APPENDIX B

PURPOSE AND NEED AND ALTERNATIVES

This appendix contains the following:

- Aviation Activity Forecast
- FAA Approval of Aviation Activity Forecast
- Runway Length Analysis
- Alaska Airlines Analysis
- FAA concurrence with Alaska Airlines Analysis
- Lumley Road Tunnel Alternative Memo
- Off Site Borrow Alternative Memo

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Aviation Activity Forecast

Raleigh-Durham International Airport

Final – September 2021

PREPARED FOR
Raleigh-Durham Airport Authority

PRESENTED BY
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1 Background

This document presents the forecasts of aviation activity (i.e. demand) at the Raleigh-Durham International Airport (RDU or the Airport). The forecasts were developed as part of the Environmental Assessment (EA) process to provide the information required to quantify the potential environmental impacts based on future activity levels.

The aviation activity forecasted includes annual enplaned passengers, air cargo tonnage, and aircraft operations through 2033. Projections for passenger and aircraft operations were also developed on a peak period basis. Timing estimates of certain threshold events are the basis of planning decisions, and should correspond to level of aviation demand, referred to as Planning Activity Levels (PALs). The projected need for facility improvements is based on these PALS, rather than specific time periods. This document addresses three future PALS, which correspond to the analysis years in the EA of 2024, 2028, and 2033. Additional details of the forecasts are presented for each of the PALs.

The forecasts represent a market-driven demand for air services. The forecasts are unconstrained, and as such, do not take facility constraints or other limiting factors into consideration. In other words, for the purposes of estimated future demand, the forecasts assume that facilities can be provided to meet demand. For the purposes of this document, all years discussed in the text, tables, and figures are expressed in calendar years (CY) unless otherwise stated.

1.1 National Role of the Airport

Based on data from the Federal Aviation Administration (FAA), approximately 6.9 million enplaned passengers boarded aircraft at the Airport in 2019, ranking it as the 37th busiest in the United States.[1] This equates to an increase of approximately 10.6% as compared to FAA data for 2018.[2] The Airport is classified by the FAA as a medium hub airport[3] based on its percentage of nationwide enplaned passengers.[4]

The Airport's total aircraft operations rankings were generally consistent with its level of passenger traffic. Airport Council International-North America (ACI-NA) data indicated that the Airport had 221,626 aircraft operations[5] in CY 2019 (including all-cargo carrier operations), which ranked the Airport as the 42nd busiest airport in the United States.[6]

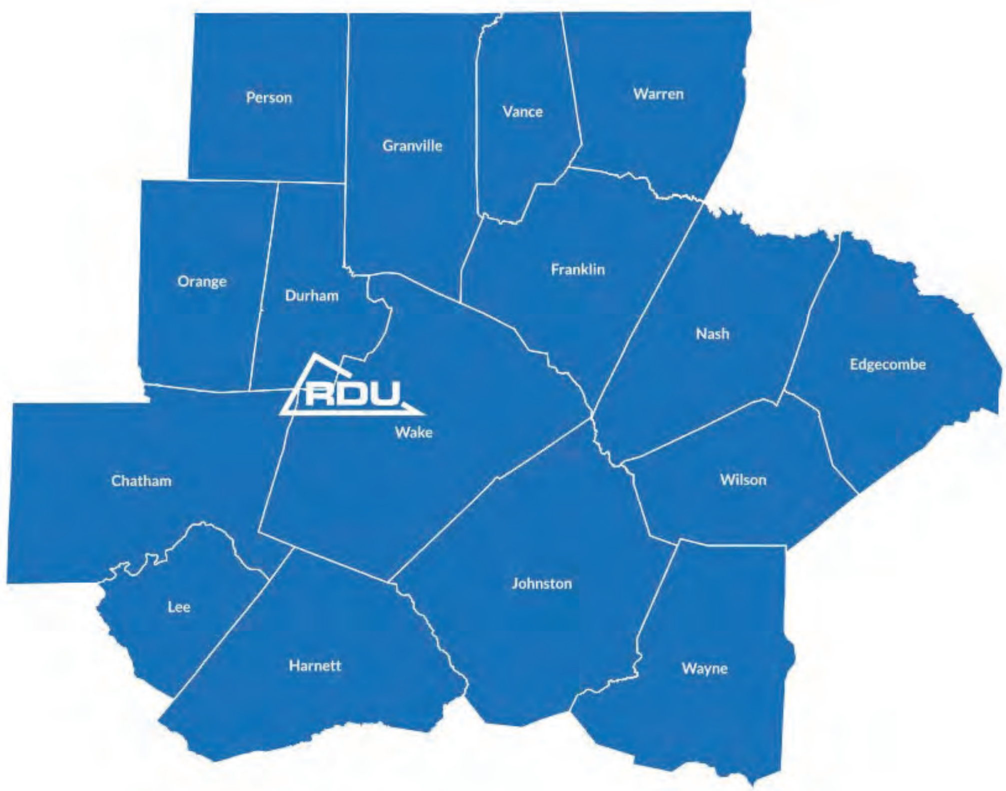
In addition to passenger traffic, there is a significant amount of air cargo processed at the Airport. According to the ACI-NA, 95,726 metric tons of air cargo, including both freight and mail, were loaded and unloaded at the Airport in CY 2019.[7] Based on this data from ACI-NA, the Airport ranked as the 43rd busiest airport for cargo in the United States for this period.

1 The 6.9 million enplaned passengers reported by the FAA is lower than the 7.1 million enplaned passengers reported by the Airport, mostly due to exclusion of non-revenue passengers.
2 Preliminary data for the calendar year enplanement and all-cargo data typically becomes available in July of the following year.
3 Federal Aviation Administration, Report to Congress: National Plan of Integrated Airport Systems (NPIAS) 2021-2025, September 30, 2020
4 To be classified as a medium-hub airport, the airport must have at least 0.25% but less than 1% of the national annual enplaned passengers.
5 An aircraft operation includes the landing, takeoff, or touch-and-go procedure by an aircraft on the runway at an airport.
6 Airports Council International-North America (ACI-NA), North American Airport Traffic Report, accessed online at https://airportscouncil.org/intelligence/north-american-airport-traffic-reports/
7 Ibid

1.2 Air Service Area

The Airport primarily serves origin and destination (O&D) traffic, as 95.3% of the Airport's passenger traffic in 2019 was O&D with the remaining 4.7% connecting. In 2020, 96.9% of the Airport's passenger traffic was O&D.[8] As such, the Airport's natural catchment area, referred to as its Air Service Area, is critical to the demand for aviation. The Airport is located in the North Carolina Piedmont region. The Airport serves the cities of Raleigh, Durham, and their surrounding areas, including the area referred to as the Research Triangle. As such, for the purposes of this forecast, the Airport's primary Air Service Area includes the Raleigh-Durham-Chapel Hill, NC Combined Statistical Area (CSA), which consists of 11 counties: Chatham, Durham, Franklin, Granville, Harnett, Johnston, Lee, Orange, Person, Vance, and Wake and an additional five counties (Warren, Nash, Wilson, Wayne, and Edgecombe) with which RDU is the primary airport. **Figure 1-1** illustrates the Airport's location in relation to its Air Service Area.

