
Hotel shuttle (e)	34	34	43	46	48	50
Scheduled bus (c)	1	1	1	1	1	1
Charter bus	2	2	3	3	3	3

	2016 (see Table 4-77)	2018 (a)	2022	2027	2032	2037
Airport parking shuttles (c, f)	40	40	40	40	40	40
Employee parking shuttle (c)	31	31	38	39	42	46
Total	**835**	**1,045**	**1,176**	**1,281**	**1,393**	**1,516**

(a) 2018 TNC volumes reflect observed 2018 activity. Private vehicle, limousine, and charter bus volumes assumed to grow at same rate as peak hour enplanements growth from 2016 to 2018.

(b) 2018 levels estimated based on activity through November 2018. 2022 through 2037: Aviation Demand Forecasts, Master Plan Update, Nashville International Airport, June 2018.

(c) Assume no peak hour volume growth as these modes are assumed to operate on a schedule.

(d) By late 2018, shared-ride van service had ceased and scheduled van service reduced to one trip per hour, or less.

(e) Assumes that vehicles operate on a schedule during peak periods and that volumes would increase only with the introduction of new operators. Assume constant peak hour volumes through 2022; beyond 2022, assume peak hour volume increase at 50% the growth r ate in hourly passengers.

(f) Includes shuttles for Terminal Lot A, Economy B, Economy C, and BNA Express.

Source: InterVISTAS, January 2019.

Table 4-80 summarizes future peak hour volumes for vehicles using the Arrivals Level curbsides, the Ground Transportation Roadway, and the Ground Transportation Center (GTC) for the "high" TNC impact scenario, as this scenario has the largest capacity requirements for the GTC. Volumes are assumed to increase as follows:

- **TNCs.** TNC volumes are assumed to increase at the rates shown in **Table 4-80**, which are identical to the rates predicted for the Departures Level. Based on observations that despite the increase in TNC activity from March 2016 to March 2017, the ratio of Arrivals Level peak hour trips (which are almost exclusively private vehicles) to monthly passengers remained constant, it was determined that the growth in TNCs was *not* due to customers switching from other curbside modes and instead, was predominantly from customers who previously used taxicabs, public parking, rental cars, and off-Airport parking.

- **Taxicabs**. Taxicab volumes are assumed to decrease at the rates shown in **Table 4-80**, which are identical to the rates predicted for the Departures Level. This rate reflects the growth in activity due to passenger growth as well as the reduced market share that taxis serve. Trips lost due to decreased market share are assumed to have shifted to TNCs.

- **Private vehicles.** Private vehicle volumes are assumed to increase at the same rate as hourly passengers through 2022. Beyond 2022, it is assumed that the growth in TNC hourly traffic starts to include passengers who previously used private vehicles at the curbsides. In 2027, it assumed that 25% of TNC volume growth due to mode shifts is from customers switching from private vehicles at the curbs. In 2032 and the 2037, that value is assumed to be 33% and 50%, respectively.

- **Limousines and charter buses.** Volumes are assumed to increase at the same rate as hourly passengers.
- **Scheduled and shared-ride vans.** By late 2018, shared-ride van service at the Airport had ceased and scheduled van service had reduced to a single operator providing service to and from Chattanooga. Therefore, future volumes were assumed to be one trip per hour.
- **Scheduled buses and airport parking shuttles.** These vehicles are assumed to operate on a schedule and thus, volumes are assumed to be constant during peak periods.
- **Off-Airport parking and hotel shuttles.** These vehicles are assumed to operate on a schedule during peak periods. Therefore, volumes will increase only with the introduction of new hotels and/or off-Airport parking facilities. To reflect the introduction of new facilities, peak hour volumes are assumed to be constant through 2022. Beyond 2022, peak hour volumes are assumed to increase at 50% the growth rate in hourly passengers.

Table 4-80. Future Peak Hour Volumes, Arrivals Level, Ground Transportation Roadway, and Ground Transportation Center

	2016 (see Table 4-78)	2018 (a)	2022	2027	2032	2037
Annual enplanements (b)	6,489,739	8,000,000	9,047,142	9,938,318	10,886,036	11,935,070
Peak hour deplanements (b)	2,652	2,999	3,391	3,725	4,080	4,473
Activity multipliers, applied to 2018 volumes (see Table 4-68)						
Private vehicles, limousines, charter buses		1	1.131	1.242	1.361	1.492
TNCs		1	1.575	2.060	2.592	3.265
Taxicabs		1	0.742	0.700	0.658	0.620
Private vehicles						
Volume based on passenger growth	659	812	919	1,010	1,106	1,212
Volume shifted to TNCs	n/a	n/a	0	(55) (c)	(109) (d)	(238) (e)
Total	**659**	**812**	**919**	**955**	**997**	**974**
TNCs						
Volume based on passenger growth	101	268	303	333	365	400
Volume shifted from private vehicles	n/a	n/a	0	55	109	238
Volume shifted from taxicabs	n/a	n/a	46	64	83	103
Volume shifted from other modes	n/a	n/a	73	100	138	135
Total	**101**	**268**	**422**	**552**	**695**	**875**
Taxicabs						
Volume based on passenger growth	116	118	133	146	160	176
Volume shifted to TNCs	n/a	n/a	(46)	(64)	(83)	(103)
Total	**116**	**118**	**87**	**82**	**78**	**73**

	2016 (see Table 4-78)	2018 (a)	2022	2027	2032	2037
Limousines	36	44	50	55	60	66
Scheduled and shared-ride vans (f, g)	14	1	1	1	1	1
Off-airport parking shuttle (h)	57	57	57	60	63	66
Hotel shuttle (h)	33	33	33	35	36	38
Scheduled bus (f)	2	2	2	2	2	2
Charter bus	4	5	6	6	7	7
Airport parking shuttles (f, i)	30	30	30	30	30	30
Parking Shuttle - BNA Express (f)	10	10	10	10	10	10
Public transit (f)	2	2	2	2	2	2
Total	**1,064**	**1,382**	**1,619**	**1,790**	**1,981**	**2,144**

(a) 2018 TNC volumes reflect observed 2018 activity. Private vehicle, limousine, and charter bus volumes assumed to grow at same rate as peak hour enplanements growth from 2016 to 2018.

(b) 2018 levels estimated based on activity through November 2018. 2022 through 2037: Aviation Demand Forecasts, Master Plan Update, Nashville International Airport, June 2018.

(c) Assumes private vehicles volumes are reduced by 25% of TNC volume growth associated with the mode shift towards TNCs.

(d) Assumes private vehicles volumes are reduced by 33% of TNC volume growth associated with the mode shift towards TNCs.

(e) Assumes private vehicles volumes are reduced by 50% of TNC volume growth associated with the mode shift towards TNCs.

(f) Assume no peak hour volume growth as these modes are assumed to operate on a schedule.

(g) By late 2018, shared-ride van service had ceased and scheduled van service reduced to one trip per hour, or less.

(h) Assumes that vehicles operate on a schedule during peak periods and that volumes would increase only with the introducti on of new operators. Assume constant peak hour volumes through 2022; beyond 2022, assume peak hour volume increase at 50% the growth rate in hourly passengers.

(i) Includes shuttles for Terminal Lot A, Economy B, and Economy C.

Source: InterVISTAS, January 2019.

Table 4-81 summarizes peak hour volumes for the Arrivals Level under the "Low" TNC Impact Scenario as this scenario creates the highest volumes for the Arrivals Level.

Table 4-81. Future Peak Hour Volumes, Arrivals Level, "Low" TNC Impact Scenario

	2016 (see Table 4-78)	2018	2022	2027	2032	2037
Annual enplanements (a)	6,489,739	8,000,000	9,047,142	9,938,318	10,886,036	11,935,070
Peak hour deplanements (a)	2,652	2,999	3,391	3,725	4,080	4,473
Activity multipliers, applied to 2018 volumes (see Table 4-68)						
Private vehicles, limousines, charter buses		1	1.131	1.242	1.361	1.492
TNCs		1	1.575	2.060	2.592	3.265
Taxicabs		1	0.742	0.700	0.658	0.620
Private vehicles						
Volume based on passenger growth	659	812	919	1,010	1,106	1,212
Volume shifted to TNCs	n/a	n/a	0	(33) (b)	(64) (c)	(136) (d)
Total	**659**	**812**	**919**	**977**	**1,042**	**1,076**
TNCs						
Volume based on passenger growth	101	268	303	333	365	400
Volume shifted from private vehicles	n/a	n/a	0	33	64	136
Volume shifted from taxicabs	n/a	n/a	46	64	83	103
Volume shifted from other modes	n/a	n/a	33	34	47	33
Total	**101**	**268**	**382**	**464**	**559**	**671**

(a) 2018 levels estimated based on activity through November 2018. 2022 through 2037: Aviation Demand Forecasts, Master Plan Update, Nashville International Airport, June 2018.

(b) Assumes private vehicles volumes are reduced by 25% of TNC volume growth associated with the mode shift towards TNCs.

(c) Assumes private vehicles volumes are reduced by 33% of TNC volume growth associated with the mode shift towards TNCs.

(d) Assumes private vehicles volumes are reduced by 50% of TNC volume growth associated with the mode shift towards TNCs.

Source: InterVISTAS, January 2019.

4.4.4.5. Curbside Requirements

As described above, the primary element defining the LOS at an airport curbside roadway is the ability of a motorist to enter and exit the curbside space of their choice (e.g., one nearest their airline door or other chosen destination). As roadway demand and congestion increases, motorists are required to stop in spaces further away from their preferred destination. This requires the motorist to either stop in a downstream curbside space, double-park, or in an extreme case, circle past the curbside area multiple times while searching for an empty space. Level of service "C" is desirable for design of a new facility or for an existing facility at medium-hub airports, recognizing that during peak hours and days of the year the level of service may fall to "D" or poorer. As noted previously, level of service on curbside roadways is estimated separately for through traffic and for curbside loading/unloading traffic, but the overall LOS is governed by the poorer of the two components.

For estimating future curbside requirements, it is assumed the curb areas will be assigned as follows (locations may vary from conditions in 2018 through 2022 as services are relocated to enable construction projects):

- Departures Level – inner roadway: serves private vehicles and limousines dropping off passengers (TNCs, which have been observed to use the inner roadway, are assumed to follow Airport policy and use only the outer roadway);
- Departures Level – outer roadway: serves all other modes dropping off passengers and the Employee Parking Shuttle (which drops off and picks up passengers on this level);
- Arrivals Level – inner roadway: serves airport parking shuttle buses picking up and dropping off customers parking in Lot A, Lot B, and the Economy Lot;
- Arrivals Level – middle roadway: serves private vehicles picking up passengers;
- Arrivals Level – outer roadway: serves private vehicles picking up passengers and the BNA Express Park shuttle picking up passengers; and
- Ground Transportation roadway: serves valet parking customers.

All other activity is assumed to occur in the Ground Transportation Center.

Table 4-83 summarizes the curbside requirements for 2016 through 2037 to achieve LOS C or better for vehicle unloading and loading. These requirements reflect the volumes presented in **Table 4-79**

and **Table 4-80** and the dwell times and vehicle lengths presented in **Table 4-76**. Other assumptions include:

- Demand will be distributed among the curbside zones based on hourly seats, during the curbside's peak period, associated with air carriers associated with each curbside zone. These distributions are provided in **Table 4-82**.
- For the Arrivals Level, observations made in Spring 2019 indicated that of the private vehicles using the Arrivals Level, approximately 32% were using the Outer curbside. This proportion is maintained through the planning period though in practice, it is likely that during periods of increased activity on the Middle curbside, a higher share of traffic would use the Outer curbside to avoid Middle curbside congestion.
- For the Departures Level roadways and the Arrivals Level Middle curbside, requirements reflect the length of curb required to achieve a curbside utilization ratio of 1.30 or better (which, as shown on **Table 4-74**, corresponds with LOS C.
- For the Arrivals Level Outer curbside (which is limited to two total lanes), requirements reflect the length of curb required to achieve a curbside utilization ratio of 1.00 or lower.

Table 4-82. Assumed Curbside Activity Distribution

	Distribution of Airline Seats During Period Associated with Curbside Peak Hour	
	2016	2018 - 2037
Departures Level:		
Inner curbside		
North zone (north of northern crosswalk)	16.1%	20.5%
Middle zone (between crosswalks)	16.8%	36.5%
South zone (south of southern crosswalk)	67.1%	43.0%
Outer curbside		
North zone (north half of curb)	16.1%	37.7%
South zone (south half of curb)	83.9%	62.3%
Arrivals Level:		
Inner curbside		
North zone (north of northern crosswalk)	13.5%	20.1%
Middle zone (between crosswalks)	28.0%	31.7%
South zone (south of southern crosswalk)	58.5%	48.3%

	Distribution of Airline Seats During Period Associated with Curbside Peak Hour	
Outer curbside		
North zone (north half of curb)	26.7%	45.2%
South zone (south half of curb)	73.3%	54.8%

Source: InterVISTAS, 2019, based on Diio airline seat reports for a Sunday and Monday in October, 2016 and 2018.

Table 4-83. Curbside Requirements – Vehicle Unloading and Loading Areas

		Required curbside length (linear feet) / Level of service provided by existing capacity					
	Existing capacity (linear feet)	2016	2018	2022	2027	2032	2037
Departures Level:							
Inner curbside							
North zone	306	75/A	115/A	115/A	95/A	95/A	95/A
Middle zone	147	75/A	**175/D**	**175/D**	**155/D**	**155/D**	135/C
South zone	305	250/B	190/A	190/A	190/A	175/A	155/A
Outer curbside							
North zone	274	125/A	225/B	245/C	265/C	**280/D**	**345/D**
South zone	274	**295/D**	255/C	270/C	**315/D**	**360/D**	**390/E**
Arrivals Level (a):							
Inner curbside (b)	400	180/A	180/A	180/A	180/A	180/A	180/A
Middle curbside							
North zone	210	60/A	95/A	95/A	95/A	115/A	115/A
Middle zone	120	95/B	**135/D**	**135/D**	**155/D**	**155/D**	**155/D**
South zone	190	175/C	175/C	190/C	**210/D**	**210/D**	**230/D**
Outer curbside							
North zone	280	50/A	125/A	125/ A	150/A	150/A	150/A
South zone (c)	250	175/A	150/A	150/A	175/A	175/A	175/A
Ground Transportation:							

Roadway	385	0	0	0	0	0	0

Note: Bold numbers indicate requirements that exceed existing capacity.

(a) Prior to the 2019 opening of the Ground Transportation Center (GTC), private vehicles were not allowed to use the Outer curbside as it was reserved for commercial vehicles. For 2016 and 2018, the table reflects conditions assuming the GTC had been in place.

(b) Assumes one space for the shuttle route serving each of the three remote parking lots.

(c) Excludes 30 linear feet reserved for BNA Express shuttle.

Source: InterVISTAS, 2019.

As shown, the Departures Level – inner curbside, middle zone requires additional capacity starting in 2018 while the other two zones have sufficient capacity. The Departures Level – outer curbside requires additional length in the south zone by 2027 and additional length in the north zone by 2032 The Arrivals Level – inner curbside, Arrivals Level – outer curbside, and Ground Transportation Roadway are expected to be able to accommodate demand through the planning period. The Arrivals Level – middle curbside requires additional capacity in the middle zone in 2018 and the south zone by 2027.

The other component of curbside requirements is the number of lanes required to carry vehicular volume, recognizing that lane capacity is influenced by the LOS provided for vehicles loading and unloading. As shown on **Table 4-74**, a 4-lane curbside roadway (such as the Departures Level – inner curbside) that operates at LOS C for vehicle loading and unloading has a maximum capacity of 2,680 vehicles per hour. As shown on **Table 4-75**, to achieve LOS C or better for the roadway, the ratio of the total volume on the roadway versus the capacity needs to be 0.6 or lower. Therefore, a 4-lane curbside operating at LOS C for vehicle loading or unloading can accommodate approximately 1,600 vehicles per hour and achieve LOS C for the roadway lanes. However, if a curbside roadway is interrupted by pedestrian crosswalks, the capacity is reduced by the portion of the hour when the crosswalks are occupied. Based on crosswalk surveys conducted during BNA Vision and observations in Spring 2019, it is estimated that the pedestrian activity in the crosswalks obstructs each crosswalk approximately 30% of the time during the peak hour. Thus, for the Departures Level – inner curbside and the Arrivals Level – middle curbside, each of which has two crosswalks, the amount of time when the road is not obstructed by pedestrians at one or both crosswalks is approximately 49%. For planning purposes, it was assumed that through increased control of the crosswalk and efforts to reduce the frequency of pedestrian crossings, this value could be raised by a factor of 1.05, to approximately 51%.

Table 4-84 summarizes the Departures Level curbside roadway lane requirements under two scenarios: (1) the curbside unloading and loading areas operate at the service levels identified in **Table 4-83**, with the poorest zone governing, and (2) the curbside unloading and loading areas operate at LOS C or better in all zones due to geometric changes or operational strategies than improve the distribution of activity between zones or between curbs on the same level.