Figure 1-1 Air Service Area



Sources: Raleigh-Durham Airport Authority and United States Census Bureau, Revised Delineations of Metropolitan Statistical Areas, Micropolitan Statistical Areas, and Combined Statistical Areas, and the Guidance on Uses of the Delineations of These Areas, accessed online at https://www.whitehouse.gov/wp-content/uploads/2018/04/OMB-BULLETIN-NO.-18-03-Final.pdf.

8 Data used to estimate an airport's share of O&D passengers is from the USDOT. These data are a random 10% sample of tickets either ticketed by a United States carrier or where a United States carrier operated at least one flight in the ticket's itinerary. Therefore, the calculation of the Airport's share of O&D passengers is an estimate based on this data, which is generally accepted in the industry as the best publicly available data source for such purposes.

1.3 Historical Aviation Activity

This section provides a summary of the historical activity levels and the current passenger air service at the Airport. The information in this section provides a context for the forecast. Although the past is not a perfect predictor of the future, an analysis of historical data provides the opportunity to understand factors that have affected traffic and how those factors may influence the forecast in the future.

This section identifies, to the extent data is available, air traffic trends at the Airport that have been impacted by the coronavirus disease 2019 (COVID-19) pandemic.[9] Certain historical information about the Airport's air traffic activity predates the ongoing COVID-19 pandemic and should be considered in light of possible or probable negative effects the COVID-19 pandemic has had and may have on current and future Airport air traffic activity.

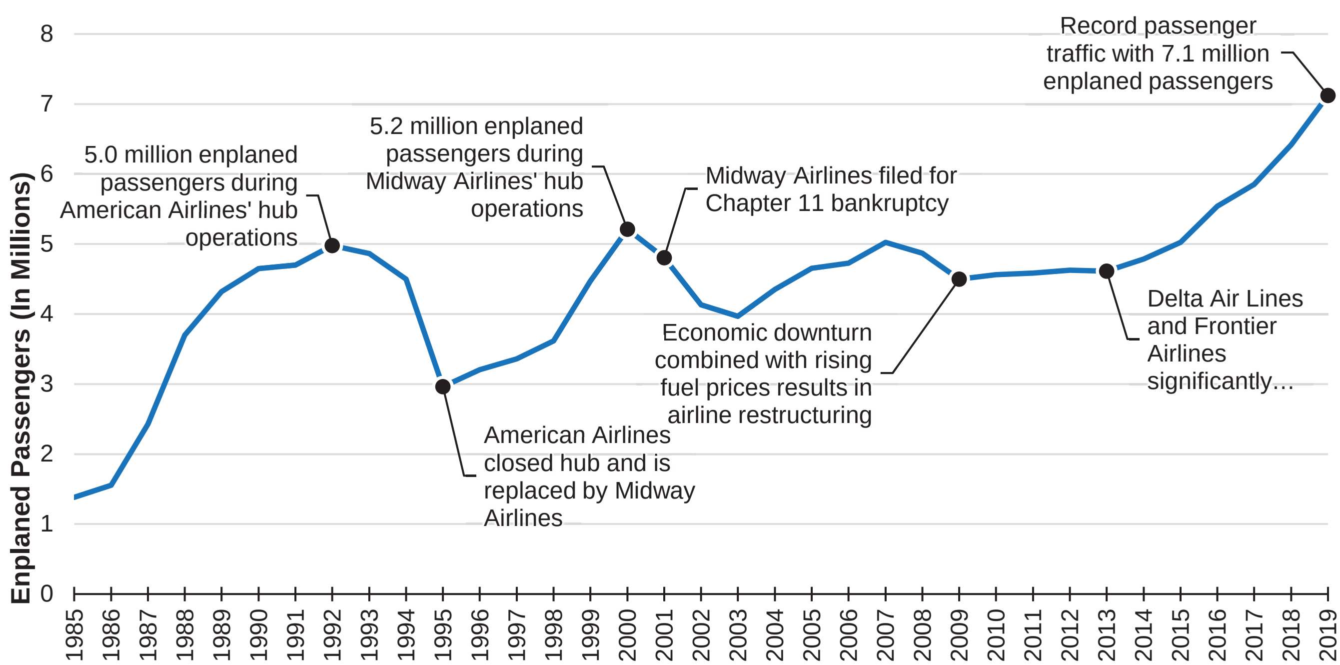
1.3.1 Passenger Activity

1.3.1.1 Enplaned Activity Trends

Pre-Pandemic Growth (1985 – 2019)

Although there have been a few periods of negative growth at the Airport, from 1985 through 2019, the overall trend of passenger growth has been positive. This is particularly true since the recovery from the 2009 economic crisis. **Figure 1-2** illustrates the passenger growth at the Airport since 1985.

Figure 1-2 Historical Enplaned Passenger Trends



Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics, accessed online at https://www.rdu.com/airport-authority/statistics/

9 Coronavirus disease 2019 has been named (COVID-19). Worldwide Covid-19 started in 2019 but the effects on the US and at RDU didn't start until 2020.

The key factors behind the changes in passenger traffic are discussed below:

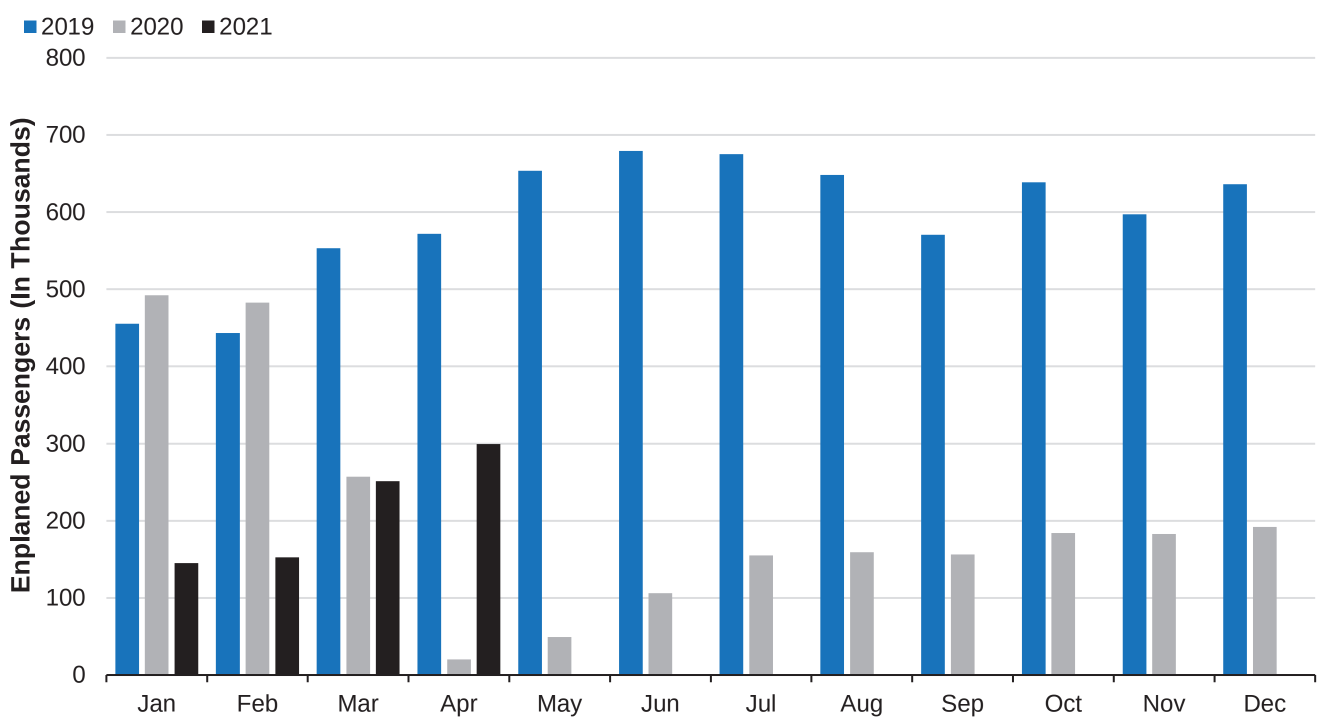
- **1985-1994:** In 1985, American Airlines began service at RDU as the Airport's seventh carrier. In June 1987, American Airlines opened its north-south hub operation at the Airport and subsequently added the Airport's first international flights. The result was rapid growth in passenger volume at the Airport over the next ten years. A significant portion of this growth was the new connecting traffic spurred by the hub operation. In 1994, the Airport reported 4.5 million enplaned passengers.
- **1994-2003:** Increased competition from Delta Air Lines at Hartsfield-Jackson Atlanta International Airport (ATL) and US Air at Charlotte Douglas International Airport (CLT) forced American Airlines to reduce operations at RDU. In June 1995, American Airlines closed its hub, drastically reducing passenger traffic at the Airport, particularly connecting passengers. However, O&D demand remained strong and another airline, Midway Airlines, quickly replaced American Airlines as the Airport's hub carrier. Passenger traffic recovered and peaked at 5.2 million enplaned passengers in 2000. However, the recession of the early 2000s combined with the start of Southwest Airlines service in June 1999 at RDU had a significant effect on Midway Airlines. The airline filed for Chapter 11 bankruptcy in August 2001. The airline continued to operate while restructuring but suspended service after the September 11 terrorist attacks and ceased operations in 2003.
- **2003-2009:** The years following the hub operations, O&D demand continued to grow, and new airlines began service at RDU to meet the demand, including Independence Air in 2004, the low-cost carrier (LCC) JetBlue in 2006, and ExpressJet in 2007. Additionally, United Airlines returned to RDU in 2007 offering flights to Washington and Chicago. However, the economic downturn combined with rising fuel prices had a significant impact on the airline industry, including at RDU. Several airlines cut service including American Airlines ending most point to point service. Enplaned passengers declined from 5.0 million in 2007 to 4.5 million in 2009.
- **2009-2019:** In 2010, passenger traffic stabilized and remained relatively flat through most of 2013. However, several airlines, including Frontier Airlines, began announcing new service indicating a turn for the Airport. Since 2013, Delta Air Lines has added several new routes and in 2015 the airline overtook American Airlines as the largest carrier at the Airport. Delta Air Lines now considers the Airport as a focus city. United Airlines also increased service at RDU during this period and nearly doubled its enplanements since 2013. Allegiant Air began service in 2015 which increased the ultra-low-cost carrier (ULCC) presence at RDU. Most recently, ULCC Spirit Airlines began service in 2019 and in its first year of operation accounted for 2.6% of the total enplaned passengers. In 2013, ULCCs accounted for less than one percent of the passenger traffic but in 2019 these airlines accounted for 10.2%.

COVID-19 Pandemic Impact (2020 – 2021)

In March 2020, the enplaned passengers at the Airport decreased dramatically primarily as a result of the impacts associated with the COVID-19 pandemic. These impacts included international travel restrictions and stay-at-home orders throughout the United States. Overall, enplaned passengers decreased by 65.8% in 2020 as compared to 2019 levels with most, if not all, of the impact occurring after mid-March 2020 when the impacts from the COVID-19 pandemic generally took hold in the United States. **Table 1-1** presents the monthly enplaned passengers for 2020 and 2021 compared to 2019. As shown, in March 2020, enplaned passengers decreased by approximately 55.9% from March 2019. The decline continued into April when enplaned passengers were 94.0% lower than April 2019. Since April 2020, enplaned passengers at the Airport have started to recover on a monthly basis. The recovery in enplaned passengers at the Airport stabilized somewhat in the fall of 2020 with monthly totals being down around 70% as compared to the same months in the prior year. However, recovery accelerated in the Spring. In April 2021, enplaned passengers were down 47.7% as compared to April 2019.

Table 1-1 Monthly Change in Enplaned Passengers at the Airport (January 2019 – April 2021)

Month	Enplaned Passengers			Percent Change from 2019	
	2019	2020	2021	2020	2021
January	455,329	492,115	145,058	8.1%	-68.1%
February	443,516	482,598	152,498	8.8%	-65.6%
March	553,278	256,900	251,404	-53.6%	-54.6%
April	571,972	20,070	299,246	-96.5%	-47.7%
May	653,760	49,232		-92.5%	
June	679,427	106,144		-84.4%	
July	675,168	154,859		-77.1%	
August	648,192	159,085		-75.5%	
September	570,542	156,164		-72.6%	
October	638,582	184,104		-71.2%	
November	597,280	182,960		-69.4%	
December	636,388	191,805		-69.9%	
Total	**7,123,434**	**2,436,036**	**848,206**	**-65.8%**	



Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics, accessed online at https://www.rdu.com/airport-authority/statistics/

1.3.1.2 Passenger Airlines at the Airport

The current United States passenger airline industry generally consists of three primary business models: network carriers or full-service carriers, LCCs, and ULCCs. Network carriers are generally considered the major airlines that have existed, in one form or another, since the deregulation of the airline industry in the late 1970s. Network airlines have extensive route networks and can operate with a "hub and spoke" system or maintain significant market share at focus cities. These airlines tend to generally cater more towards the business traveler segment. LCCs are generally defined as passenger airlines that focus on lower operating costs to be able to provide customers lower fares while still providing some amenities within the cost of the ticket. LCCs typically focus upon carrying point-to-point traffic at relatively lower airfares, while offering comparable (to network carriers) airfares for connecting passengers. However, as compared to network airlines, LCCs do not have as extensive route networks. ULCCs are somewhat similar to LCCs but generally focus on the leisure traveler. These airlines offer the lowest airfares and do not provide any amenities within the cost of the ticket. Thus, ULCCs will typically charge for everything outside of the ticket cost such as checked baggage, carry-on baggage, and seat selection.

The Airport has a diverse, stable base of air carriers. Currently, there are four United States network airlines,[10] three LCC,[11] three ULCCs,[12] and one foreign-flag airline. In 2013, American Airlines was the largest carrier at the Airport accounting for 32.3% of enplaned passengers. However, significant growth by other network carriers, particularly Delta Air Lines, and the introduction of ULCCs has resulted in a decline in the airline's market share. Delta Air Lines has consistently been the largest carrier in terms of enplaned passengers, accounting for 29.8% of the market on average over the past five years. **Table 1-2** presents the Airport's enplaned passenger market share by airline since from 2016 through 2020.

1.3.1.3 Current Nonstop Service

Prior to the COVID-19 pandemic, there was service to 55 domestic destinations and 5 international destinations from the Airport. By May 2020, service to 21 domestic airports and all five international airports was suspended as a primary result of the COVID-19 pandemic. As of May 2021, there was scheduled service to 45 domestic destinations and 2 international destinations from the Airport. **Table 1-3** provides a breakdown of the changes to the scheduled nonstop destinations service through the COVID-19 pandemic.

1.3.1.4 Top Passenger Markets

Table 1-4 provides information regarding the Airport's top O&D markets, including the number of daily O&D enplaned passengers for 2019 and 2020. The table also presents daily departures, and daily departing seats. The table helps to illustrate how the Airport's air travel demand has changed since the start of the COVID-19 pandemic. In total, daily O&D passengers decreased by almost a third while the number of daily departures and departing seats decreased by approximately half.

[10] For the purposes of this document, Alaska Airlines, American Airlines, Delta Air Lines, and United Airlines are considered network airlines.
[11] For the purposes of this document, JetBlue Airways, Southwest Airlines, and Sun Country Airlines are considered LCCs.
[12] For the purposes of this document, Allegiant Air, Frontier Airlines, and Spirit Airlines are considered ULCCs.

Table 1-2 Enplaned Passenger Market Share (2016 – 2020)

Airline	Enplaned Passengers (In Thousands)					Market Share				
	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
Delta	1,654.4	1,800.9	1,966.7	2,173.5	667.4	29.9%	30.8%	30.6%	30.6%	27.3%
American	1,509.0	1,541.3	1,524.8	1,620.9	644.6	27.2%	26.3%	23.8%	22.8%	26.3%
Southwest	1,161.8	1,196.6	1,242.8	1,301.5	498.2	21.0%	20.5%	19.4%	18.3%	20.4%
United	686.8	746.7	822.8	831.3	296.8	12.4%	12.8%	12.8%	11.7%	12.1%
Frontier	129.7	135.8	370.7	496.7	118.5	2.3%	2.3%	5.8%	7.0%	4.8%
JetBlue	259.1	263.7	277.3	292.6	94.3	4.7%	4.5%	4.3%	4.1%	3.9%
Spirit	0.0	0.0	0.0	183.5	72.4	0.0%	0.0%	0.0%	2.6%	3.0%
Alaska	54.6	63.3	97.1	95.3	33.2	1.0%	1.1%	1.5%	1.3%	1.4%
Allegiant	43.4	55.3	67.4	41.5	12.1	0.8%	0.9%	1.0%	0.6%	0.5%
Air Canada	37.6	44.2	43.4	54.8	8.6	0.7%	0.8%	0.7%	0.8%	0.4%
Charters	2.5	3.2	3.7	3.4	1.9	0.0%	0.1%	0.1%	0.0%	0.1%
Total	5,538.9	5,851.0	6,416.8	7,095.2	2,447.9	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Other includes charter service.
Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics, accessed online at https://www.rdu.com/airport-authority/statistics/

Table 1-3 Nonstop Destinations

City	Airport	Airlines	Maintained	Resumed	Suspended	Future
Domestic			**24**	**21**	**7**	**1**
Atlanta	ATL	DL, F9, WN	●			
Baltimore-Washington	BWI	WN	●			
Boston	BOS	DL, B6	●			
Charlotte	CLT	AA	●			
Chicago-Midway	MDW	WN	●			
Chicago-O'Hare	ORD	AA, UA	●			
Dallas-Fort Worth	DFW	AA	●			
Denver	DEN	F9, WN, UA	●			
Detroit	DTW	DL	●			
Fort Lauderdale	FLL	DL, B6, WN, NK	●			
Fort Myers	RSW	B6	●			
Houston-Bush	IAH	UA	●			
Miami	MIA	AA, DL, F9	●			
Minneapolis	MSP	DL, SY	●			
Nashville	BNA	AA*, WN	●			
New York-JFK	JFK	DL, B6	●			
Newark	EWR	B6, UA	●			
Orlando-International	MCO	AA, DL, F9, B6, WN, NK	●			
Philadelphia	PHL	AA, F9	●			
Punta Gorda	PGD	G4	●			
San Juan	SJU	F9, B6	●			
Seattle	SEA	AK, DL	●			
St. Louis	STL	WN	●			
Washington-Dulles	IAD	UA	●			
Austin	AUS	AA, DL, B6, WN		●		
Buffalo	BUF	F9		●		
Cleveland	CLE	F9		●		
Dallas-Love	DAL	WN		●		
Hartford	BDL	F9		●		
Houston-Hobby	HOU	WN		●		

Table 1-3 Nonstop Destinations (continued)

City	Airport	Airlines	Maintained	Resumed	Suspended	Future
Jacksonville	JAX	DL, B6		●		
Las Vegas	LAS	DL, F9, B6, WN		●		
Los Angeles	LAX	AA, DL, B6		●		
New Orleans	MSY	WN		●		
New York-LaGuardia	LGA	AA, DL		●		
Orlando-Sanford	SFB	G4		●		
Phoenix	PHX	AA, WN		●		
Pittsburgh	PIT	AA		●		
Portland	PWM	F9		●		
Salt Lake City	SLC	DL		●		
San Francisco	SFO	B6, UA*		●		
St. Pete-Clearwater	PIE	G4		●		
Tampa	TPA	DL, F9, B6, WN		●		
Trenton	TTN	F9		●		
Washington-Reagan	DCA	AA		●		
Albany	ALB	F9			●	
Cincinnati	CVG	F9			●	
Columbus	CMH	DL, F9			●	
Indianapolis	IND	DL			●	
New York-Long Island	ISP	F9			●	
Providence	PVD	F9			●	
Syracuse	SYR	F9			●	
Destin	VPS	AA				●
International			**2**	**0**	**4**	**0**
Cancun	CUN	DL, B6	●			
Montego Bay	MBJ	B6	●			
London	LHR	AA			●	
Montréal	YUL	AC			●	
Paris	CDG	DL			●	
Toronto	YYZ	AC			●	

Note: AS = Alaska Airlines, DL = Delta Air Lines, AA = American Airlines, WN = Southwest Airlines, NK = Spirit Airlines, B6 = JetBlue, F9 = Frontier Airlines, UA = United Airlines, AC = Air Canada.