Table 4-84. Curbside Requirements – Curbside Roadway Lanes, Departures Level

	2016	2018	2022	2027	2032	2037
Departures Level – inner curb:						
Volume (vehicles per hour)	468	577	545	513	475	409
Curbside LOS for unloading	B	D	D	D	D	C
Capacity (vehicles per hour) (a)	1,443	1,132	1,132	1,132	1,132	1,367
Volume / capacity (v/c) ratio	0.32	0.51	0.48	0.45	0.42	0.30
Additional lanes required to achieve v/c of 0.6 (LOS C) or lower	n/a	n/a	n/a	n/a	n/a	n/a
Departures Level – outer curb:						
Volume (vehicles per hour)	368	468	632	768	918	1,109
Curbside LOS for unloading	D	C	C	D	D	E
Capacity (vehicles per hour) (a)	860	1,580	1,580	860	860	750
Volume / capacity (v/c) ratio	0.43	0.30	0.40	0.89	1.07	1.48
Additional lanes required to achieve v/c of 0.6 (LOS C) or lower	n/a	n/a	n/a	1	1	1
Additional lanes required to achieve v/c of 0.6 *if curbside LOS for unloading achieved LOS C or better*	n/a	n/a	n/a	0	0	1

(a) Includes capacity reduction due to pedestrian activity in crosswalks.

Source: InterVISTAS, 2019.

As shown, the Departures Level – inner curb roadway has sufficient capacity to meet demand through 2037 while the Departures Level – outer curb would need one additional lane in 2027, unless the curbside unloading LOS can be improved to LOS C or better. In that case, the additional lane would be needed prior to 2027. The need for the additional could be potentially be mitigated by encouraging some outer curb traffic to use the inner curb, and/or choosing to accept LOS D.

Table 4-85 summarizes the Arrivals Level curbside roadway lane requirements under two scenarios: (1) the curbside unloading and loading areas operate at the service levels identified in **Table 4-83**, with the poorest zone governing, and (2) the curbside unloading and loading areas operate at LOS C or better in all zones due to geometric changes or operational strategies than improve the distribution of activity between zones or between curbs on the same level.

Table 4-85. Curbside Requirements – Curbside Roadway Lanes, Arrivals Level

	2016	2018	2022	2027	2032	2037
Arrivals Level – inner curb:	Curb serves 30 buses per hour, significantly below the capacity of a one-lane roadway					
Arrivals Level – middle curb:						
Volume (vehicles per hour)	448	552	625	664	708	732
Curbside LOS for loading	C	D	D	D	D	D
Capacity (vehicles per hour) (a)	806	439	439	439	439	439
Volume / capacity (v/c) ratio	0.56	1.26	1.43	1.52	1.62	1.67
Additional lanes required to achieve v/c of 0.6 (LOS C) or lower	n/a	1	1	1	2	2
Additional lanes required to achieve v/c of 0.6 *if curbside LOS for unloading achieved LOS C or better*	n/a	1	1	1	1	1
Arrivals Level – outer curb:						
Volume (vehicles per hour)	211	260	294	313	333	344
Curbside LOS for loading	A	A	A	A	A	A
Capacity (vehicles per hour) (a)	880	880	880	880	880	880
Volume / capacity (v/c) ratio	0.24	0.31	0.35	0.36	0.38	0.39
Additional lanes required to achieve v/c of 0.6 (LOS C) or lower	n/a	n/a	n/a	n/a	n/a	n/a

Source: InterVISTAS, 2019.

As shown, the Arrivals Level – middle curb requires up to two additional lanes, depending on whether the curbside loading LOS improves to LOS C. Due to the locations of columns supporting the Departures Level, it is unlikely this roadway could be widened. Therefore, LOS improvement would require diversion of volume to the Arrivals Level – outer curb, which could, in turn, require additional lanes to accommodate the increased volumes.

4.4.4.6. Ground Transportation Center

The Ground Transportation Center (GTC), located on the first level of Garage A, opened in late 2018. For purposes of facility requirements, it is assumed the GTC accommodates pickup operations for the following modes:

- TNCs
- Taxicabs
- Limousines
- Off-Airport parking shuttles
- Hotel shuttles
- Scheduled and shared-ride vans
- Scheduled buses
- Charter buses
- Public transit

Table 4-86 summarizes the number of loading positions required in the GTC for each of these modes. In addition to these loading positions, it is recommended that a five-vehicle taxicab feeder queue be provided close to the taxicab loading area to ensure that customers do not need to wait for a vehicle.

Table 4-86. Ground Transportation Center Requirements

	Existing Capacity	Required loading positions					
		2016	2018	2022	2027	2032	2037
TNCs	24	7	10	14	17	21	25
Taxicabs	13	5	4	4	4	3	3
Limousines	13	11	12	13	14	16	17
Scheduled and shared-ride vans	(a)	5	1	1	1	1	1
Off-airport parking shuttle	9	6	6	6	6	6	6
Hotel shuttle	7	6	6	6	6	6	6
Scheduled bus	1	1	1	1	1	1	1
Charter bus	5	2	2	3	3	3	3
Public transit	1	1	1	1	1	1	1

(a) No space is currently assigned to scheduled vans. This service is assumed to use off-airport parking shuttle area.

Source: InterVISTAS, 2019.

As shown, the current allocation of space is expected to be able to substantially meet requirements through 2037. TNCs would require one additional position by 2037 and limousines would require four (4) additional positions.

A key assumption in these determinations is the average dwell time. For TNCs, the average dwell time was determined from a dwell time survey conducted in 2017 when TNCs picked up passengers in the Garage located immediately across from the Terminal (this garage was demolished in 2019). Observations conducted in early 2019 in the GTC indicted that dwell times appeared to be longer than those observed in 2017. This was potentially due to the longer walking distance between the Terminal and the TNC pickup area located in the GTC. In 2017, if a passenger requested a TNC while in the Terminal, the passenger would likely arrive at the TNC loading area before their vehicle. With the GTC, when a passenger requests a TNC while in the Terminal, there is an increased likelihood that the vehicle arrives at the pickup zone before the passenger. Requirements described above assume implementation of measures (e.g., prohibiting passengers from hailing a TNC until the passenger is close to the TNC loading area) that will reduce the chance that a TNC arrives at the GTC before their passenger does.

4.4.5. Public Parking

From 2018 through 2023, the Airport will be implementing improvements to the parking facilities, including removing the existing public parking garage and replacing it with approximately 7,000 total garage spaces. This section summarizes public parking demand and corresponding public parking facility requirements through the planning period. Requirements are presented for both a "design day" and a "holiday." The design day represents a typical busy day during a busy month but does not represent the busiest day of the year, as there are a limited number of days, such as holidays, when Airport parking demand is expected to be significantly higher than other days during the year. Thus, the design day is used to identify the quantity of spaces needed on a day-to-day basis that should be provided in parking structures and/or paved surface parking lots. Conversely, the holiday demand represents the busiest day of the year; spaces used only during such periods may be built as temporary facilities.

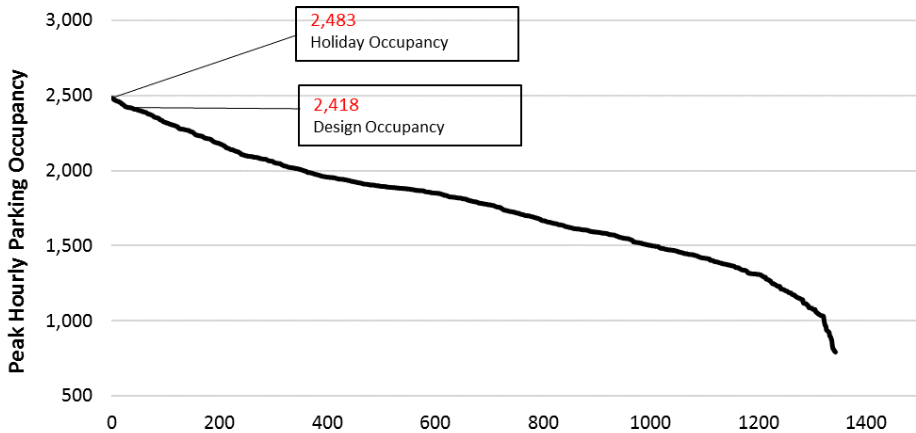
4.4.5.1. Base Year Activity

For public parking requirements, 2018 represents Base Year conditions. Due to the ongoing changes in uses of parking, TNCs, and other services, Base Year conditions reflect activity observed in 2018 to provide the most up-to-date basis possible.

Historical Analysis

Current and historical peak period occupancies, by facility, provided the basis for estimates of future public parking requirements. These data were analyzed to identify the design day occupancy and the peak occupancy. For 2018, the design day was identified by sorting the observed occupancies for each facility during October and November and ordering them from highest to lowest, creating an "s-curve". The s-curve for the Terminal Garage is shown in **Figure 4-32** and is an example of the curves developed for each facility.

Figure 4-32. Daily Peak Parking Occupancy, October and November 2018, Terminal Garage



Source: InterVISTAS, from data provided by MNAA.

Similar s-curves were developed for all parking facilities; this peak occupancy data is summarized in **Table 4-87**. The 'peak premium,' which represents the difference between the busiest day of the year and the design day (expressed as a share of the design day) are also identified in **Table 4-87.** A comparison of peak occupancy data with passenger volumes reveals that parking occupancy has increased at a slower rate than passenger growth. As shown in **Table 4-88**, the tendency of passengers to park in Terminal Area facilities, as measured by design day occupancy compared to monthly enplanements, decreased 23% from 2017 to 2018. Over the same period, the tendency of passengers to park in Remote facilities increased 2%.

Table 4-87. Parking Occupancy, October 2018, All Facilities

	Design Day Occupancy	Peak Occupancy	Peak Premium
Terminal Area Parking:			
Terminal Garage	2,418	2,483	3%
Terminal Lot A	1,077	1,136	5%
Valet	957	1,158	21%
Total	4,452	4,776	7%
Remote Area Parking:			
Economy Lot C	3,274	4,244	30%
Economy Lot B	2,230	2,693	21%
Express Park	890	946	6%
Total	6,394	7,883	23%

Source: InterVISTAS, January 2019

Table 4-88 - Parking Demand and Monthly Passengers, October 2017 and 2018

		October 2017	October 2018	*Growth*
Monthly Epax.		654,334	771,444	18%
Terminal Area Parking:		Design day space demand		*Growth*
Terminal Garage	Spaces	2,361	2,418	2%
	Spaces per 1,000 Epax.	3.61	3.13	(13%)
Terminal Lot A	Spaces	1,843	1,077 (a)	(42%)
	Spaces per 1,000 Epax.	2.82	1.40	(50%)
Valet	Spaces	699	957	37%
	Spaces per 1,000 Epax.	1.07	1.24	16%
Total	Spaces	4,902	4,402	(9%)
	Spaces per 1,000 Epax.	7.49	5.77	(23%)
Remote Parking:				
Economy Lot C	Spaces	2,842	3,274	15%
	Spaces per 1,000 Epax.	4.34	4.24	(2%)
Economy Lot B	Spaces	2,031	2,230	10%
	Spaces per 1,000 Epax.	3.10	2.89	(7%)
Express Park	Spaces	421	890	111%
	Spaces per 1,000 Epax.	0.64	1.15	79%
Total	Spaces	5,294	6,394	21%
	Spaces per 1,000 Epax.	8.08	8.28	2%

Epax. = enplaning passengers

(a) Capacity reduced prior to October 2018 due to construction.

Source: InterVISTAS, January 2019

As shown in **Table 4-88**, terminal area parking (Terminal Garage, Terminal Lot A, and Valet) has experienced a larger decrease in passenger willingness to park than remote parking (Economy Lot B, Economy Lot C, and BNA Express Park). While the overall decrease in parking demand is likely the result of the increasing popularity of TNCs, the larger decrease in terminal area parking demand per passenger is likely due to frequently full facilities that required passengers to park elsewhere. The frequently full conditions were the result of rapid passenger growth as well as ongoing construction in 2018 that reduced the capacity of Terminal Lot A.

Unconstrained Demand Estimate

Recognizing the constrained facility conditions in 2018, future requirements for public parking demand are based on estimated demand levels that would have occurred were there no construction impacts to facility capacity.

To isolate the change in behavior of airport customers from increases in airline passenger volumes, unconstrained demand estimates are expressed as a number of occupied spaces per enplanement. The 2018 unconstrained demands were estimated as follows:

- Identify the parking space demand per passenger prior to the introduction of TNCs. As described in *Preliminary Basis of Design Report, Terminal Area Parking Garage (*Walker Consultants, May 2016) in 2016, the advent of TNCs resulted in a 6% decrease in parking space demand per passenger from 2014 to 2015. As shown on **Table 4-89**, prior to the introduction of TNCs, demand for terminal-area, remote, and total parking was 10.32, 7.52, and 17.84 spaces per 1,000 monthly passengers, respectively, during October, the peak month for parking.

- Determine the total reduction in parking demand per passenger from 2014 to 2018. As shown on **Table 4-89**, 2018 demand for parking was 14.06 spaces per 1,000 monthly passengers, respectively, a 3.78 space reduction.

- Estimate the parking demand reduction due to TNC activity. Analysis of 2018 parking activity levels compared to 2014 estimated that TNCs accounted for a 20.6% decrease in parking demand per passenger. As shown in **Table 4-89**, TNCs reduced demand for terminal-area, remote, and total parking by 2.12, 1.55, and 3.67 spaces per 1,000 monthly passengers, respectively. *It is assumed that these customers are unlikely to choose to park again.*

- Assume that the remaining reduction in parking spaces per 1,000 passengers (0.11 spaces per 1,000 passengers) was due to Terminal Garage customers choosing to park off-airport or use non-TNC modes. *It is assumed that once new Garages B and C are complete, these customers will return and park in terminal-area parking facilities.*

- Assume that upon completion of Garages B and C, customer use of terminal-area versus remote facilities will return to the distribution observed prior to the introduction of TNCs. It is estimated that in 2018, demand for 2.31 spaces per 1,000 passengers occurred in the remote parking lots instead of terminal-area parking facilities due to insufficient terminal-area parking capacity.

Table 4-89. Unconstrained Parking Demand, October 2018

	Spaces per 1,000 monthly enplanements		
	Terminal	Remote	Total
Parking demand prior to introduction of TNCs	10.32	7.52	17.84
Shift to TNCs (20.6%)	(2.12)	(1.55)	(3.67)
Capacity constraints			
Shift from Terminal-area to Remote [A]	(2.31)	2.31	0
Shift to off-Airport parking and other modes [B]	(0.11)	0	(0.11)
Actual October 2018 (see Table 4-88) [C]	5.77	8.28	14.06
Unconstrained October 2018 [D = C – A – B]	8.20	5.97	14.17

Source: InterVISTAS, January 2019.

Based on Walker Consultants report for 2015 conditions, adjusted to reflect Walker conclusions regarding TNC impact on parking demand (decrease of 6% from 2014 to 2015).

4.4.5.2. Activity Growth Assumptions

As discussed in **Section 4.4.2.2**, passenger use of parking facilities is expected to gradually decrease due to continued maturation of TNC market, increasing share of autonomous vehicles, and increasing use of subscription-based car-sharing services. The parking demand forecast reflects potential variations in the rate of adoption of these services. In addition to the evolution of mode share, assumptions used in developing the future parking requirements include:

- Upon completion of terminal area facilities construction in 2023, demand currently diverted to remote parking facilities come back to terminal area facilities. The share of parking demand occurring in the terminal-area versus remote parking facilities is assumed to remain constant through the planning period. In practice, however, the Airport can use pricing and other strategies to modify those shares to encourage or discourage use of certain parking facilities.

- Holiday demand will increase at the same rate as design day parking demand.

- Future design day parking space requirements include a circulation factor to reflect the difficulty motorists have in locating the last available parking spaces in a large facility, vehicles circulating within a parking structure, and to allow for improperly parked vehicles and other inefficiencies. Holiday requirements do not include a circulation factor as during holiday periods, airport parkers typically expect to experience congested conditions and may allow extra time to find vacant parking spaces.

4.4.5.3. Requirements

Parking space requirements reflect the "low TNC impact" scenario, as that would result in the higher capacity requirement, and are provided in **Table 4-90**. As shown, current facility capacity (10,800 spaces) is 600 spaces and 2,400 spaces below typical busy day and peak day demand, respectively. During such periods, customers frequently parked in aisles and in other areas not intended for parking. Once Garages A, B and C are completed in 2023, future facility capacity (17,658 spaces) is expected to accommodate design day and holiday requirements through 2037.

As shown in **Table 4-90**, in 2032 through 2037, remote parking requirements are expected to exceed supply.

Table 4-90. Total Parking Requirements, "Low TNC Impact" Scenario

	Baseline (2018)	PAL 1 (2022)	PAL 2 (2027)	PAL 3 (2032)	PAL 4 (2037)
Annual enplanements	8,000,000	9,047,142	9,938,318	10,886,036	11,935,070
Terminal Area:					
Total space per enplanement	8.20	7.84	7.42	7.10	6.80
Design Day Demand	6,800	7,150	7,550	7,950	8,350
Design Day Requirement (a)	7,100	7,500	7,950	8,350	8,750
Parking Supply (b)	4,031	7,673	11,783	11,783	11,783
Surplus/(Shortfall)	(3,069)	173	3,833	3,433	3,033
Remote Area:					
Total space per enplanement	5.97	5.71	5.41	5.18	4.96
Design Day Demand	4,600	4,850	5,150	5,400	5,650
Design Day Requirement (a)	4,850	5,100	5,650	5,950	6,250
Parking Supply	6,769	5,875	7,775	7,775	7,775
Surplus/(Shortfall)	1,919	775	2,125	1,825	1,525
Total Parking:					
Total space per enplanement	14.17	13.55	12.82	12.28	11.76
Design Day Demand	11,400	12,000	12,700	13,350	14,000
Design Day Requirement (a)	11,950	12,600	13,600	14,300	15,000
Holiday Requirement	12,950	13,650	14,450	15,200	15,900
Parking Supply (b)	10,800	13,548	19,558	19,558	19,558
Surplus/(Shortfall) – Design Day (c)	(1,150)	948	5,958	5,258	4,558
Surplus/(Shortfall) – Holiday	(2,150)	102	5,108	4,358	3,658

Source: Parking requirements—InterVISTAS, January 2019; Parking supply—MNAA.