Sources: Diio Mi, Schedule – Dynamic Table. Raleigh-Durham Airport Authority, Nonstop Destinations, accessed online at https://www.rdu.com/airline-information/airline-destinations/

Table 1-4 Top Domestic and International O&D Markets

Market	2019			2020		
	Average Daily O&D Passengers	Average Daily Departures	Average Daily Seats	Average Daily O&D Passengers	Average Daily Departures	Average Daily Seats
New York	1,601	34	2,713	444	13	1,140
Chicago	905	15	1,856	267	8	936
Boston	875	12	1,220	220	5	508
South Florida	773	9	1,203	384	5	706
Orlando	748	7	1,064	300	4	561
Wash, D.C.	731	21	2,167	184	9	1,009
Atlanta	575	14	2,355	243	10	1,580
Los Angeles	513	2	346	212	1	104
Denver	518	5	774	242	4	583
SF Bay Area	508	3	394	130	0	71
Dallas	485	7	1,030	190	4	626
Philadelphia	486	9	877	143	4	379
Las Vegas	384	2	351	136	0	73
Tampa	390	5	573	127	2	178
Nashville	351	5	552	135	3	375
Houston	312	5	582	130	3	261
Detroit	316	5	614	101	3	328
Seattle	278	2	312	104	1	238
Minneapolis	237	4	403	83	2	249
Phoenix	233	2	256	98	1	89
New Orleans	239	1	212	72	0	70
Austin	217	1	89	84	0	20
San Diego	194	0	50	67	0	0
Kansas City	163	1	135	57	0	40
St. Louis	160	2	261	67	1	160
Top 25 Markets	**12,192**	**172**	**20,389**	**4,221**	**85**	**10,286**
Others	5,704	21	2,549	1,930	10	1,335
Total	**17,895**	**193**	**22,938**	**6,151**	**95**	**11,620**

Note: AS = Alaska Airlines, DL = Delta Air Lines, AA = American Airlines, WN = Southwest Airlines, NK = Spirit Airlines, B6 = JetBlue, F9 = Frontier Airlines, UA = United Airlines, AC = Air Canada.

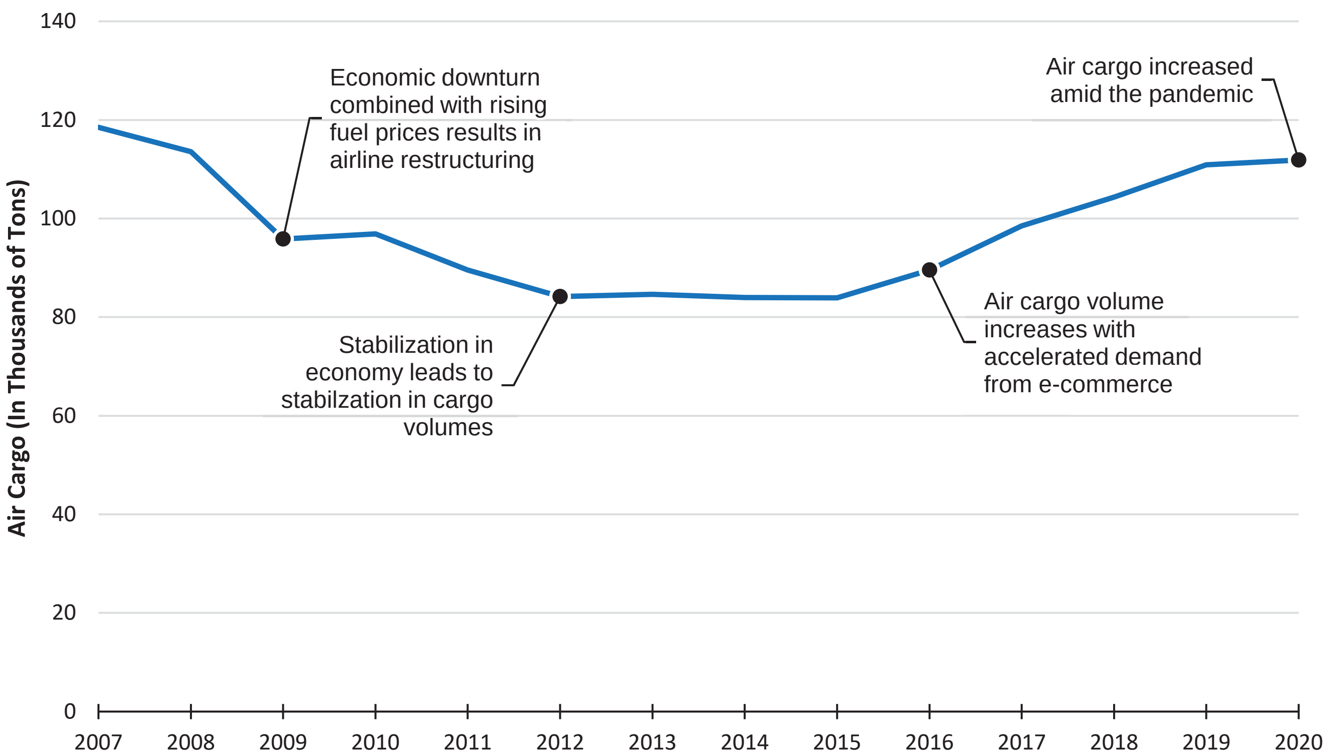
Source: United States Bureau of Transportation Statistics, Air Passenger Origin and Destination Survey Data (DB1B), accessed online through Diio Mi.