(a) Until 2023, space requirements are based on a 10% circulation allowance both for Terminal-Area and Remote parking facilities. Assuming space guidance upon completion of Garage A, B and C in 2023, space requirements include 5% allowance for Terminal-Area parking facilities and 10% for Remote parking facilities

(b) Includes valet storage, excludes valet customer service spaces at the curb.

(c) October 2018 design day occupancy is higher than 100%. Surplus/(Shortfall) for subsequent years is based on marked space availability and is based on design day requirement. Surplus/(Shortfall) estimates do not include employee and hotel demand.

4.4.5.4. High Growth Sensitivity

As noted above, the parking requirements presented in this section reflect the "Base" passenger forecast. Passenger activity growth since 2014 has exceeded projections from multiple forecasts and it is possible that growth will continue to exceed forecasts. To test potential impacts of growth exceeding forecast, the "High" passenger forecast, as presented in BNA Master Plan Update, *Aviation Demand Forecasts,* dated August 17, 2018, was applied to the future parking space-per-enplanement ratios presented in **Table 4-90** (low TNC impact scenario). The result parking requirements are summarized in **Table 4-91**.

Table 4-91. Total Parking Requirements, High Forecast Scenario

	Baseline (2018)	PAL 1 (2022)	PAL 2 (2027)	PAL 3 (2032)	PAL 4 (2037)
Annual enplanements	8,000,000	9,553,211	10,950,798	12,517,561	14,308,485
Terminal Area:					
Total space per enplanement	8.20	7.84	7.42	7.10	6.80
Design Day Demand	6,800	7,550	8,350	9,150	10,000
Design Day Requirement (a)	7,100	7,950	8,750	9,600	10,500
Parking Supply (b)	4,031	7,673	11,783	11,783	11,783
Surplus/(Shortfall)	(3,069)	123	3,433	2,633	1,783
Remote Area:					
Total space per enplanement	5.97	5.71	5.41	5.18	4.96
Design Day Demand	4,600	5,150	5,650	6,200	6,800
Design Day Requirement (a)	4,850	5,400	6,200	6,800	7,500
Parking Supply	6,769	5,875	7,775	7,775	7,775
Surplus/(Shortfall)	1,919	475	1,575	975	275
Total Parking:					
Total space per enplanement	14.17	13.55	12.82	12.28	11.76
Design Day Demand	11,400	12,700	14,000	15,350	16,800
Design Day Requirement (a)	11,950	13,350	14,950	16,400	18,000
Holiday Requirement	12,950	14,450	15,900	17,450	19,100
Parking Supply (b)	10,800	13,548	19,558	19,558	19,558
Surplus/(Shortfall) – Design Day (c)	(1,150)	198	4,608	3,158	1,558
Surplus/(Shortfall) – Holiday	(2,150)	(902)	3,658	2,108	458

Source: InterVISTAS, January 2019.

(a) Until 2023, space requirements are based on a 10% circulation allowance both for Terminal-Area and Remote parking facilities. Assuming space guidance upon completion of Garage A, B and C in 2023, space requirements include 5% allowance for Terminal-Area parking facilities and 10% for Remote parking facilities

(b) Includes valet storage, excludes valet customer service spaces at the curb.

(c) October 2018 design day occupancy is higher than 100%. Surplus/(Shortfall) for subsequent years is based on marked space availability and is based on design day requirement. Surplus/(Shortfall) estimates do not include employee and hotel demand.

4.4.6. Rental Cars

This section summarizes rental car requirements through the planning period.

4.4.6.1. Base Year Activity

The existing Consolidated Rental Car Facility (CONRAC) accommodates eleven rental car brands, which are owned by four companies: Enterprise Holdings; Hertz Corporation; AvisBudget Group; and Advantage. In November 2018, questionnaires were distributed to the four rental car companies to understand their current facility capacity and operations. Follow-up interviews were conducted to better understand the questionnaire responses and to conduct a facility walk-through. Representatives of Enterprise, Avis, and Advantage participated in the process. Hertz did not participate and therefore market share data was used to estimate their facility requirements. The facility requirements are presented in aggregate to protect the confidentiality of individual companies.

The rental car facility requirements are divided into four separate areas: Customer Service Counters, Ready and Return Garage, Quick Turn Around (QTA), and Remote Storage Sites.

4.4.6.2. Activity Growth Assumptions

The 2018 facility requirements were calculated using peak-hour transaction data from a typical busy day, as provided by the rental car companies. The 2018 requirements were then increased in accordance with (a) the passenger activity forecast and (b) the decline in rental car transactions per airline passenger, as described in **Section 4.4.2.2**.

In 2017, DeMattei Wong Architecture (DWA) developed rental car facility requirements based on 2016 activity. A comparison to DWA's estimated 2016 facility requirements is included in the descriptions below. DWA's future estimated requirements are significantly higher due to differences in assumed future changes in mode shares.

Table 4-92 summarizes the future rental car facility requirements, which reflect the "low TNC impact" scenario as this provides the more conservative assumption for rental car requirements. Key assumptions for each of the four facility elements are provided below.

Table 4-92. Rental Car Requirements

	Existing capacity	2018	2022	2027	2032	2037
Annual Enplanements		8,000,000	9,047,142	9,938,318	10,886,036	11,935,070
Customer Service Counters	45	41	43	45	46	47
Ready and Return Area (acres)	18	17.3	19.0	20.2	21.1	22.0
QTA Area						
Wash/Fuel Area (acres)	2.6	4.1	4.6	4.9	5.0	5.3
Short-Term Storage (acres)	2.2	7.2	7.9	8.4	8.8	9.2
Remote Storage Sites (acres)	27	14.5	15.9	16.9	17.6	18.4

Source: InterVISTAS, January 2019

Customer Service Counters

The number of required customer service counters was calculated for each individual company using industry-accepted standards regarding the number of counters per-bypass and per-counter-transaction. Because of the increasing number of customers that bypass the counters and go directly to their vehicle, the required number of counters is assumed to grow at half the growth rate of other rental car facilities, which is consistent with the overall industry trend.

41 counters are required in 2018, 45 in 2027, and 47 in 2037. There are currently 45 counters. Any queues that extend beyond the allocated queueing area is due to either (a) the company is not fully-staffing their counters during a peak hour and/or (b) the number of counters allocated to a single company is not sufficient for their market share. DWA also indicated a need of 41 counters in 2016.

Ready and Return Garage

The ready/return garage consists of four key components: the ready spaces (clean vehicles ready to be rented); the return spaces (rows where vehicles are returned—these vehicles are considered dirty); customer service kiosks; and exit booths/lanes. Facility requirements were identified for each of these four components, based on industry-accepted metrics regarding the required number of ready spaces, return spaces, and exit booths per the peak-hour transactions.

The requirements are summarized into an area requirement. 17.3 acres of ready/return floor space is required in 2018, 20.2 acres in 2027, and 22.0 acres in 2037. The existing ready/return garage provides approximately 18 acres. DWA estimated that 19 acres were required for ready/return in 2016.

Quick Turn Around (QTA) Areas

The QTA consists of two parts: (a) a wash and fuel area, which includes fuel islands, car wash tunnels, and vehicle queueing areas (referred to as stacking spaces) and (b) a short-term storage area. Requirements for each individual component of the QTA were developed, but they are summarized as area requirements in **Table 4-92.** It is assumed that all of the returns during the peak rental hour are processed within an hour to partly replenish the vehicles available for rentals. As such, the requirements are based on industry-accepted metrics regarding the time it takes to fuel, vacuum, and wash a vehicle. Sufficient short-term storage should exist to provide for all rentals on a typical busy day, accounting for available vehicle storage in ready/return and the wash and fuel area.

For the wash and fuel area, 4.1 acres are currently required while 2.6 acres are provided. The stacking area is under-sized according to industry standards. Also, most CONRAC QTAs include light maintenance bays, which are not included in the QTA at the Airport. The area requirement for wash and fuel increases to 4.9 acres in 2027 and 5.3 acres in 2037.

For short-term storage, 7.2 acres are required in 2018, 8.4 acres in 2027 and 9.2 acres in 2037. The current short-term storage on the roof of the QTA provides 2.2 acres. Due to the significant shortage of short-term storage area, rental car companies are frequently shuttling vehicles to the remote storage sites on peak return days and returning them to the terminal on peak rental days.

Combined, the 2018 demand for QTA area is 11.3 acres. DWA estimated that 12.23 acres of QTA area was required in 2016. DWA's estimate for remote storage is significantly lower, so it is believed that their requirement traded more short-term storage area for less remote storage area.

Remote Storage Sites

The remote storage sites consist of maintenance bays, offices, vehicle storage for maintenance, vehicle parking for in-fleeting and de-fleeting, and area for car transports to load/off-load. It was estimated that 10% of returns must be sent to the remote storage sites for maintenance needs. Data was also collected regarding in-fleeting and de-fleeting operations.

14.5 acres are required for remote activities in 2018, which increases to 16.9 acres in 2027 and 18.4 acres in 2037. Approximately 27 acres are available in the remote sites. The shortage of available short-term storage in the QTA is somewhat mitigated by the excess capacity available in the remote sites. DWA estimated that 10.9 acres were required for the remote sites in 2016.

4.4.7. Employee Parking

This section summarizes employee parking requirements through 2037. These requirements are based on those identified as part of the *Employee Parking Lot Analysis*, completed in January 2019. In general, the employee parking requirements are based the following assumptions:

- Employees currently parking at the Airport include MNAA employees, "tenant" employees (comprised of employees of concessionaires, Federal agencies, service provide, and airline employees that are not flight crew), and "commuter" employees (comprised of airline flight crews who typically park for multiple days).
- 2018 demand was based on observations of peak accumulations in July through November and December in multiple facilities used by employee parkers.
- Requirements do not include employees currently parking within leased property or off-Airport.
- Employee parking demand is assumed to grow at the average of annual growth in enplanements and annual growth in commercial operations.
- In 2019 and 2020, employee parking demand will increase slightly faster due to the introduction of a new concession management team that expects to use higher numbers of employees to staff the in-terminal concessions.
- Employee parking demand generally increases at a rate reflecting the blended growth rates in total passengers and commercial operations.
- Requirements include a 10% circulation allowance to improve a parker's ability to locate a space in a large, full parking facility.
- As of March 2019, the Airport was developing additional employee parking such that 2,285 spaces would be available by May 2019.

Table 4-93 summarizes the employee parking facility requirements. Values for 2027 and 2032 were not included in the *Employee Parking Lot Analysis* and are based on applying the growth rate assumptions used in that analysis to the interim years. As shown, following the capacity expansion (planned for completion in May 2019), the Airport will have sufficient employee parking capacity through the planning period.

Table 4-93. Employee Parking Requirements

	Required Parking Spaces					
	Post-BNA Vision capacity (a)	2019	2024	2027	2032	2037
Employee parking	2,257	1,525	1,850	1,900	2,075	2,250

(a) Includes 1,882-space expanded Employee Lot (as of June 2019), 75 spaces in the D&E Lot, and 300 spaces to be available in the new Terminal Garages.

Source: Employee Parking Lot Analysis, AECOM, January 2019.

4.4.8. Landside Facility Requirements Summary

- Roadways:
  - Ramp entering the Airport from eastbound I-40 requires one additional lane by 2022 and another by 2032.
  - Ramp exiting the Airport to westbound I-40 requires one additional lane by 2022.
  - Up to 11 other roadway segments (links) may require additional capacity if future activity varies from TARI assumptions
- Curbside – Departures Level:
  - Requires immediate redistribution of demand from inner curb to outer curb
  - Requires additional lane on outer roadway *or* relocation of Employee Shuttle from outer roadway by 2037 *and* allow up to 33% of TNCs to drop off on inner curbside
- Curbside – Arrivals Level:
  - Requires immediate redistribution of demand from middle curb to outer curb
  - Requires two additional lanes by 2032
- Ground Transportation Center:
  - Requires additional capacity for TNCs and limousines, which should be achieved by reallocating area from services that have surplus capacity

- Public Parking:
  - No additional parking spaces required following completion of Garage and TARI project.
- Rental Cars:
  - Requires an immediate 6.5 additional acres in the quick turn-around area and up to 10 total additional acres by 2037. The additional area required is to provide additional short-term storage associated with fueling and washing operations.
  - Requires one additional customer service counter by 2032 and another by 2037.
  - Requires 1.0 additional acres of ready/return capacity by 2022 and up to 4.0 total additional acres by 2037.
- Employee Parking:
  - Requires no additional capacity following completion of the programmed Employee Lot expansion and Garage B/C.

4.5. Air Cargo Capacity & Requirements

FAA design standards and industry standard planning factors were referenced from the following guidance:

- Airports Council International – North America's (ACI-NA) 2013 Air Cargo Guide
- ACRP Report 143, *Guidebook for Air Cargo Facility Planning and Development*
- IATA Airport Development Reference Manual 10th Edition

Table 4-94 provides a summary of the existing cargo buildings. In general, the *integrator carriers* (such as FedEx and DHL) concentrate on the West Side, where as the *combination carriers* (such as the airlines) are located near the passenger terminal to facilitate belly cargo operations. Detailed definition of the carrier types can be found in **Section 3.4.6, Air Cargo**, in Chapter 3, Aviation Demand Forecasts.

Table 4-94. Existing Cargo Buildings

Building No.	Building Name	Tenant Type	Square Footage	Location
4106	Old Freight Building	Integrator carrier	112,368	West Side
4143	Air Cargo Terminal 2	Integrator carrier	34,533	West Side
4144	FedEx	Integrator carrier	82,851	West Side
4321	Air Freight Building	Combination carrier	41,530	Terminal Area

Source: MNAA GIS Buildings Shapefile.

Due to the different operational needs and characteristics between integrator carriers and combination carriers, it is important to plan the facilities with their distinct preferences taken into consideration.

Figure 4-33 depicts the cargo facilities in the West Side used by the integrator carriers. The north apron is marked for three ADG-IV aircraft and is mostly utilized by FedEx Boeing 757-200s. There is an unnamed ADG-IV taxilane providing circulation between parking positions.

The south apron is marked for four ADG-III positions and two ADG-IV positions with wingtip clearance of 20 feet between each position. This apron space can accommodate a maximum of five Boeing 767-300s with wingtip clearance of 35 feet. As of late 2018 only a DHL B767 aircraft utilizes this apron on a regular basis. Occasionally an A330 charter aircraft for football teams occupy this apron when they visit Nashville for games. Building 4106 adjacent to this apron is underutilized, with only 79% of space occupied by tenants.

Figure 4-33. Existing Cargo Facilities for Integrator Carriers (West Side)

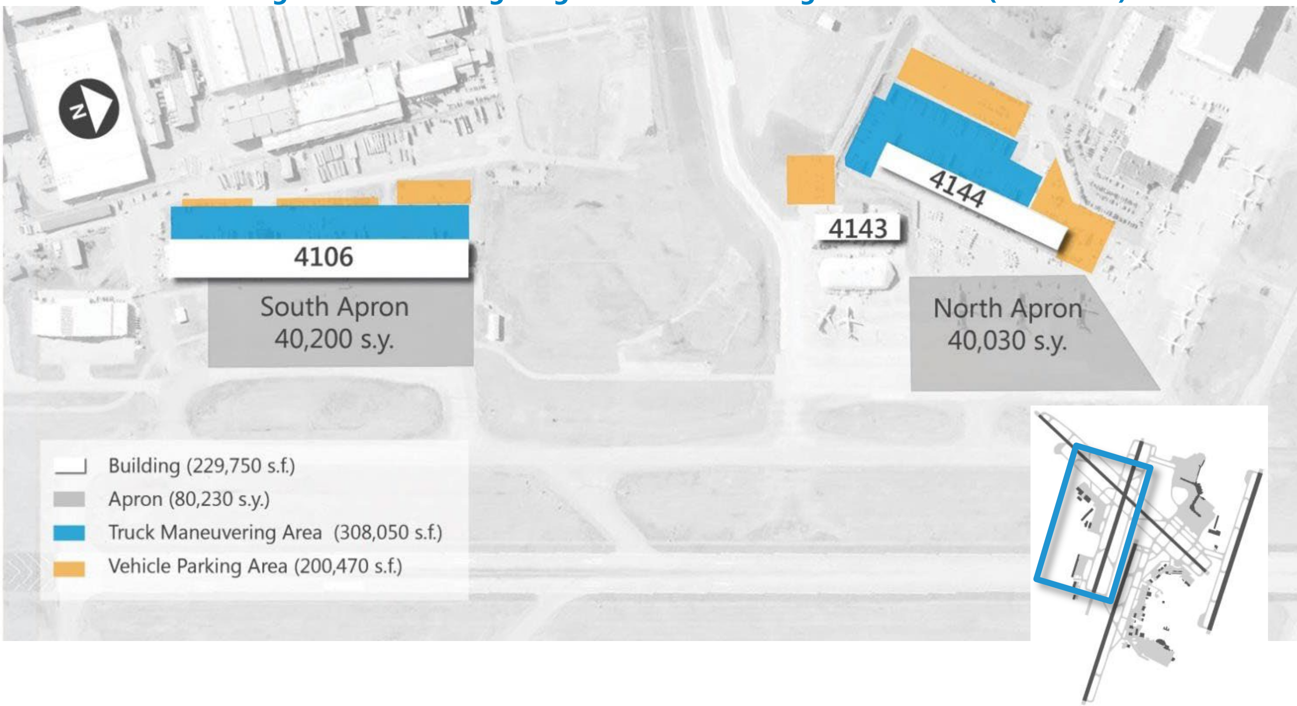
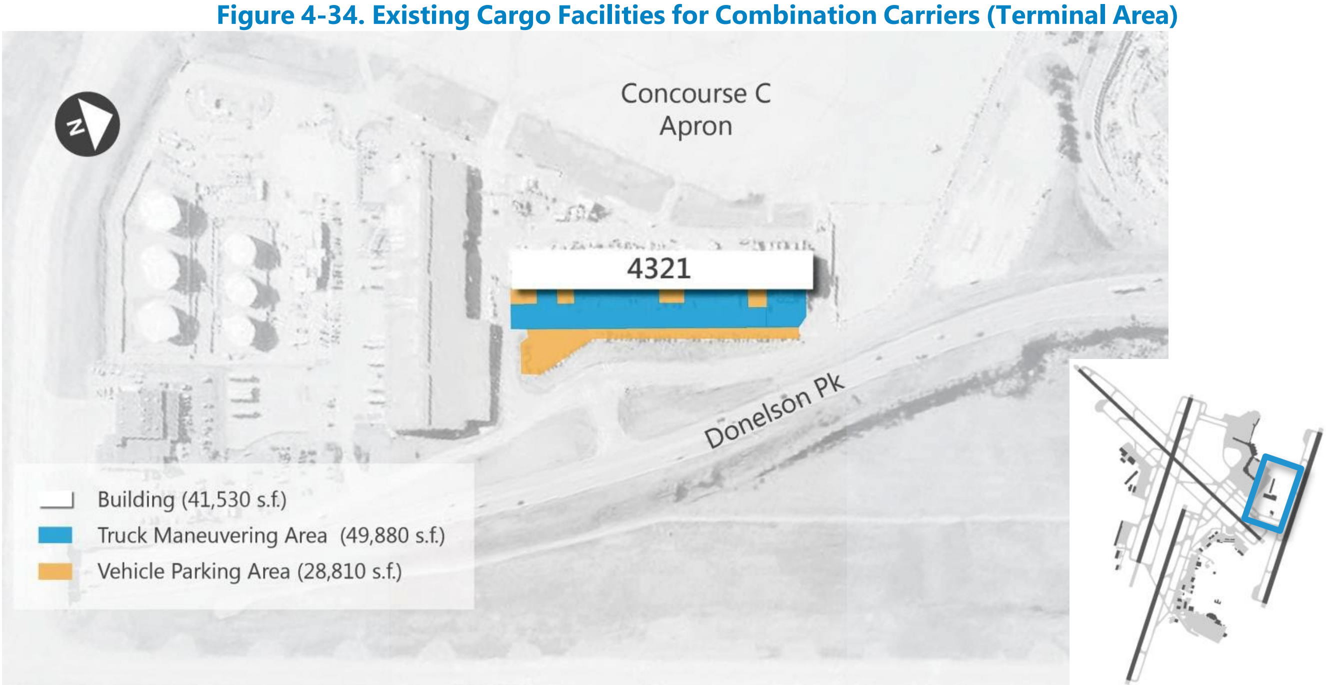


Figure 4-34 depicts the cargo facility in between the passenger terminal area and the fuel farm. This facility serves the combination carriers.

Figure 4-34. Existing Cargo Facilities for Combination Carriers (Terminal Area)



4.5.1. Air Cargo Apron Requirements

The combination carriers load their cargo to the belly compartments of their passenger aircraft, which are located at the terminal apron. This section focuses on estimating the aircraft parking needs for the integrator carriers, who currently occupy the north and south cargo aprons on the West Side.

4.5.1.1. Air Cargo Aircraft Parking Positions

The air cargo aircraft fleet mix presented in **Table 4-95** was used to determine an adequate apron area to accommodate the air cargo fleet at BNA. Based on the information found in **Section 3.4.6, Air Cargo**, in 2017, over 78% of freighter operations at BNA were flown by B757-200 aircraft and those operations are increasing with the growth of FedEx. Meanwhile, the DHL operations are driving the increase of B767-300 freighter operations at BNA. This analysis is based on the assumption that the future fleet mix for freighter at BNA will still be dominated by B757-200 with slight increase in B767-300 operations. These two aircraft are selected as the design aircraft for the cargo facility requirements.

Table 4-95. Air Cargo Design Aircraft Characteristics

Aircraft Type	Percentage of Total 2017 Cargo Operations	Wingspan(ft.)	Length(ft.)	ADG
Boeing 757-200F	78%	124.87	155.25	IV
Boeing 767-300F	8%	156.07	180.18	IV

Sources: FAA's Traffic Flow Management System Counts (TFMSC). AECOM analysis.

Based on the FAA Traffic Flow Management System Counts (TFMSC) data, in 2017 the peak month cargo operations (arrivals and departures) accounted for 10% of the total annual cargo operations (arrivals and departures). This analysis assumes this peak month ratio of 10% remains constant throughout the planning horizon.

The average day in the peak month (ADPM) operations can be calculated using the following formula:

(Annual Operations) x (Peak Month Ratio) / (30 days) = ADPM Operations

As of 2017, the cargo aprons were occupied by a maximum of four aircraft at the same time (three 757-200s on the north apron, and one 767-300 on the south apron), accounting for approximately 45% of the ADPM operations. Assuming the integrator carriers maintain similar daily scheduling profiles throughout the planning horizon (i.e. only 45% of the ADPM operations will need to be parked at BNA at the same time), the total required parking positions are interpolated from the ADPM operations and presented in **Table 4-96**. This table also provides a breakdown of the required positions for the two design aircraft types, based on their corresponding proportions in the fleet mix.

Table 4-96. Air Cargo Aircraft Parking Position Requirements

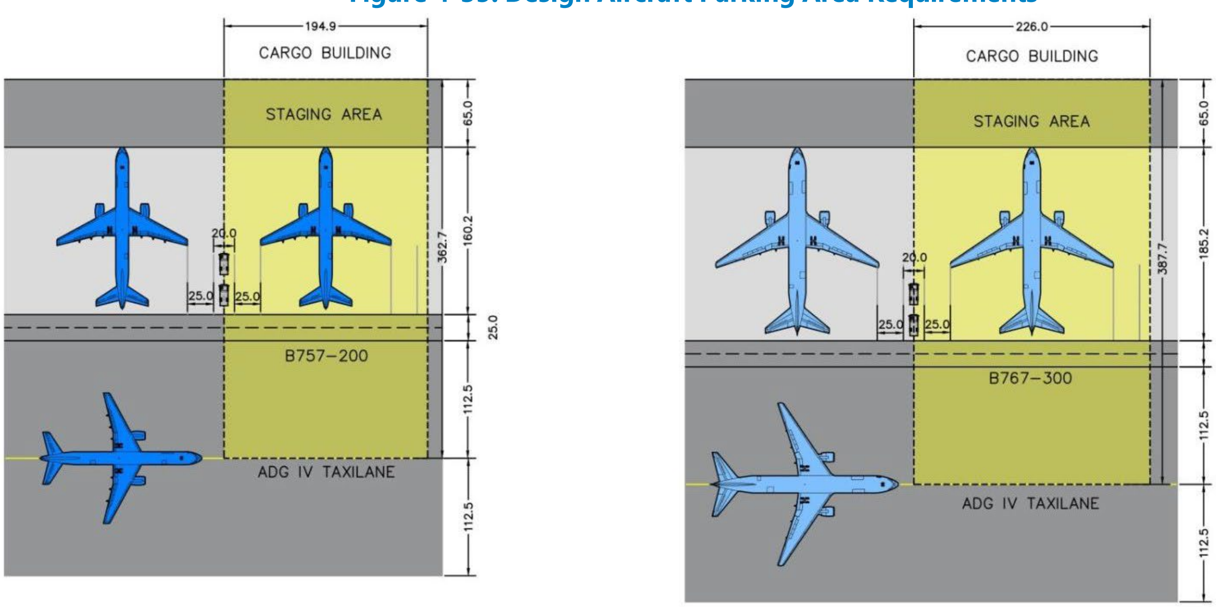
Year	Annual Operations[1]	ADPM Operations	Required Design Aircraft Positions		
			Total	B757-200	B767-300
2017 (Existing)	2,662	9	4	3	1
2022	3,099	11	5	3	2
2027	3,343	12	6	4	2
2032	3,610	13	6	4	2
2037	3,901	14	7	5	2

Sources:
1. *BNA Master Plan Update 2018: Demand Forecast Report*

4.5.1.2. Air Cargo Aircraft Parking Apron Area

The air cargo fleet presented in **Table 4-96** was used to determine adequate apron area to accommodate the required aircraft parking positions.

Figure 4-35. Design Aircraft Parking Area Requirements



As depicted in **Figure 4-35**, the size for each aircraft parking position includes:

- ADG-IV taxilane clearance (112.5-feet)
- Aircraft stand (aircraft length plus 5-foot aircraft tail clearance)
- 25-feet-wide vehicle service road (VSR) for GSE operations
- 65-feet of clearance from head of stand service road to building for marshaling and other support functions
- 25-feet of clearance between aircraft wingtips and fixed/movable objects
- 20-foot ground support equipment (GSE) maneuvering/staging area between aircraft parking positions

The apron paving area requirements for B757-200 and B767-300 parking are approximately 7,900 SY and 9,800 SY respectively.

Table 4-97 summarizes the cargo apron area requirements. The existing cargo apron areas are approximately 80,230 square yards in total. Therefore, the cargo aprons are expected to be sufficient to accommodate existing and future cargo operations through the planning horizon.

Table 4-97. Cargo Aircraft Parking Apron Area Requirements

Year	ADPM Operations	Required Parking Positions[1]	Apron Size	
			SF	SY
2017 (Existing)	9	4	301,500	33,500
2022	11	5	389,700	43,300
2027	12	6	460,800	51,200
2032	13	6	460,800	51,200
2037	14	7	531,900	59,100

Note:

1. *Calculated based on the previously discussed assumption that only 45% of the ADPM operations will need to be parked at BNA at the same time*

Based on the assumed square yardage per aircraft parking position and percentage split of 757 and 767 operations, it is estimated that the existing apron area of 80,230 square yards can accommodate up to 9 design aircraft positions (seven 757-200s and two 767-300s) at a given time, and therefore is adequate to serve the projected cargo aircraft parking demand. In addition to the projected cargo aircraft parking demand, the capacity of nine (9) design aircraft positions can also absorb some additional demand from a new carrier. Should any new carrier require more cargo aircraft parking position than calculated in this analysis, the cargo apron in the west can be expanded to accommodate the growth.

4.5.2. Air Cargo Building Area

Air cargo building requirements are estimated as a function of projected cargo volumes. The air cargo building must have sufficient space for the following functions:

- Consolidating outbound freight into unit load devices (ULD) or onto cargo carts for loading onto cargo aircraft
- Breaking down, sorting, and loading inbound freight onto individual trucks for ground shipping.
- Short-term storage of cargo while awaiting additional material for consolidation, aircraft arrival/departure, and truck arrival/departure

Typically, in order to avoid congestion and maintain a smooth process, increase in cargo volume would mean higher building space requirements. Based on information found in **Section 3.5.2**, *Air Cargo Forecast*, cargo throughput is expected to grow at BNA. **Table 4-98** provides a summary of projected cargo throughput by integrator carriers and combination carriers. As discussed in Section 3.4.6, the air mail at BNA is carried by combination carriers as well. The cargo building facility requirements are estimated based on the different cargo throughputs associated with each carrier type.

Table 4-98. Projected Cargo Throughput by Type

Year	Freight (Tons)		Air mail (tons)
	Integrator Carriers[1]	Combination Carriers[1]	Combination Carriers[2]
2017 (Existing)	39,720	8,633	808
2022	46,234	11,031	959
2027	49,878	13,301	1,034
2032	53,858	15,812	1,117
2037	58,210	18,638	1,207

Sources:
1. *Chapter 3, Aviation Demand Forecasts, Table 27*
2. *Chapter 3, Aviation Demand Forecasts, Table 26*

Cargo building utilization rate is a factor used in determining projected building space required for cargo operations. The cargo utilization rate is calculated through dividing cargo volume by the available cargo processing space. The resulting quotient is a measure of cargo tonnage per square foot. Utilization rates can fluctuate based on how the cargo is processed, as well as the addition or removal of available cargo processing space.

According to the previous master plan, BNA experienced cargo building utilization rates between 0.26 and 0.36 annual cargo tons per square foot. As of 2018, the cargo buildings on the west side are less utilized, with a utilization rate of approximately 0.18 tons per square foot.

ACRP Report 143, *Guidebook for Air Cargo Facility Planning and Development*, indicates that the building utilization rate for all-cargo carriers (i.e. integrator carriers) is typically 0.81 annual ton per square foot, and the rate for passenger airlines (i.e. combination carriers) is typically 0.64, based on extensive data collection efforts. In order to avoid overbuilding based on current low building utilization rates, these typical rates suggested by ACRP are used to calculate the future cargo building requirements at BNA to process the projected cargo tonnage.

Table 4-99 provides a summary of the building space requirements by carrier types.

Table 4-99. Projected Cargo Building Requirements by Carrier

Year	Integrator Carriers (0.81 annual ton per square foot) Existing Space: 229,750 s.f.		Combination Carriers (0.64 annual ton per square foot) Existing Space: 33,030 s.f.			
	Building s.f. Required for Freight	% of the Existing Building Utilized	Building s.f. Required for Freight	Building s.f. Required for Air Mail	Total Building s.f. Required	% of the Existing Building Utilized
2017	49,100	21%	13,500	1,300	14,800	45%
2022	57,100	25%	17,300	1,500	18,800	57%
2027	61,600	27%	20,800	1,700	22,500	68%
2032	66,500	29%	24,800	1,800	26,600	81%
2037	71,900	31%	29,200	1,900	31,100	94%

Source: AECOM Analysis.

As summarized above in **Figure 4-33**, the three buildings leased to, or are suited to be leased to integrator carriers on the West Side provide 229,750 square feet of total building space, which is more than adequate for the projected integrator carriers demand throughout the planning horizon. Since the integrator cargo buildings are underutilized in the current condition, the available capacity could be available to new carriers that wish to start operations at BNA.

Only one building is used by the combination carriers - Building 4321 (Air Freight Building) comprising 41,530 square feet located near the passenger terminal for easier integration with airline operations. Only 83% of the Building 4321 is currently occupied by combination carriers (i.e. 33,030 square feet), and the remaining 17% of space is rented to tenants providing ground support equipment (GSE) maintenance and support services. Although **Table 4-99** indicates that the required building footage for the projected freight and air mail tonnage is lower than 33,030 square feet, the airlines in Building 4321 are experiencing space shortage as of late 2018 because they use this building not only for belly cargo processing, but also for GSE storage and maintenance. In order to ensure sufficient space for cargo processing, a separate facility should be identified for GSE. Moreover, based on industry experience, some airlines experience space shortage due to a suboptimal workflow. Enhancing cargo processing workflow would help airlines better utilize existing building space without requiring facility expansion.

4.5.3. Cargo Landside Facilities

The landside facilities are a key element in evaluating the overall efficiency of cargo operations. As noted in the ACI-NA Air Cargo Guide, the ground networks of integrator carriers are expanding, increasing demand for adequate landside facilities at key junction points. Landside facilities include mainly the truck docks, the associated maneuvering area, and vehicle parking area.

Figure 4-33 above depicted the landside areas for each of the cargo buildings on the West Side. The truck maneuvering area for FedEx (Building 4144) consists of truck docks behind the building, circulation area, and container staging areas. The total available truck docks with capabilities to load/unload directly from the building are estimated to be 32. The adjacent Building 4143 does not have truck docking capability. Building 4106 has a total building frontage of 1,155 linear feet, but currently some segments of the building frontage are used for employee vehicle parking or equipment staging instead of truck docks. The total available truck docks with capabilities to load/unload directly from the building are estimated to be 59.

Figure 4-34 above depicted the landside areas for Building 4321 in the terminal area. Similar to the condition at Building 4106, the building frontage of Building 4321 is not entirely dedicated to truck docks; instead, several areas are marked for vehicle parking.