1.3.2 Cargo Activity

1.3.2.1 Air Cargo Throughput Trends

Air cargo at airports is comprised of two segments: air mail and air freight. Air mail refers to parcels that are carried by aircraft as part of a contract with the United States Postal Service. Air freight refers to all air cargo that is not air mail. From 2011 through 2019, only 1.6% of total air cargo processed at RDU was air mail. In 2020, air mail only accounted for 0.4% of total air cargo driven in large part to the suspension of international passenger flights. Since 2007, air cargo has followed a similar trend as passenger traffic at the Airport. Air cargo declined from 2007 through 2012, mostly attributable to the global financial crisis. The following four years, air cargo averaged just over 84,000 tons. Beginning in 2016, growth in the economy, as well as increased demand for goods through e-commerce, has led to growth in air cargo at the Airport. In 2020, there was a reported 11,855 tons of air cargo processed at the Airport amid the pandemic. **Figure 1-3** graphically depicts the trend in air cargo at the Airport since 2007.

Figure 1-3 Historical Air Cargo Trends



Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics, accessed online at https://www.rdu.com/airport-authority/statistics/

1.3.2.2 Mode of Transportation

There are two shipping methods for transporting air cargo: (1) in the cargo compartment (belly) of commercial passenger aircraft or (2) aboard dedicated all-cargo aircraft (freighters). Most passenger airlines accommodate air cargo as a by-product of their primary activity of carrying passengers. Cargo fills belly space that would otherwise be empty. The incremental cost of transporting cargo in passenger aircraft is negligible and includes ground handling expenses and a modest increase in fuel consumption.

From 2007 through 2019, domestic air cargo has accounted for 94.7% of all air cargo at the Airport. In 2020, domestic air cargo accounted for 99.5% of all air cargo at the Airport primarily due to the suspension of international passenger flights. A majority of this traffic is handled by dedicated freighter operators such as Federal Express (FedEx) and United Parcel Service (UPS). As such, most of the total air cargo processed at RDU, approximately 90% since 2012, has been handled by all-cargo carriers. However, international air cargo is nearly exclusively handled by passenger airlines, in particular, American Airlines operating to London and Delta Air Lines operating to Paris.

1.3.3 Aircraft Operations

An aircraft operation consists of either a take-off or landing. For the purposes of developing the forecasts, aircraft operations were classified into four key categories: (1) passenger; (2) freighter; (3) air-taxi and general aviation; and (4) military.

Pre-Pandemic Growth (2007 – 2019)

Passenger aircraft operations refer to operations handled by airlines with scheduled service, i.e. certified as a scheduled air carrier by the FAA under Part 121.[13] From 2007 through 2019, passenger aircraft operations have declined at a compound annual growth rate (CAGR) of 1.0% despite growth in passenger traffic of 2.9% during that period. This is the result of airlines drastically changing their operations to remain profitable during the recession, which began in 2009. Airlines opted for larger aircraft with higher load factors and fewer flights. From 2014 through 2019, passenger aircraft operations have been increasing more in line with the passenger traffic.

From 2007 through 2009, all-cargo, or freighter, aircraft operations declined significantly. However, like the cargo tonnage, as the economy began to stabilize, the cargo aircraft operations began to stabilize. From 2009 through 2019, all-cargo aircraft operations have accounted for 2.5% of the total aircraft operations at the Airport.

Air taxi represents charter aircraft operated by companies that operate under Part 91[14] (i.e., not certified as scheduled air carrier by the FAA and not covered under Part 121). Business charters at RDU, such as Causey Aviation, provide ad-hoc service utilizing mostly business jet aircraft. These airlines account for most of the air taxi service at RDU. General aviation (GA) aircraft operations represent all civil operations not classified as commercial. The combination of air taxi and GA aircraft operations declined significantly in 2008 and 2009 but has been relatively consistent through 2015. From 2015 through 2019, the combined category has increased at a CAGR of 4.8%.

Military aircraft operations represent operations conducted by military or government aircraft. Military aircraft operations have declined steadily from 2015 through 2019 at an annual rate of 10.4%. A summary of the aircraft operations prior to the COVID-19 pandemic is provided in **Table 1-5**.

[13] 14 Code of Federal Regulations Part 121.
[14] 14 Code of Federal Regulations Part 91

Table 1-5 Historical Aircraft Operations

Year	Passenger	All-Cargo	Air Taxi/ General Aviation	Military	Total
2007	162,290	6,354	79,623	4,441	252,708
2008	147,066	5,324	71,004	6,012	229,406
2009	131,610	4,870	55,013	3,610	195,103
2010	124,872	5,078	52,830	4,721	187,501
2011	128,302	4,784	54,580	5,693	193,359
2012	135,540	4,058	43,355	5,264	188,217
2013	122,580	4,156	54,045	4,794	185,575
2014	120,746	4,326	54,153	4,332	183,557
2015	115,776	4,360	56,996	3,996	181,128
2016	123,342	4,598	59,696	3,712	191,348
2017	127,155	5,078	64,732	2,863	199,828
2018	135,658	5,118	66,386	2,239	209,401
2019	144,098	6,110	68,837	2,581	221,626
Compound Annual Growth Rates					
2007-19	-1.1%	-1.8%	-1.3%	-4.4%	-1.2%

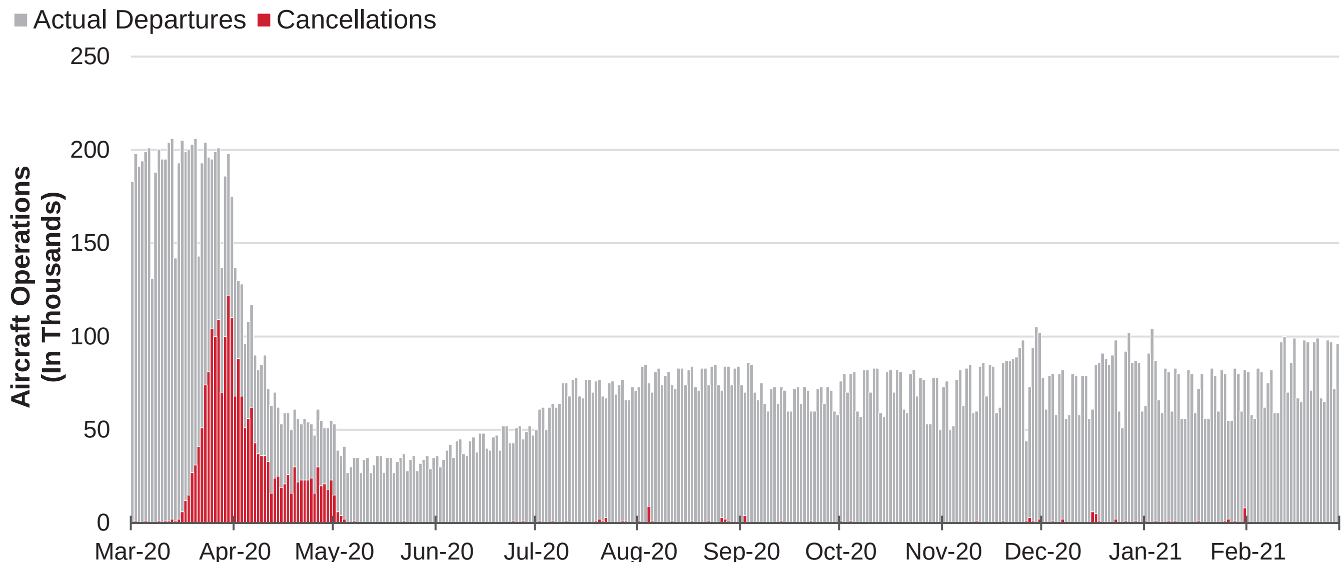
Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics, accessed online at https://www.rdu.com/airport-authority/statistics/. FAA, Air Traffic Activity System (ATADS), accessed online at https://aspm.faa.gov/opsnet/sys/Airport.asp.