Based on guidelines provided in the ACI-NA Air Cargo Guide and ACRP Report 113, the following planning parameters were used for sizing the landside facilities:

- Truck dock spaces: 0.6 spaces per 1,000 square feet of building
- Truck dock area depth: 150 feet to allow for docking and maneuvering
- Personal vehicle parking:
    - Two employee parking spaces per 1,000 square feet of cargo building
    - One customer parking space per 10,000 square feet of cargo building
    - 350 square feet per vehicle parking space

Table 4-100 summarizes landside facility requirements based on these parameters. Based on industry guidelines, the landside areas for cargo operations, including truck dock, truck maneuvering, and vehicle parking are adequate through the planning period.

Table 4-100. Air Cargo Landside Facility Requirements

	Required Air Cargo Building Space (s.f.)	Required Truck Dock Positions	Required Truck Maneuvering Areas (s.f.)	Vehicle Parking Areas (s.f.)
Landside Facility - Combination Carriers				
Existing	41,530	26	49,540	25,250
2017	14,800	9	20,250	10,500
2022	18,800	12	27,000	13,300
2027	22,500	14	31,500	15,750
2032	26,600	16	36,000	18,900
2037	31,100	19	42,750	22,050
Landside Facility – Integrator Carriers				
	Required Air Cargo Building Space (s.f.)	**Required Truck Dock Positions**	**Required Truck Maneuvering Areas (s.f.)**	**Vehicle Parking Areas (s.f.)**
Existing	229,750	91	290,906	183,570
2017	49,100	30	67,500	36,400
2022	57,100	35	78,750	42,350
2027	61,600	37	83,250	45,850
2032	66,500	40	90,000	49,000
2037	71,900	44	99,000	53,200

Source: AECOM Analysis.

4.5.4. Cargo Facility Requirements Summary

Based on the cargo facility requirements analysis, it is summarized that:

- Apron Area:
  - The south and north cargo aprons are adequately sized to accommodate future cargo aircraft parking needs during the peak hour
- Buildings:
  - The three cargo buildings on the West Site are sufficiently sized for future integrator cargo processing needs
  - The Air Freight Building (4321) in the terminal area is sufficiently sized for future combination carrier and air mail demand; however, the airlines experience space shortage due to their need to also store and maintain GSE in the same building. It is recommended that a separate facility be identified for GSE so that Building 4321 can be dedicated to belly cargo operations. Also, the airlines' cargo processing flows can be further optimized to facilitate efficient use of building space.
- Landside Facilities:
  - Truck docks, truck maneuvering, and vehicle parking are adequate through the planning period.

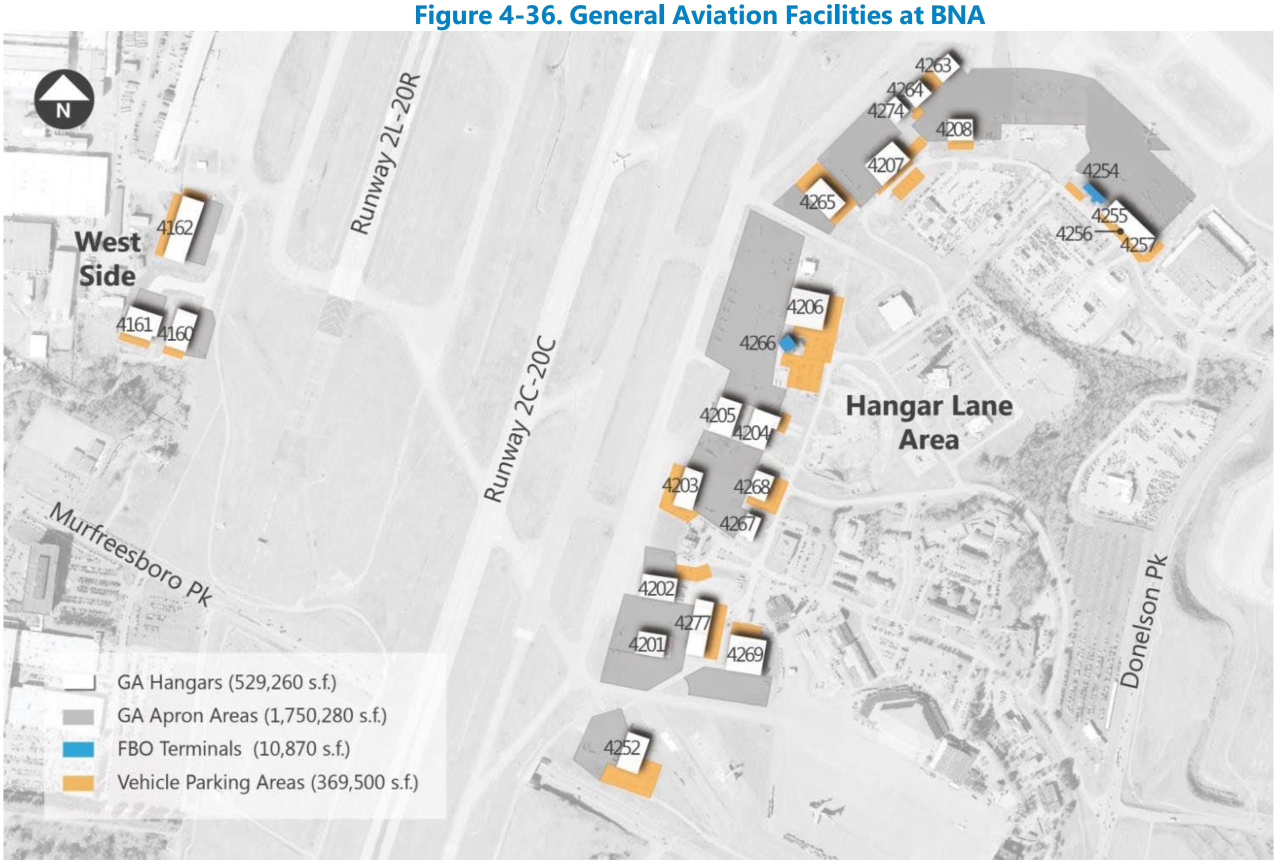
Based on the evaluation of existing air cargo facilities, there is sufficient building, apron, and landside space to accommodate additional integrator cargo operations. Recently, Amazon announced the opening of an "Operations Center of Excellence" to serve as the company's Eastern U.S. hub for Retail Operations in downtown Nashville. The company expects to add 5,000 new employees to their existing 2,500-person customer fulfillment infrastructure. While it could be expected that the growth of Amazon's presence in the Nashville area would have positive effects on passenger and airline activity[1], there has been no indication to date that Amazon intends to begin air cargo operations at BNA. Nevertheless, there are available facilities for modest introduction of new air cargo service or increased utilization by existing integrator cargo carriers at BNA.

1 https://www.bisnow.com/national/news/office/amazons-operations-center-announcement-for-nashville-means-big-plans-for-citys-infrastructure-housing-and-hospitality-94962

4.6. General Aviation Capacity and Requirements

This section focuses on evaluating the General Aviation (GA) facility needs for the planning horizon. The GA facilities include hangars, apron areas, Fixed Base Operator (FBO) terminal buildings, and vehicle parking areas, as illustrated on **Figure 4-36**.

Figure 4-36. General Aviation Facilities at BNA



The following documents provided standards, guidance, and industry recommendations and planning factors for the analysis:

- Federal Aviation Administration (FAA) Advisory Circular 150/5300-13A (Change 1), *Airport Design*
- FAA Advisory Circular 150/5360-13 (AC13), *Planning and Design Guidelines for Airport Terminal Facilities*
- Transportation Research Board (TRB) Airport Cooperative Research Program (ACRP) Report 113: *Guidebook on General Aviation Facility Planning*
- Federal Aviation Administration (FAA) Advisory Circular 150/5390-2C, *Heliport Design*

GA aircraft are typically categorized into two groups at airports – **based aircraft** and **transient aircraft**.

- **Based aircraft** are aircraft normally stored at the airport, requiring a parking position either on the apron or in a hangar. The tenants (pilots, aircraft owners, etc.) choose between these two options according to their aircraft's characteristics (size, condition, age, needs, etc.) and based on space availability, preference, price, location, weather, and other needs (maintenance, storage of parts, frequency of usage, etc.).
- **Transient aircraft** are visiting aircraft and, therefore, do not rent parking positions at BNA and typically use the Airport for takeoff, landing, fueling, and occasionally maintenance.

The FAA classifies aircraft based on their category and class. The typical based and transient aircraft categories at BNA are listed below.

Single-Engine Airplanes (SE)

Single-engine airplanes are powered by one piston or turbine engine, typically located at the nose of the airplane with one propeller attached to it. These aircraft are characterized by their smaller size, lighter weight, and lower purchasing cost. The representative models that are observed at BNA include Cessna 210 and Pilatus PC-12.

Cessna 210

Photo Source: AOPA

Pilatus PC-12

Photo Source: Pilatus

Multi-Engine Airplanes (ME)

Multi-engine airplanes are powered by more than one piston or turbine engine, typically located on the wings of the airplane with one propeller attached to each engine. The representative models that are observed at BNA include Beechcraft King Air C90 and 350 models.

Beechcraft King Air C90

Photo Source: Beechcraft

Beechcraft King Air 350

Photo Source: Beechcraft

Jet Airplanes

Although jet airplanes can be considered both single-engine and multi-engine depending on the number of engines they have, they are all included in this separate category for the purpose of this report. Jet airplanes (or simply referred to as "jets") are aircraft propelled by jet engines through jet propulsion, as compared to propeller-powered airplanes under the previous two categories. The propeller-powered airplanes generally achieve maximum efficiency at lower speeds and altitudes, whereas jets can achieve much higher speeds and altitudes and are typically used for longer-range trips. The representative jets that are observed at BNA for GA purposes include the Dassault Falcon 50EX and Gulfstream IV.

Dassault Falcon 50EX

Photo Source: Dassault Aviation

Gulfstream IV (G400)

Photo Source: Globalair.com

Helicopters

Compared to fixed-wing airplanes, helicopters are a type of rotorcraft in which lift and thrust are generated from the rotors instead of the wings. The rotors allow aircraft to take off and land vertically, in comparison to the fixed-wing aircraft which require a runway for takeoff run and landing deceleration. One based GA helicopter at BNA is a Bell 206.

Bell 206

Photo Source: Globalair.com

Table 4-101 provides a summary of the percentage of GA aircraft operations (based and transient) at BNA by each aircraft category based on 2017 annual operations data obtained from the FAA Traffic Flow Management System Counts (TFMSC) database. The TFMSC database reports GA operations under two categories, **air taxi** and **general aviation.** As defined in the TFMSC glossary, "general aviation" is defined as takeoffs and landings of all civil aircraft, except those classified as air carriers or air taxis. An "air taxi" is an aircraft designed to have a maximum seating capacity of 30 seats or less or a maximum payload capacity of 7,500 pounds or less, carrying passengers or cargo for hire or compensation. With this definition, the scheduled passenger services operated by regional jets (both Bombardier and Embraer) at the passenger terminal by the airlines would be included in the number of air taxi operations in the TFMSC database. These operations are excluded from this analysis because they do not utilize the GA facilities.

Table 4-101. Percentage of Annual Operations at BNA by Aircraft Category

Aircraft Category	Percentage of Annual Operations
Air Taxi	**100%**
Multi-Engine	0.20%
Jet	99.80%
General Aviation	**100%**
Single-Engine	9.78%
Multi-Engine	23.15%
Jet	67.05%
Helicopter	0.02%

Source: FAA Traffic Flow Management System Counts (TFMSC) 2017 database

4.6.1. GA Design Aircraft

In order to estimate the hangar and apron size needed to accommodate future GA activities at BNA, the "design aircraft" and square footage required to accommodate it are identified. The design aircraft enables airport planners and engineers to design the airport in such a way as to satisfy the operational requirements of such aircraft and meet FAA design separation standards.

For fixed-wing airplanes:

- The square footage requirements for **indoor parking in the hangars** account for the aircraft wingspan, overall length, and a clearance of 10 feet around the aircraft for maneuvering and equipment storage purposes[4].
- The square footage requirements for **outdoor tie-down and FBO parking on the apron** account for the aircraft wingspan, overall length, 10-feet wingtip clearance[5], and clearance from the taxilane Object Free Area (OFA). Typically, the requirements for outdoor parking are higher than those for indoor due to the inclusion of the adjacent required taxilane object free area (OFA).

For helicopters[6]:

- Based helicopters are typically parked in hangars. The square footage requirements for indoor parking are assumed to be 50 feet by 50 feet per helicopter based on the recommendation in the ACRP Report 113, Exhibit 5-13, for the design aircraft Bell 206. (More information on design aircraft in subsequent section)
- Transient helicopters are typically parked outdoor. The square footage requirements for outdoor helicopter parking pads are assumed to be 80 feet by 80 feet per helicopter for the design aircraft Bell 206.

Given the observed pressing demand for based aircraft hangar space at BNA as indicated by the fixed based operators (FBOs), this analysis assumes that all hangars are dedicated to based aircraft, and only common-use hangars will accommodate transient aircraft when there is space available in the hangars.

Design Aircraft for Based Aircraft

As summarized in **Table 4-102**, the design aircraft for the different based aircraft categories is determined based on the 2018 inventory list showing 87 based aircraft at BNA. The average square footage was calculated for different aircraft categories including single engine, multiengine, jet, and helicopter, and will be used as the key input for assessing additional hangar and apron space needs for the growing number of based GA aircraft at BNA.

[4] ACRP Report 113, page 62.
[5] ACRP Report 113, page 62.
[6] ACRP Report 113, page 59, Exhibit 5-13.

Table 4-102. Design Aircraft for Different Based Aircraft Categories

Aircraft Category	Design Aircraft[1]	Hangar Area Required Per Aircraft (s.f.)[2]	Apron Area Required Per Aircraft (s.f.)[3]
Single-Engine	C-210	1,870	6,700[4]
Multi-Engine	King Air C90A	2,470	9,070
Jet	Dassault Falcon 50EX	4,430	15,960[5]
Helicopter	Bell 206	2,500[6]	6,400[6]

Source: AECOM analysis.
Notes:

1. *The aircraft with the required square footage closest to the average square footage for each aircraft category is selected as the design aircraft for that aircraft category.*
2. *This area accounts for aircraft wingspan, overall length, and a clearance of 10 feet around the aircraft for maneuvering and equipment storage purposes.*
3. *This area accounts for aircraft wingspan, overall length, 10-feet wingtip clearance, and clearance from the taxilane OFA.*
4. *Although the design aircraft C-210 is an Airplane Design Group(ADG)-I aircraft, ADG-II taxilane OFA standards are used for the single-engine type to make sure ADG-II single-engine airplanes can maneuver to the apron parking positions.*
5. *Although the design aircraft Falcon 50EX is an ADG-II aircraft, ADG-III taxilane OFA standards are used for the jet type to make sure ADG-III jet airplanes can maneuver to the apron parking positions.*
6. *Based on ACRP Report 113, page 59, Exhibit 5-13.*
7. *Numbers all rounded up to the nearest tenth.*

Design Aircraft for Transient Aircraft

Since transient aircraft is a category based on GA operations at an airport, the FAA TFMSC Annual Operations data was used to determine the design aircraft for transient aircraft. Among the aircraft with more than 500 operations at BNA in 2017, the model with the largest footprint is selected as the design aircraft under each aircraft category. **Table 4-103** summarizes the design aircraft for each aircraft category, as well as their respective parking requirements.

Table 4-103. Design Aircraft for Transient Aircraft

Aircraft Category	Design Aircraft[1]	Apron Area Required Per Aircraft (s.f.)[2]
Single-Engine	PC-12	10,280
Multi-Engine	King Air 350	10,980
Jet	Gulfstream IV	21,990
Helicopter	Bell 206	6,400[3]

Source: AECOM analysis.
Notes:

1. *The aircraft with the required square footage closest to the average square footage is selected as the design aircraft for each engine type.*
2. *This area accounts for aircraft wingspan, overall length, 10-feet wingtip clearance, and clearance from the taxilane OFA.*
3. *Based on ACRP Report 113, page 59, Exhibit 5-13.*
4. *Numbers all rounded up to the nearest tenth.*

4.6.2. Hangar Storage Space

Two types of hangars are typically provided for GA operators: T-hangars and conventional hangars.

- T-hangars typically serve smaller single-engine and twin-engine aircraft, while the conventional hangars provide more flexibility to store a variety of different aircraft types and sizes. All T-hangars at BNA were demolished to provide room for new conventional hangars. The airport is not planning on developing new T-hangars.
- Conventional hangars are characterized as high-bay, clear span, rectangular structures, often capable of accommodating two or more aircraft. Conventional hangars typically have the majority of space dedicated to aircraft storage, with a small fraction of space dedicated to offices and equipment storage.

Given that the airport is not planning on developing new T-hangars, the hangar storage analysis focuses on conventional hangars. As discussed under **Section 4.6.1**, Design Aircraft, hangar space is only planned for based aircraft and not transient aircraft.

The growth of based aircraft is a deciding factor for the future hangar facility needs. Chapter 3, *Aviation Demand Forecasts*, projects that the number of based aircraft at BNA will increase from 87 today to 164 aircraft in the planning horizon, not including military aircraft. **Table 4-104** provides a detailed breakdown by aircraft category.

Table 4-104. Existing and Forecasted Based Aircraft by Category

Aircraft Category	Existing	Forecast (Baseline)			
	2017	2022	2027	2032	2037
Single-Engine	17	20	24	27	32
Multi-Engine	12	14	16	18	21
Jet	57	67	79	93	109
Helicopter	1	1	1	2	2
Total Based Aircraft	**87**	**102**	**120**	**140**	**164**

Source: BNA Master Plan Update 2018: Aviation Demand Forecasts Chapter

Several key assumptions were established for this analysis, based on general industry standards as well as discussions with the GA operators and the Airport sponsor:

- The ratios of based aircraft[7] stored in hangars differ between different aircraft types. While most of the SEs and some MEs are parked on the apron, all corporate jets are stored indoors to avoid exposure to weather and possible damage. Based on the current inventory, the hangar parking ratios are as follows:

    - SE: 29%
    - ME: 75%

[7] Calculated from the 2018 based aircraft parking inventory.

  - Jet: 100%
  - Helicopter: 100%

- An additional 20% of square footage is included for office, training, and maintenance areas. Apron areas in front of the hangars are also provided to allow based aircraft to have room to be fueled, tugged into the hangar, and loaded in front of the hangar without blocking other aircraft using the adjacent taxiway/taxilane[8]. This analysis assumes that such apron area would be of the same size as the hangar it serves, based on typical hangar/apron configuration at BNA.

- The total required apron area does not include area for taxiways or taxilanes that lead to hangars, because such required area could vary significantly with different taxiway/taxilane configurations. During the GA alternatives analysis stage it is important to make sure sufficient taxiway/taxilane areas are provided for aircraft to access the hangars.

Table 4-105 summarizes the space requirements for hangars to accommodate the projected based aircraft growth through the planning horizon. It is estimated that **additional hangars would be required before 2032.**

Table 4-105. Hangar Space Requirements

Item	Existing 2017	Forecast 2022	2027	2032	2037
Based Aircraft Parked Indoor					
Single-Engine	5	6	7	8	10
Multi-Engine	9	11	12	14	16
Jet	57	67	79	93	109
Helicopter	1	1	1	2	2
Total Aircraft	**72**	**85**	**99**	**117**	**137**
Required Hangar Square Footage					
Required Hangar Storage (s.f.)		337,700	395,200	466,530	546,090
Additional Area (s.f.)	529,260	67,540	79,040	93,306	109,218
Total Required Hangar Area (s.f.)[1,2]		**405,240**	**474,240**	**559,840**	**655,310**
Total Required Apron Area in Front of Hangars (s.f.)[1,2]	529,260	**405,240**	**474,240**	**559,840**	**655,310**

Source: AECOM analysis.
Notes:
1. *Red text indicate deficiencies*
2. *Numbers rounded up to the nearest tenth*

[8] ACRP Report 113, page 16.

4.6.3. Apron Area

Both based aircraft and transient aircraft can be parked on the GA apron. The smaller, lighter-weight aircraft are parked in tie-downs such as those in front of Building 4207 (shown on **Figure 4-36**) for the flight school, whereas the larger, heavier-weight jets mostly concentrate on the apron areas in front of the FBO terminals (Buildings 4254 and 4266 for Atlantic Aviation and Signature Flight Support, respectively).

4.6.3.1. Transient Aircraft Parking Requirements

Transient aprons are utilized by aircraft that are only at the airport on a short-term basis and usually have faster turnaround times, although some can be on the ground for a few days. Transient aprons are best located near GA terminal buildings. Both Atlantic Aviation and Signature Flight Support provide tie-down spaces to secure the lighter-weight SE and ME aircraft.

The number of aircraft parking positions required for transient aircraft is determined through the methods provided in Appendix C of ACRP Report 113. The ACRP method utilizes annual transient operations to identify an adequate number of parking positions.

The ACRP formula is:

(X / 2 * T) / 365 * P = Number of Transient Parking Positions, where:

X = Number of general aviation operations
T = Percentage of transient operations
P = Percentage of transient aircraft that are parked on the apron at any one time

The following data and assumptions are used as input for the formula above:

X: Number of GA and air taxi operations from Chapter 3, *Aviation Activities Forecast*
T: Section 3.5.3.3, GA and Air Taxi Operations, of Chapter 3, *Aviation Demand Forecasts*, specifies that approximately 80% of general aviation operations and 60% of air taxi operations were considered to be by transient aircraft in 2017
P: 50% of transient aircraft would be parked on the apron at the same time during a day

Table 4-106 provides a summary of existing and forecasted annual GA and air taxi operations by transient aircraft. The annual operations by aircraft categories are also derived based on the percentage breakdowns provided previously in **Table 4-101**. This information translates into a required transient aircraft parking positions when applying the ACRP formula.

Table 4-106. Annual Operations and Corresponding Transient Aircraft Parking Requirements

Item	Existing 2017	Forecast 2022	2027	2032	2037
Annual GA & Air Taxi Operations[1]					
GA-Itinerant[a]	36,570	37,649	42,240	46,363	51,596
GA-Local[b]	7	8	9	10	11
Air Taxi[c]	7,536	7,904	9,030	10,099	11,245
Annual Operations by Aircraft Category[2]					
General Aviation					
Single-Engine	3,577	3,683	4,132	4,535	5,047
Multi-Engine	8,469	8,719	9,782	10,737	11,949
Jet	24,524	25,249	28,327	31,093	34,602
Helicopter	7	7	8	9	10
Air Taxi					
Multi-Engine	15	15	18	20	22
Jet	7,522	7,888	9,013	10,079	11,223
Required Transient Aircraft Parking Positions[3]					
Single-Engine	2	3	3	3	3
Multi-Engine	6	6	7	7	8
Jet	18	18	20	23	24
Helicopter	1	1	1	1	1
Total Required Apron Positions	**27**	**28**	**31**	**34**	**36**

Sources:
1. *Table 3-35, BNA Master Plan Update 2018: Aviation Demand Forecasts Chapter*
2. *Calculated based on the projected annual GA and Air Taxi operations and Table 4-101. Percentage of Annual Operations at BNA by Aircraft*
3. *Calculated based on the ACRP Report 113 formula: (X / 2 * T) / 365 * P = Number of Transient Parking Positions*

Notes:
a. *Itinerant – Represents operations that arrive from outside the traffic pattern or depart the airport traffic pattern.*
b. *Local – Represents operations that stay within the traffic pattern airspace (non-itinerant).*
c. *The scheduled passenger services operated on Bombardier CRJs and Embraer ERJs at the passenger terminal by the airlines are excluded from this analysis.*

4.6.3.2. Based Aircraft Parking Requirements

In addition to transient aircraft, based aircraft can also be parked on the apron instead of in the hangars. With the exception of flight schools, based aircraft parking aprons often have lower activity but a higher density as aircraft are parked for longer periods of time.

Table 4-105 in the previous section listed the number of based aircraft that are projected to utilize hangar storage. The remaining based aircraft are assumed to be parked outdoors. **Table 4-107** summarizes the number of based aircraft positions needed on the apron by aircraft category.

Table 4-107. Based Aircraft Apron Parking Requirements

Aircraft Category	Existing	Forecast			
	2017	2022	2027	2032	2037
Single-Engine	12	14	17	19	22
Multi-Engine	3	3	4	4	5
Jet	0	0	0	0	0
Helicopter	0	0	0	0	0
Total Required Apron Positions	**15**	**17**	**21**	**23**	**27**

Source: AECOM Analysis.

4.6.3.3. Apron Size Requirements

Based on the apron parking area required for the design aircraft in **Table 4-103**, the total apron area requirements to accommodate future transient and based aircraft are estimated in **Table 4-108**. The total required apron area include the apron area to park transient and outdoor based aircraft, as well as the apron area in front of hangars for temporary staging and maneuvering of indoor based aircraft, as previously discussed in **Section 4.6.2**. Nonetheless, the total required apron area does not include area for taxiways or taxilanes that lead to hangars, because such required area could vary significantly with different development options.

The existing GA apron at BNA has a total area of 1,750,280 square feet, which can accommodate the estimated GA apron parking requirements throughout the planning horizon.

Table 4-108. Apron Parking Area Requirements

Aircraft Category	Existing 2017	Forecast 2022	2027	2032	2037
Aircraft Positions Required on the Apron (Transient & Based)					
Single-Engine	14	17	20	22	25
Multi-Engine	9	9	11	11	13
Jet	18	18	20	23	24
Helicopter	1	1	1	1	1
Total Required Apron Positions	**42**	**45**	**52**	**57**	**63**
Apron Size Required (s.f.)[1]					
Single-Engine	144,000	124,640	144,740	158,140	178,240
Multi-Engine	98,900	85,980	103,660	103,660	121,340
Jet	395,900	395,820	439,800	505,770	527,760
Helicopter	6,400	6,400	6,400	6,400	6,400
Subtotal	**645,200**	**612,840**	**694,600**	**773,970**	**833,740**
Apron Required In front of Hangars	343,908	405,240	474,240	559,840	655,310
Total Required Apron Area	**989,108**	**1,018,080**	**1,168,840**	**1,333,810**	**1,489,050**

Source: AECOM Analysis.
Note:
1. *Apron sizes rounded up to the nearest tenths.*

4.6.4. Fixed Base Operator (FBO) Terminal Buildings

BNA has two major FBOs – Atlantic Aviation and Signature Flight Support. Each FBO operates from its own terminal building that consists of a waiting lounge, offices, meeting rooms, pilot briefing rooms, restrooms, and other amenities. The Atlantic Aviation terminal building is Building 4266 (4,820 square feet), and the Signature Flight Support terminal building is Building 4254 (6,050 square feet). Both buildings are single story.

As of late 2018, Signature Flight Support is constructing a new FBO terminal building to upgrade facilities and enhance capacity. The new Signature terminal will have a total of 8,000 square feet. Once the new terminal building is open, the old terminal building will be demolished to provide space for other development. Therefore, for the purpose of this analysis, the upcoming Signature terminal (8,000 square feet) and the existing Atlantic terminal (4,820 square feet) account for a total of 12,820 square feet of terminal space.

The required size of an FBO terminal is largely based on the needs of the specific FBO and, in turn, its clients. Based on recommendations in ACRP Report 113, the following planning factors are used for estimating FBO terminal needs:

- Peak month operations accounts for 9% of annual operations[9]
- Peak hour operations accounts for 9.1% of daily operations[10]
- Assuming 4 persons (crew and passengers) will use the terminal building for each peak hour operation[11]
- Assuming 150 square feet is needed for each person[12]

Table 4-109 summarizes the FBO terminal requirements based on the planning factors above. It is estimated that the FBO terminals would require expansion before 2027.

Table 4-109. FBO Terminal Building Requirements

Aircraft Category	Existing 2017	Forecast 2022	2027	2032	2037
Total Annual GA & Air Taxi Operations	67,117	69,686	78,844	87,299	97,176
Peak Hour Operations	18	19	22	24	27
Persons per Peak Hour Operation	4	4	4	4	4
Space Per Person (s.f.)	150	150	150	150	150
Required FBO Terminal Area (s.f.)[1 2]	**12,820**	**12,800**	**14,400**	**16,000**	**17,800**

Source: AECOM analysis.
Notes:
1. *Terminal area rounded up to the nearest hundreds.*
2. ***Red** text denotes deficiency.*

4.6.5. Vehicle Parking Area

Adequate vehicle parking areas are required to provide safe and efficient access to the GA facilities. Currently a total of 369,500 square feet of land is dedicated to GA vehicle parking. **Figure 4-36** shows the existing parking lots for GA facilities in both the Hangar Lane Area and on the West Side.

The two elements used to determine vehicle parking area requirements include the number of parking spaces required and the dimensions used for each parking space and driving lane. Per Exhibit 5-48 of ACRP Report 113, the number of required parking spaces differs for each type of GA facility including terminals, hangars, and parking positions. This analysis assumes the following planning factors from

[9] Figure 3-39, BNA Master Plan Update 2018 Aviation Demand Forecasts Chapter
[10] Table 3-45, BNA Master Plan Update 2018 Aviation Demand Forecasts Chapter
[11] ACRP Report 113, page 95, recommends 2.5 persons per operation but this analysis increases that to 4 to provide a more accurate estimate considering the clientele at BNA use larger business jets requiring two pilots and sometimes even having a flight attendant.
[12] ACRP Report 113, page 95.

ACRP Report 113 as well as industry and local observations to derive the parking spaces required for different types of GA functions:

- Hangars
  - 1 space per 1,000 Square Footage (SF) of hangar floor area
  - 1 space per 200 SF of office/operations area
  - 1 space per 750 SF of maintenance area
- FBO Terminals
  - 4 spaces per peak hour operation
  - 1 space per 200 SF of office space
  - 10 spots per FBO terminal for rental car staging
- Based Aircraft Apron Area
  - 1 space for every two based aircraft parking spaces
- 45 parking spaces for charter operations in total

As depicted in **Figure 4-37**, the standard parking space size (10-feet by 20-feet) and driving lane width (25-feet) used in ACRP Report 113 are used to determine the size of each parking area. Each 140-feet of parking lot length can accommodate 4 parking spaces. Therefore, an average parking space factor of 350 square feet per car (1,400 square feet divided by 4) is used for the purposes of this analysis.

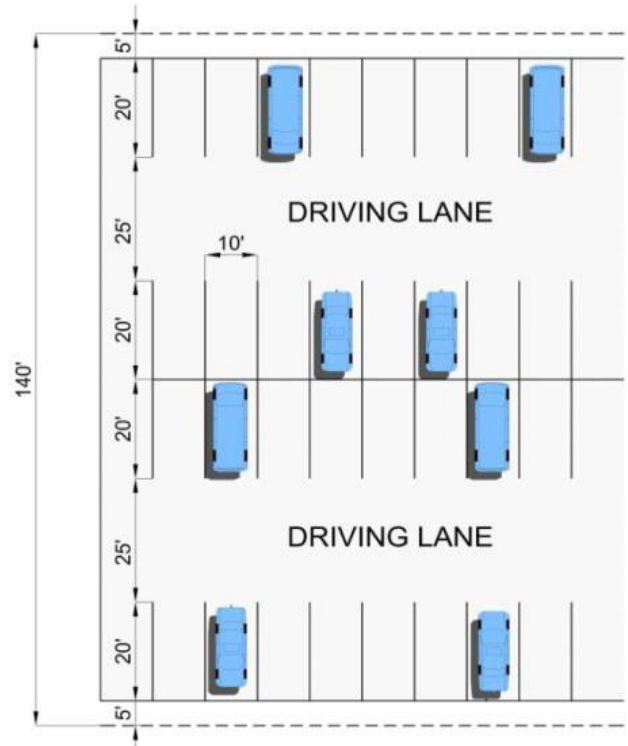


Figure 4-37. Standard Vehicle Parking Spaces

Table 4-110 provides a breakdown of the vehicle parking requirements. Overall, the existing vehicle parking area could accommodate the growth in demand through 2032. However, for 2037, the vehicle parking areas should be expanded.

Table 4-110. Vehicle Parking Requirements

Item	Required				
	2017	2022	2027	2032	2037
Hangar Area					
Total Required Hangar Area	343,908	405,240	474,240	559,840	655,310
Hangar Floor Area	275,126	324,192	379,392	447,872	524,248
1 space/1,000 SF of Hangar Floor Area	276	325	380	448	525
Office Area	34,391	40,524	47,424	55,984	65,531
1 space/200 SF of Office Area	172	203	238	280	328
Maintenance Area	34,391	40,524	47,424	55,984	65,531
1 space/750 SF of Maintenance Area	46	55	64	75	88
Total Vehicle Parking Spaces	**494**	**583**	**682**	**803**	**941**
FBO Terminal Buildings					
Required Terminal Size	*12,300*	*12,800*	*14,400*	*16,000*	*17,800*
Peak Hour Operations	*20*	*21*	*24*	*27*	*30*
2.5 spaces/peak-hour operation	82	85	96	107	119
Office Area	*8,610*	*8,960*	*10,080*	*11,200*	*12,460*
1 space/200 sf of office space	44	45	51	56	63
10 spots per FBO terminal for rental car staging	20	20	20	20	20
Total Vehicle Parking Spaces	**146**	**150**	**167**	**183**	**202**
Based Aircraft Apron					
Total Required Apron Parking Spaces	*15*	*17*	*21*	*23*	*27*
1 space for 50% of Apron Positions	**8**	**9**	**11**	**12**	**14**
Charter Operations					
Charter Parking Spaces	45	45	45	45	45
Total Parking Needs					
Total Vehicle Parking Spaces	**693**	**787**	**905**	**1,043**	**1,202**
Total Vehicle Parking Area (s.f.)	**242,550**	**275,450**	**316,750**	**365,050**	**420,700**

Source: AECOM analysis.
Notes:
1. ***Red*** *text denotes deficiency.*

4.6.6. General Aviation (GA) Facility Requirements Summary

Below is a summary of GA facility requirements:

- There is a need for more hangar space before 2032.
- The apron areas are sufficient to accommodate both base and transient aircraft throughout the planning horizon. However, additional hangars require additional apron areas to be provided in front of them.
- FBO terminal buildings require expansion before 2027 even with the new Signature Flight Support terminal.
- Vehicle parking areas require expansion before 2037.

4.7. Airport & Airline Support Requirements

4.7.1. Aircraft Deicing

4.7.1.1. Aircraft Deicing Areas

Aircraft deicing activities at BNA are performed both at-gate and also in dedicated deicing areas, as shown on **Figure 4-38**. **Table 4-111** shows the number of deicing positions in each deicing area. Section 2.6.9 in Chapter 2, Inventory, provides detailed deicing positions layout for each of the deicing pads.