COVID-19 Pandemic Impact (2020 – 2021)

In response to the significant decline in enplaned passengers in the United States and at the Airport during the ongoing COVID-19 pandemic, the airlines reduced the number of daily flights and air service in kind. There were 1,063 flight cancellations at the Airport in March 2020 and 998 cancellations in April 2020 before tailing off in May and June.[15] The cancellations allowed for near-term changes until revised schedules could be developed. **Figure 1-4** illustrates the high concentration of flight cancellations early in the pandemic, followed by a reduction in flights, and a gradual increase in flights in the summer of 2020 before remaining flat though February 2021.

[15] Federal Aviation Administration, Airline Service Quality Performance System: Airport View: Causal Report, accessed online at https://aspm.faa.gov/asqp/sys/Airport.asp

Figure 1-4 Flight Departures and Cancellations at the Airport (March 2020 – January 2021)

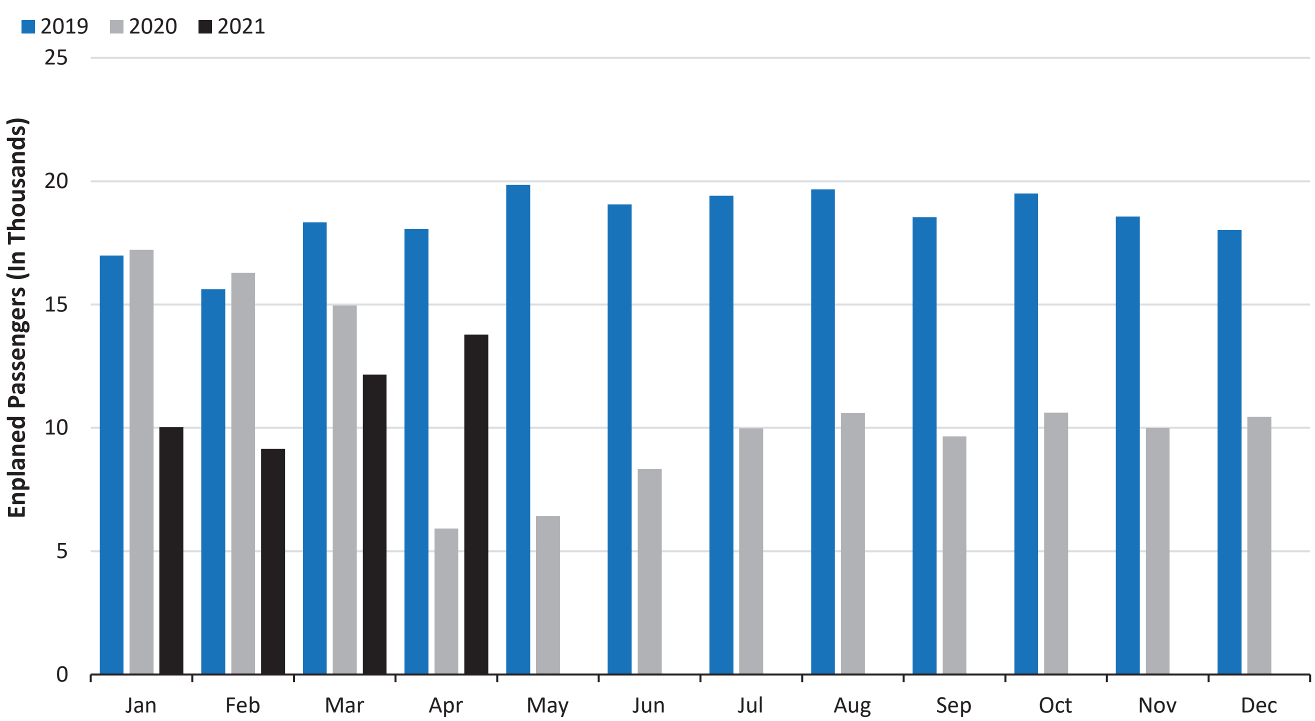


Source: Federal Aviation Administration, Airline Service Quality Performance System: Airport View: Causal Report, accessed online at https://aspm.faa.gov/asqp/sys/Airport.asp

Overall, aircraft operations decreased by 41.2% in 2020 as compared to 2019 levels with the primary impacts occurring after mid-March 2020. **Table 1-6** presents the monthly aircraft operations for 2020 and 2021 compared to the 2019. As shown, starting in March 2020, aircraft operations decreased by approximately 18.4% from March 2019, compared to 53.6% for enplaned passengers. Normally, aircraft operations would be more directly related to enplaned passengers. However, there was an initial reluctance to remove flights because of the implementation of social distancing practices (i.e. restricting the use of middle seats) and to a smaller degree the continued operations of all-cargo airlines that were impacted to a lesser degree by the pandemic. The decline continued into April 2020 and May 2020 when aircraft operations were 67.2% and 67.7% lower than the same months in the prior year, respectively. Since May 2020, aircraft operations at the Airport have started to recover. In April 2021, aircraft operations were only down 23.7% from 2019 compared to 67.2% in April 2020.

Table 1-6 Monthly Change in Aircraft Operations at the Airport (January 2019 – April 2021)

Month	Aircraft Operations			Percent Change from 2019	
	2019	2020	2021	2020	2021
January	16,980	17,223	10,030	1.4%	-40.9%
February	15,617	16,282	9,146	4.3%	-41.4%
March	18,331	14,958	12,164	-18.4%	-33.6%
April	18,066	5,924	13,786	-67.2%	-23.7%
May	19,857	6,423		-67.7%	
June	19,066	8,330		-56.3%	
July	19,404	9,978		-48.6%	
August	19,674	10,600		-46.1%	
September	18,544	9,648		-48.0%	
October	19,506	10,615		-45.6%	
November	18,561	9,988		-46.2%	
December	18,020	10,441		-42.1%	
Total	**221,626**	**130,410**	**45,126**	**-41.2%**	



Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics, accessed online at https://www.rdu.com/airport-authority/statistics/

2 Key Factors of Air Traffic

The forecast of future air traffic activity at the Airport was prepared partly on the basis of quantitative factors including socioeconomic variables such as population, employment, and income. Additionally, there are a number of qualitative factors that could impact air traffic activity, both nationwide and at the Airport. Both the quantitative and qualitative factors driving air traffic at RDU are discussed in this section.