Figure 4-38. Aircraft Deicing Areas

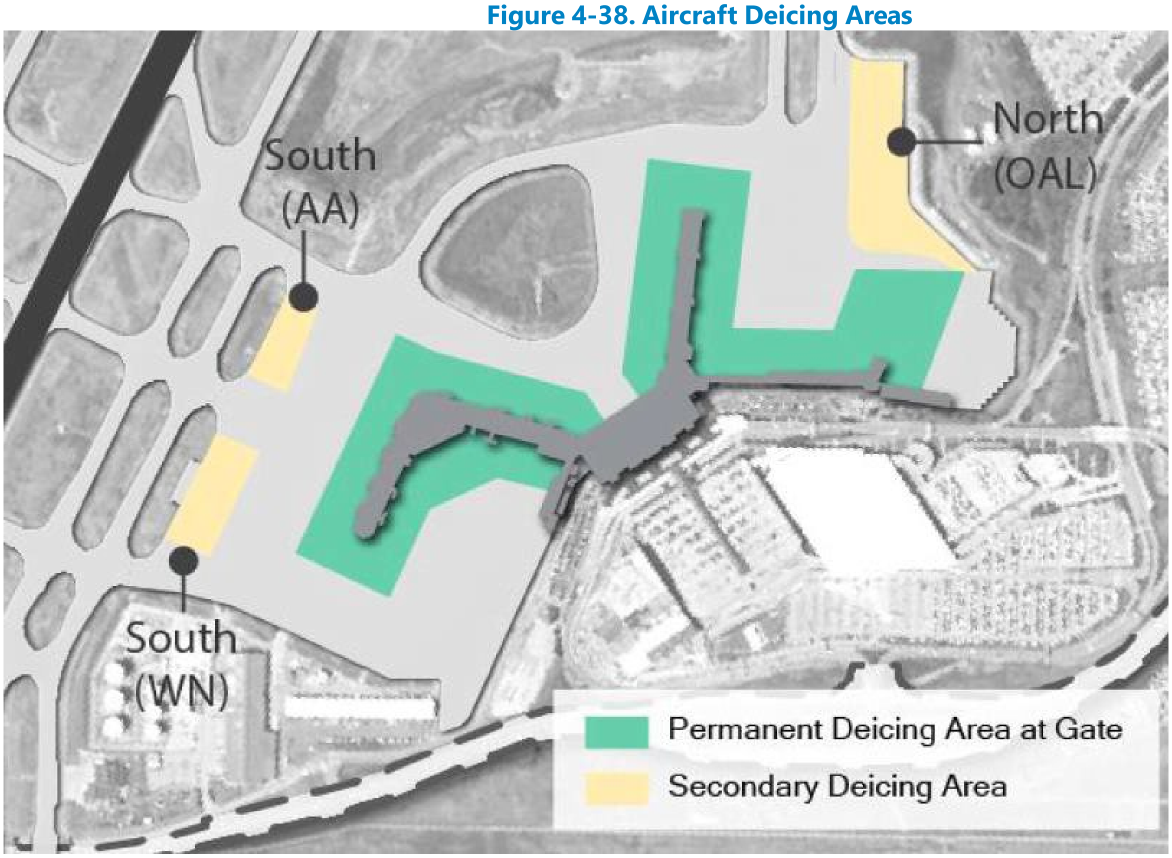


Table 4-111. Existing Aircraft Deicing Positions

	Deicing Positions
North Deicing Pad	3 for ADG-III; 1 for up to E-195
South Deicing Pad	5 for ADG-III; 1 for ADG-II
Terminal Deicing (All Gates)	All Gates

Source: Section 2.6.9, Chapter 2, Inventory.

The deicing positions needed at the dedicated deicing area are estimated based on the number of peak hour departures from the future design day flight schedule (DDFS), as well as the time required to deice each aircraft. **Table 4-112** summarizes the number of peak hour departure flights based on the DDFS. The aircraft operated during the departure peaks are predominantly ADG-III narrowbody aircraft, or ADG-II regional jets.

Table 4-112. Peak Hour Departures

Aircraft	Number of Peak Hour Departure Flights (7:36-8:35am)				
	Baseline	2022	2027	2032	2037
Narrowbody					
319	1	2	2	2	2
320	0	3	3	4	4
717	0	1	1	1	1
738	0	1	1	1	2
739	0	1	1	1	1
73H	1	2	2	2	3
73W	12	12	13	13	13
7M8	1	1	1	1	1
M88	1	1	0	0	0
Subtotal	16	24	24	25	27
Regional Jet					
CNC	1	1	1	1	1
CR7	2	2	2	2	2
CR9	1	2	2	2	2
E75	0	0	0	1	1
E7W	2	3	3	3	3
E90	0	0	1	1	1
ERD	1	1	0	0	0
ERJ	0	0	1	1	1
Subtotal	7	9	10	11	11
Total PH Departures	**23**	**33**	**34**	**36**	**38**

Sources: BNA Design Day Flight Schedule, TransSolutions, September 2018. AECOM analysis.

A planning factor of deicing time per aircraft is used to estimate how many deicing positions are required to process the peak hour departures. It is assumed that 20 minutes are required to deice a narrowbody, and 15 minutes are required to deice a regional jet. **Table 4-113** summarizes the number of deicing positions required based on the hourly deicing throughput for narrowbody and regional jets. The existing number of deicing positions will be inadequate before 2022. Therefore, the deicing pads need to be expanded or reconfigured to accommodate the forecast deicing activities during the peak hour.

It is not uncommon for airports to use the same apron area for both RON and deicing functions. Given that departures at BNA start as early as 5:00am and the departure peak is not until 7:30am, the RON and deicing functions would not be conflicting needs as long as the RON aircraft are moved in a timely fashion to the terminal gates for departure.

Table 4-113. Deicing Position Requirements

	Deicing Time	Hourly Deicing Throughput	Number of Positions Required				
			Baseline	2022	2027	2032	2037
Narrowbody	20 min	3 departures	2	3	3	3	3
Regional Jet	15 min	4 departures	6	8	8	9	9
Total			**8**	**11**	**11**	**12**	**12**

Source: AECOM analysis.

In addition to commercial air carrier operations, air cargo and GA aircraft could also require deicing during peak periods. Currently, both cargo and GA aircraft travel long distances across the airfield to be deiced at the terminal deicing aprons; however, the operators have been requesting to have deicing areas dedicated close to their facilities in Hangar Lane Area and also the West Side to improve operational efficiency.

4.7.2. MNAA Maintenance Facilities

Currently the MNAA maintenance facilities are located in two areas – the Consolidated Service Facility (CSF, Building 4351) in the Hangar Lane Area, and scattered buildings on the West Side. The functions in the scattered buildings on the West Side include the Airfield Electricians unit (AFEL), Grounds, Mobile Equipment and Welding, Procurement, and Material Controls. The MNAA is planning on relocating most functions on the West Side to the CSF Building so that maintenance functions are consolidated, except for a Mobile Equipment Facility to house portions of the Maintenance team for quick response.

4.7.3. Aircraft Maintenance Facilities

Aircraft maintenance facilities at BNA are operated by different tenants, including the FBOs and Embraer. The FBOs provide maintenance to the GA aircraft at the GA facilities, whereas Embraer is based in Buildings 4140 and 4141 on the West Side. Embraer has been requesting additional space for expanding their facilities at BNA.

4.7.4. Ground Support Equipment (GSE) Facilities

The GSEs at BNA are stored and maintained both outdoors on the terminal apron, in covered areas surrounding the terminal gates, and indoors at the Air Freight Building (Building 4321). In previous years, Building 4323 adjacent to Building 4321 was also dedicated to GSE storage and maintenance workshops for airline operations. However, the MNAA plans to use Building 4321 as a consolidated concession screening facility, and the belly cargo operations require more space in Building 4321. Therefore, a dedicated GSE building should be provided in the vicinity of the passenger terminal complex to support all the day-to-day GSE needs, including vehicle storage, offices, maintenance shops, supply storage, electric vehicle charging, etc.

4.7.5. Aircraft Fuel Storage Facilities

Fuel is stored at the airport in several scattered sites, including the main fuel farm, the West Side, and the Hangar Lane Area. The fuel facilities are capable of storing over 8 million gallons of Jet-A fuel. Also, the two FBOs operate two 100 low-lead AvGas tanks with a total capacity of 22,000 gallons.

Based on discussions with the airport users, among the six tanks in the main fuel farm (about 8.7 million gallons total capacity), three are used as issue tanks, and three as receive tanks. When needed, all six tanks can be used as receive tanks to double the capacity. The fuel farm was upgraded at the beginning of this Master Plan Update so the tanks are expected to have another 20 to 30 years of useful life. It is important that the fuel facilities provide sufficient capacity to support the activity growth throughout the planning period. This analysis evaluates two indicators relevant to fuel storage requirements – the ADPM fuel demand, and the 7-day fuel reserve requirement.

In order to calculate the ADPM fuel demand, future ADPM operations were estimated based on the annual operations forecast. Also, a gallons-per-operation fuel consumption factor was used to estimate how much fuel would be needed to support the ADPM operations. The gallons-per-operation factor for Jet-A fuel was derived from the 2014-2017 monthly Jet-A fuel consumption reports from the MNAA, and the factor for AvGas was cited from the previous Master Plan. Lastly, the 7-day fuel reserve requirements were derived from the ADPM fuel demands throughout the planning horizon.

Table 4-114. Fuel Reserve Requirements

	2017 (Base)	2022	2027	2032	2037
Jet-A					
Total Airport Operations[1]	205,802	256,599	273,924	291,664	311,114
Jet-A Operations[a]	198,394	247,362	264,063	281,165	299,914
Jet-A ADPM Operations[b]	591	743	793	844	900
Fuel per Jet-A Operation (Gallons)[2]	488	488	488	488	488
AMPD Jet-A Fuel Demand (Gallons)	288,408	362,327	386,709	411,580	438,888
7-Day Jet-A Fuel Reserve (Gallons)	2,018,854	2,536,286	2,706,965	2,881,057	3,072,217
AvGas					
Total Airport Operations[1]	205,802	256,599	273,924	291,664	311,114
AvGas Operations[c]	7,408	9,237	9,861	10,499	11,200
AvGas ADPM Operations[b]	23	28	30	32	34
Fuel per AvGas Operation (Gallons)[3]	14	14	14	14	14
AMPD AvGas Fuel Demand (Gallons)	322	392	420	448	476
7-Day AvGas Fuel Reserve (Gallons)	2,254	2,744	2,940	3,136	3,332

Sources:
1. *BNA Master Plan Update 2018: Aviation Demand Forecasts Chapter, Table 46*
2. *MNAA 2014-2017monthly fuel consumption reports & BNA monthly Aviation Statistical Summary from 2014 to 2017*
3. *2013 BNA Master Plan Section 3.8.8*
4. *AECOM analysis*

Notes:

a. *This analysis follows the same assumption in the previous MP, that 96.4% of the total operations are Jet-A operations, and the rest are AvGas operations*

b. *Based on historical operations data from 2014 to 2017, ADPM operations account for 0.3% of the total annual operations. The previous MP held the same assumption.*

As shown in **Table 4-114**, the BNA fuel storage facilities are adequate to store a 7-day fuel reserve for the projected activity growth. Nonetheless, routine maintenance may be required to ensure the expected useful life of these facilities. Airport users indicated that the pipelines that transport fuel to the ground fuel hydrant system at the terminal apron are typically full and the operators are increasing the use of fuel trucks to catch up with the fuel transport needs. Given that the fuel farm has limited space to accommodate and load fuel trucks, the Airport is working with Colonial Pipeline to expand the pipeline network. If the pipelines cannot be expanded, additional area to accommodate and load fuel trucks should be provided adjacent to the fuel farm to the extent feasible.

4.7.6. Aircraft Rescue and Firefighting Facility (ARFF)

Airport ARFF facilities provide first response services for aircraft involved in emergencies as well as a wide variety of other incidents such as building fires and medical emergencies. Specific requirements for airport ARFF services are established in 14 CFR Part 139; however, the FAA and NFPA also provide guidance for ARFF facilities. Two of the primary elements used to evaluate ARFF facilities include:

1. The applicable ARFF Index and associated equipment (vehicles and fire extinguishing agents) requirements and personnel
2. The ARFF Station's location (s) on the airfield

4.7.6.1. ARFF Index

For Part 139 airports like BNA, it is important to review if its Aircraft Rescue and Firefighting (ARFF) index will change during the planning period, based on the aircraft operations forecast.

An airport's ARFF Index is based on the length of the largest aircraft conducting an average of 5 or more daily departures. **Figure 4-39** depicts the aircraft characteristics and examples for the five ARFF Indexes from A to E, as prescribed in Section 315 of Part 139. Given the varying aircraft sizes, different index levels have different requirements for the number and capacity of firefighting agents carried on the response vehicles, as specified in Section 317 of Part 139. BNA is currently at Index C.

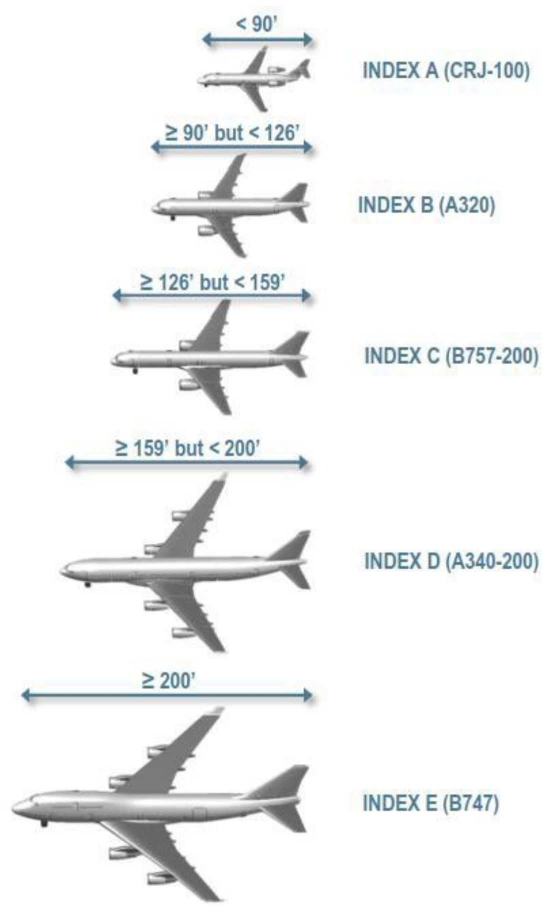


Figure 4-39. ARFF Indices

Table 4-115 shows the annual departures by aircraft type at BNA with the larger aircraft that fall under Indices C, D, and E. In 2018, none of the aircraft that fall under Indices D and E meet the requirement of five or more average daily departures. Therefore, the existing ARFF Index at BNA remains at Index C.

Table 4-115. 2018 Annual Departures and Average Daily Departures at BNA by Aircraft Type

Aircraft Type[1]	Aircraft Length[2]	2018 Annual Departures[1]	Average Daily Departures
Index E			
A346 - Airbus A340-600	247.24	2	0.005
B744 - Boeing 747-400	231.85	3	0.008
B742 - Boeing 747-200	231.83	2	0.005
B77L - Boeing 777-200LRF/LR	209.08	2	0.005
A333 - Airbus A330-300	208.99	1	0.003
B764 - Boeing 767-400	201.33	9	0.025
MD11 - Boeing (Douglas) MD 11	200.75	3	0.008
Index D			
A332 - Airbus A330-200	193.57	1	0.003
B788 - Boeing 787-800	186.08	163	0.447
DC10 - Boeing (Douglas) DC 10-10/30/40	182.25	6	0.016
B763 - Boeing 767-300	180.25	154	0.422
B753 - Boeing 757-300	178.58	21	0.058
A306 - Airbus A300 B4-600	177.43	89	0.244
B762 - Boeing 767-200	159.17	83	0.227
Index C			
B752 - Boeing 757-200	155.25	1,604	4.395
A310 - Airbus A310 All Series	153.16	27	0.074
MD90 - Boeing (Douglas) MD 90	152.58	350	0.959
MD81 - Boeing (Douglas) MD 81	147.83	1	0.003
MD82 - Boeing (Douglas) MD 82	147.83	154	0.422
MD83 - Boeing (Douglas) MD 83	147.83	625	1.712
MD88 - Boeing (Douglas) MD 88	147.83	3,095	8.479
A321 - Airbus A321 All Series	146.03	237	0.649
B739 - Boeing 737-900	138.17	623	1.707
B738 - Boeing 737-800	129.50	12,295	33.685
E190 - Embraer 190	126.83	631	1.729

Sources:
1. *FAA Traffic Flow Management System Counts (TFMSC), Aviation System Performance Metrics (ASPM), BNA 2018 data*
2. *FAA Aircraft Characteristics Database, October 2018*

Table 4-116 shows the number of operations by aircraft on the future design day flight schedule (DDFS). Aircraft that fall under Index D include A330-200, and B787-8. The projected total daily operations of these two aircraft triple from 2 in 2017 to 6 in 2037, which equates to 3 daily departures on the 2037 design day. Since the average daily departure of the Index D aircraft are no more than 5, the ARFF Index at BNA should remain Index C for the planning period based on the future DDFS.

Nonetheless, if any airlines decide to operate Index D aircraft for more than 5 departures a day on average beyond the expectations of the DDFS, the ARFF Index should be revisited and adjusted.

Table 4-116. Future DDFS Daily Operations by Aircraft Type at BNA

Aircraft Type	DDFS Operations by Aircraft[1] 2019	2022	2024	2027	2032	2037	ARFF Index[2]
319	22	28	28	28	34	34	B
320	30	34	34	34	36	38	B
32A	6	8	8	8	8	8	C
330	0	0	0	2	4	4	D
717	10	14	14	14	14	14	B
738	24	32	32	34	40	52	C
739	4	4	4	4	4	4	C
788	2	2	2	2	2	2	D
73H	54	68	68	74	92	108	C
73W	168	190	220	220	214	212	B
7M8	4	6	6	6	6	6	C
CNC	2	4	4	4	4	4	A
CR7	32	32	34	34	32	32	B
CR9	28	38	36	36	40	42	B
CRJ	18	20	20	20	20	20	B
E75	18	18	18	26	28	32	B
E7W	30	36	36	36	38	40	B
E90	6	8	8	10	10	10	B
ER4	6	8	2	2	2	0	B
ERD	10	14	14	0	0	0	B
ERJ	4	6	16	26	24	22	B
J31	10	14	14	14	14	14	A
M80	4	4	0	0	0	0	C
M88	18	18	0	0	0	0	C
M90	4	4	0	0	0	0	C
PL2	6	8	10	10	10	10	A
Total	520	618	628	644	676	708	-

Sources:
1. *TransSolutions Technical Memorandum, BNA Design Day Flight Schedules, Table 4*
2. *Determined based on aircraft length information from the FAA Aircraft Characteristics Database, October 2018*

4.7.6.2. ARFF Station

Section 139 in CFR Part 139 requires that the ARFF station must be located so that the first response vehicle can reach the midpoint of the farthest runway within 3 minutes. The existing ARFF station driving response time to each of the existing runways are analyzed based on the following assumptions.

The primary ARFF vehicle characteristics specified in the National Fire Protection Association (NFPA) 414, Standard for Aircraft Rescue and Fire-Fighting Vehicles (2017 Edition), Chapter 4 are used to define the vehicle driving parameters[13]:

- Maximum speed of the vehicle is not greater than 70 miles per hour (mph) or **103 feet per second** (fps)
- Maximum acceleration time is from 0 to 80.5 kph (or 73.3 fps) for 30 seconds, which translated to a **2.5 feet per square second** (f/s^2) acceleration rate (a constant acceleration rate was assumed for this analysis)
- Decelerate from 33 kph (or 30.2 fps) to a stop is within less than 36 feet for a deceleration rate of **-12.53** $\mathbf{ft/s^2}$
- Speed of 40 kph (or **36.4 fps**) on a 100 feet radius turn
- Speed of 48 kph (or **43.7 fps**) on a 150 feet radius “J” turn

Additionally, the analysis included a period of 30 seconds to account for the typical alarm response time (the time from when the alarm sounds until the trucks are moving). Other factors affecting vehicle performance include roadway surface conditions, weather, driver technique, vehicle impediments, etc. However, these factors were not included in this analysis due to the difficulty in quantifying them and the relatively minimal impact on overall response time. In order to determine the shortest duration from the facility to the required points on the airfield, a route which combined the shortest path available and the ability to reach top speed for the greatest distance was used.

Based on these assumptions, the response time from the existing ARFF station to the midpoint of each runway was calculated and summarized in **Table 4-117.** The response time to Runway 2C-20C is the longest and close to the three-minute requirement.

While the existing location of the ARFF station allows for a response time within the maximum allowed, proposed runway extension or a new runway may increase it. Also, the Department of Public Safety expressed the need to have more space in the ARFF building and expressed concerns about the ARFF station being located adjacent to the main fuel farm. Such proximity eliminates the possibility of co-locating an ARFF training facility with the ARFF station. Therefore, a new or supplemental ARFF

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[13] All the numbers are translated from the original metric units to imperial units.

location will be explored as a part of the alternatives analysis to ensure response time to new runways as well as providing enhanced space, safety, and flexibility to the facility.

Table 4-117. Response Time from Existing ARFF Station to the Midpoint of Each Runway

Runway	Response Time (seconds)	Response Time (minutes)
2L-20R	134.4	2.2
2C-20C	170.2	2.8
2R-20L	70.2	1.2
13-31	128.6	2.1

Source: AECOM analysis.

4.7.7. Airport & Airline Support Requirements Summary

- Aircraft Deicing
  - The existing number of deicing positions will be inadequate before 2022. Therefore, the deicing pads need to be expanded or reconfigured to accommodate the forecast deicing activities during the peak hour.
  - Provide dedicated deicing areas close to the cargo and GA facilities in Hangar Lane Area and also on the West Side to improve operational efficiency.
- MNAA Maintenance Facilities
  - The MNAA is planning on relocating the functions on the West Side to the CSF Building so that all maintenance functions are consolidated.
- Aircraft Maintenance Facilities
  - The amount of space needed will be dependent upon specific operational need of the operator.
- Ground Support Equipment Facilities
  - A dedicated GSE building should be provided in the vicinity of the passenger terminal complex to support all the day-to-day GSE needs, including vehicle storage, offices, maintenance shops, supply storage, electric vehicle charging, etc.
- Aircraft Fuel Storage Facilities
  - The BNA fuel storage facilities are adequate to store a 7-day fuel reserve for the projected activity growth.
  - The Airport is working with Colonial Pipeline to expand the pipeline network. If the pipelines cannot be expanded, additional area to accommodate and load fuel trucks should be provided adjacent to the fuel farm to the extent feasible.
- Aircraft Rescue and Firefighting Facility
  - The ARFF Index at BNA should remain Index C for the planning period based on the future DDFS.

- If any airlines decide to operate Index D aircraft for more than 5 departures a day on average beyond the expectations of the DDFS, the ARFF Index should be revisited and adjusted, if necessary.
- While the existing location of the ARFF station allows for a response time within the maximum allowed, proposed runway extension or a new runway may increase it. Also, the Department of Public Safety expressed the need to have more space in the ARFF building and expressed concerns about the ARFF station being located adjacent to the main fuel farm.

4.8. Sustainable Facilities

Sustainability is a core objective of planning at BNA. In 2012, the *Nashville International Airport Sustainability Study* was developed in accordance with guidance issued by FAA for airports that choose to incorporate sustainability in their master plans.[14] In alignment with this guidance, BNA identified a sustainability mission[15] and specified categories that were designated as the main focus of its sustainability planning. In 2017 the study was updated but the MNAA's mission statement and goals/objectives from the 2012 study did not change. The main sustainability areas of focus are:

- Passenger Terminal Energy Efficiency
- Materials Management
- Natural Resources Conservation
- Socioeconomic and Community Support
- Air Quality and Greenhouse Gas (GHG) Emissions
- Surface Transportation
- Aircraft Noise

[14] https://www.flynashville.com/.../Nashville_IntlAirport_SustainabilityStudy_2012HR.pdf

[15] BNA's sustainability mission, developed by the Sustainability Committee, is defined as: "To sustain the heartbeat of the Mid-South by cherishing its resources to ensure Music City keeps flying high." This messaging is featured on BNA's and throughout its outreach and public-relations materials.

4.8.1. Overview

As part of its commitment to sustainability criteria, the MNAA integrates sustainability planning into master planning and project implementation activities undertaken at BNA. In keeping with this process, and to ensure that additional support facilities are identified which enable the advancement of BNA sustainability and encourage integration into future planned facilities, a review of existing BNA sustainability plans and ongoing regional sustainable development planning efforts was completed and compared with the MNAA's current growth and expansion plan, BNA Vision.

4.8.2. Methodology

The goal of the assessment was to evaluate existing BNA plans for initiatives and facility requirements and determine the need for additional support or ancillary facilities that could advance BNA sustainability initiatives or integrate them into future planned facilities. A broader definition of 'facilities' was utilized to ensure that all potential opportunities were considered. Multiple documents were reviewed [16] with an emphasis on resource needs of particular interest to BNA (such as stormwater, waste, and transportation); however, additional elements were also considered and noted when appropriate.

Where applicable, identified sustainability-related facilities needs were integrated directly into applicable sections of this chapter. However, the following section provides an overview of the facilities that were identified as discrete opportunities necessary to meet the sustainability needs as identified above.

4.8.3. Sustainability Facilities Opportunities

Stormwater

Stormwater management is an area of increasing concern for residents of Nashville. As of 2016, the frequency and intensity of Tennessee's flood events (now occurring every 10.2 days) has elevated flooding to the state's second leading natural hazard.[17] To address the growing need for proactive stormwater management and help reduce the probability of high impact water-related events, BNA can align new development and redevelopment to allow for appropriate stormwater control in accordance with the Metro Water Service Low Impact Development (LID) Manual.[18] For new

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[16] Reviewed documents included: Sustainability Study (October 2012), Sustainability Update (2017), Energy Strategy Plan, BNA Vision, Recycling, Reuse, and Waste Reduction Plan, Livable Nashville, Nashville Next, Metro's National Pollutant Discharge Elimination System (NPDES) Phase 1 Municipal Separate Stormwater Sewer System (MS4) permit, Metro Water Services Low Impact Development Manual, and Nashville's Solid Waste Master Plan (not yet published).

[17] https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2016/12/tennessee-flood-risk-and-mitigation

[18] https://www.nashville.gov/Portals/0/SiteContent/WaterServices/Stormwater/docs/SWMM/2016/Vol5LID/2016_FullVol5LIDManual.pdf

infrastructure, the stormwater runoff reduction goal is 80% and for redevelopment the goal is 60% to reach post-construction water quality compliance.

For BNA, this means planning for necessary infrastructure for stormwater collection, retention, and/or treatment when new development and redevelopment at the airport occurs, to allow for appropriate stormwater control in accordance with the Metro Water Service Low Impact Development Manual.

The LID Manual details Green Infrastructure Practices (GIP) for improving stormwater management beyond conventional means and provides specific guidance related to optimizing stormwater runoff. The following benefits of GIP's are articulated in the LID Manual for new and redevelopment projects and are ways BNA could contribute to enhanced stormwater management in the community:

- Volume control and pollutant removal
- Groundwater and stream base flow recharging
- Restoration and protection of stream channels
- Reduction of Combined Sewer Overflows
- Ancillary environmental benefits such as improved aesthetics and public awareness

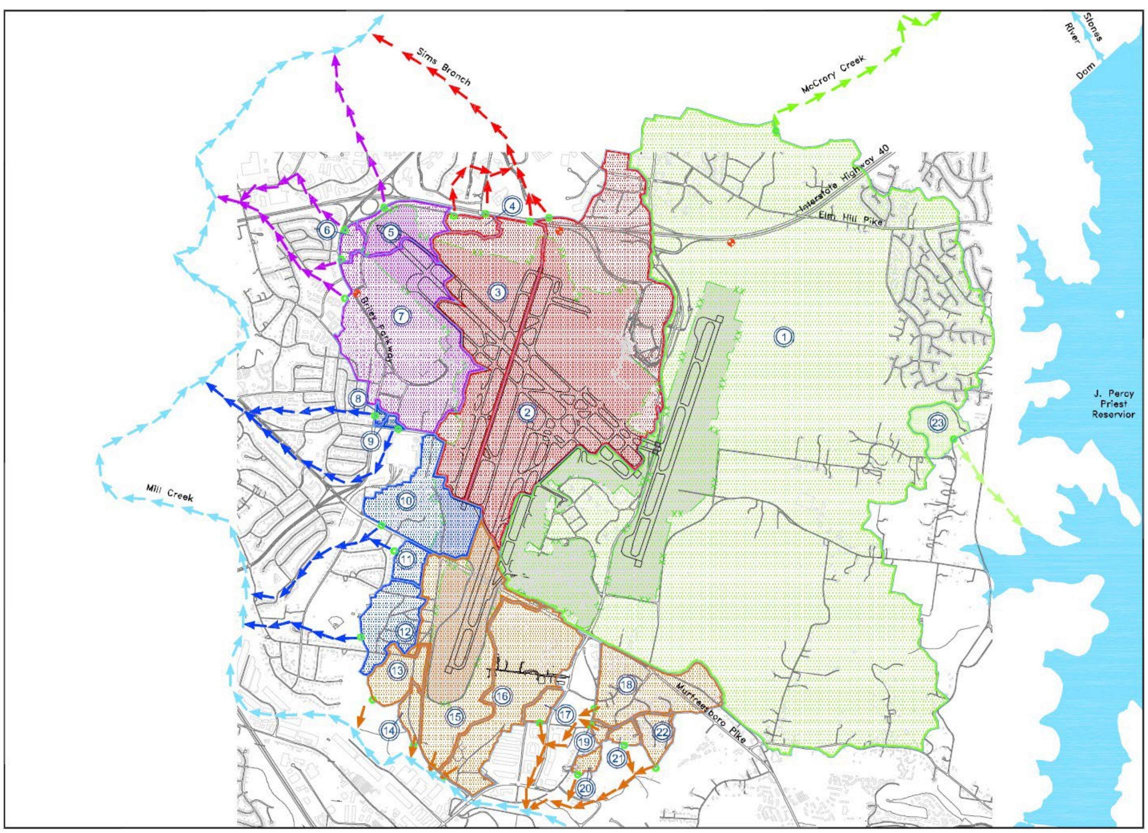

Figure 4-40. Depiction of the drainage basin area encompassing BNA.

Image courtesy of MNAA

Waste and Recycling

As domestic waste and recycling conditions shift in response to international markets, it is important that BNA's facilities and infrastructure keep pace. Given BNA's current size, future waste program needs identified in recent analyses, and potential program changes, determining an overall size footprint for waste/recycling facilities and infrastructure is essential. Considering current passenger volume and expected growth at BNA, an appropriate space allocation to support the current waste program and help ensure additional capacity to match growth would be approximately 2,200 square feet.[19] For example, this would adequately support a 30 yd. roll-off waste container, up to 5 individual large compactors, 16 yards of total food waste/organics collection, and an area for staging source-separated and additional specialized recycling and materials aggregation, including refrigerated storage for a food donation program. BNA's size also makes it an excellent candidate for a single pass-through location, a Central Waste Area (CWA)[20], where many of the largest-generating and geographically-connected waste collection points could be consolidated; however, regardless of whether a CWA is pursued, the specific space requirements (referenced above) should be addressed.

Alternative Transportation

Accommodating alternative fueling options for landside fleet and/or airside vehicles may require additional facilities support and infrastructure in the future. As of 2017, the MNAA Planning and Sustainability Committee recommended switching to a CNG (Compressed Natural Gas) Fleet at BNA. While specific facility needs related to an alternative fuel fleet will be highly dependent on fleet size and specific vehicle type, infrastructure related to fueling will need to be considered. Alternative fueling could be provided from an on-site or off-site fueling facility. Currently there is no on-site fueling for CNG buses or alternative vehicles. A full evaluation related to CNG or Renewable Natural Gas (RNG) facility and the amount of fuel storage will be essential to determine if an on-site station is appropriate for BNA, and, if so, inform the design, size, and footprint of the fueling station. [21]

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[19] Proxy space estimation is based on program footprint at Portland International Airport (PDX). This meets or exceed BNA's current requirements given the size differential between the two airports.

[20] Benefits of a CWA may include reduced hauler service levels (thereby lowering both costs and emissions associated with vehicle miles), a single access point for monitoring waste/recycling compliance, more targeted outreach opportunities, and fewer staff hours allocated for program management. If a single CWA is not feasible, a disaggregated "hub-and-spoke" approach that is similar in design can still offer these benefits and be used to maintain control over material flow (though some oversight and outreach efficiency may be lost.

[21] Specific guidance related to utilizing alternative fuels can be found in Airport Cooperation Research Program (ACRP) Synthesis 85: Alternative Fuels in Airport Fleets: http://www.trb.org/Publications/Blurbs/176442.aspx

Wellness

Because socioeconomic and community support are included among MNAA's primary sustainability focus areas, investing in healthy spaces is encouraged. Specifically, by including space for health and wellness facilities such as spiritual/reflection areas, yoga facilities and outdoor or natural areas that promote relaxation, MNAA will contribute to improved passenger experiences at BNA. Additionally, supporting facilities that encourage healthy lifestyle trends will align BNA with regional planning initiatives like Livable Nashville[22] that support active transit goals to increase bicycle and pedestrian transportation to 7% by 2020, 12% by 2030, and 30% by 2050. New development and redevelopment associated with the BNA Vision and Master Plan should consider bike commuter-related and active transit amenities (for BNA staff, tenants, and concessionaires) where appropriate, including: bike parking, showers, and lockers. This will reduce barriers that prevent active transportation by offering commuters and travelers maximum convenience related to active transit. Additionally, as the number of physical and emotional support animals onboard commercial airlines continues to climb at a significant rate,[23] accommodating pets at BNA is increasingly important. Considering additional space for pet relief areas in association with new and redevelopment of terminal space will serve the growing number of passengers who travel with four-legged companions.

[22] https://www.nashville.gov/Portals/0/SiteContent/MayorsOffice/Sustainability/docs/LN%20DRAFT.pdf

[23] United airlines reported a 75 percent increase in year-to-year increase in in customers bringing emotional support animals onboard. https://hub.united.com/united-emotional-suppport-animal-policy-2530539164.html