2.1 The COVID-19 Pandemic

COVID-19 is a respiratory disease caused by a novel strain of coronavirus. The World Health Organization (WHO) declared the outbreak of COVID-19 a public health emergency of international concern on January 30, 2020, and subsequently declared it a pandemic on March 11, 2020. As of March 21, 2021, WHO has reported over 165 million confirmed cases of COVID-19 and over 3.4 million deaths worldwide.[16] For the United States (U.S.), as of March 15, 2021, WHO reported over 32.7 million confirmed cases and over 582,346 deaths.

Since the first reported U.S. cases in January 2020, there has been a focus on containing the disease by prohibiting non-essential travel, limiting person-to-person contact, and restricting travel into the U.S. of certain foreign nationals.[17] Across the U.S., states and local governments, including North Carolina, initially issued “stay at home” or “shelter in place” orders designed to restrict movement and limit businesses and activities to essential functions, which substantially reduced activities that normally engaged or facilitated air travel. While stay at home orders have generally been lifted in the U.S., air travel has not yet recovered.

While passenger traffic, and to a lesser extent aircraft operations, was dramatically affected by the impacts associated with the COVID-19 pandemic initially, both started to recover through the summer of 2020. However, during the fall of 2020, the recovery stalled before starting to gain momentum again in the winter of 2020 and into the Spring of 2021.

Two factors are assumed to be necessary for passenger traffic and aircraft operations to recover back to levels experienced prior to the COVID-19 pandemic. First, confidence needs to be restored such that passengers feel that traveling on aircraft and using airport facilities is safe from a health standpoint. Second, the United States public health response must constrain the spread of the virus sufficiently to demonstrate that our travel origins and destinations are deemed safe.

Airlines and airports have put forth great effort to show that air transportation is safe during this pandemic. Despite the CDC concluding “that the risk for on-board transmission of SARS-CoV-2 during long flights is real and has the potential to cause COVID-19 clusters of substantial size”,[18] another study suggests that on-board transmission is a rare event.[19] The United States government, airlines, and airports, including RDU, have taken further steps to reduce risks through enhanced cleaning, contactless boarding, use of physical barriers, physical distancing, temperature screening of employees, and requiring use of face coverings during all phases of aviation travel. According to a report from the Harvard’s Aviation Public Health Initiative, airports have made “consistent and impressive commitments to reduce the risks of disease transmission in their facilities” between passengers, employees, concessionaires, contractors and visitors through layered, interlinked, risk-mitigation strategies that,

[16] World Health Organization, WHO Coronavirus (COVID-19) Dashboard, https://covid19.who.int/table, accessed March 2021.
[17] President of the U.S. Executive Proclamation, January 31, 2020
[18] Transmission of SARS-CoV 2 During Long-Haul Flight, Nguygen Cong Khanh et al, EID Journal Volume 26, Number 11, accessed via CDC website https://wwwnc.cdc.gov/eid/article/26/11/20-3299_article accessed February 10, 2021
[19] Risk of COVID-19 During Air Travel, Rui Pombal, MD et al, Journal of the American Medical Association, October 1, 2020, accessed via https://jamanetwork.com/journals/jama/fullarticle/2771435, accessed on February 10, 2021

when used together, can effectively control the risk of exposure. The report concluded that, overall, the probability of being infected in an airport is very low.[20]

In order to return to a similar lifestyle that Americans experienced prior to the pandemic, we must achieve some level of population immunity on a national and global scale. Population immunity, also known as herd immunity, is the indirect protection from an infectious disease that happens when a population is immune either through vaccination or immunity developed through previous infection. To reach herd immunity it is estimated that a significant percent of the population must be immune to a virus to interrupt the chain of transmission. At this time, the exact share of the population needed to achieve herd immunity from COVID-19 is uncertain, but it is generally understood to be 70% or higher. The United States government has aggressively promoted the development of an effective vaccine since the start of the pandemic. To-date, the Federal Food and Drug Administration has given emergency use authorization for three vaccines, Pfizer's Comirnaty, Moderna's mRNA-1273, and Johnson & Johnson's Ad26.COV2.S. The first COVID-19 vaccination in the United States administered to the public occurred on December 14, 2020. As of May 12, 2021, approximately 344.1 million doses have been distributed with nearly 111.6 million people (44.7% of population over the age of 18) fully vaccinated.[21]

At this point, achieving herd immunity is generally viewed as one of the largest obstacles to returning to normal activities. A survey from PEW Research Center in February 2021 indicated that approximately 69% of Americans intend to get a vaccine or already have.[22] While this presents a gap between the amount required to reach herd immunity and the number of those likely to be vaccinated, it should be noted that this is an increase of nine percent from those surveyed in November 2020 and 18% from those surveyed in September 2020. However, 31% said they would either probably not or definitely not get the vaccine.[23] Certain experts have indicated that it is becoming more unlikely that herd immunity will be reached in the United States as people may opt not to take the vaccine and variants of the virus spread. Some experts believe that without reaching herd immunity, the virus will continue to circulate but will become more manageable. The virus will still result in hospitalizations and deaths, but in much smaller numbers than seen during the earlier stages of the pandemic. It is assumed that those wanting to be vaccinated in the United States will be fully vaccinated by the fourth quarter of 2021. With more manageable infection rates, hospitalizations, and deaths, it is expected that domestic passenger traffic and aircraft operations will steadily increase. International traffic is not likely to recover until 2022 or later because many parts of the world have not been as successful as the United States in obtaining and delivering vaccines.[24]

2.2 Socioeconomic Base

The intrinsic link between the level of activity and socioeconomic growth is well documented. Simply put, growth in population, employment, and income typically lead to increased demand for air travel both for business and for leisure purposes. This section discusses socioeconomic trends and conditions of the Raleigh-Durham-Chapel Hill, NC CSA, and present data indicative of the area's capability to generate a growing demand for air transportation throughout the next several years. For the purposes of this report, the socioeconomic conditions provided reflect the Raleigh-Durham-Chapel Hill, NC Combined Statistical Area (CSA) and excludes the five additional counties included in primary Air Service Area.

20 AAAE, Top Stories for Thursday, February 11, 2021: Harvard: Risk of Virus Infection 'Low' In Airports.
21 CDC COVID Data Tracker accessed at https://covid.cdc.gov/covid-data-tracker/#vaccinations
22 Pew Research Center, *Growing Share of Americans Say They Plan To Get a COVID-19 Vaccine – or Already Have*, accessed online at https://www.pewresearch.org/science/2021/03/05/growing-share-of-americans-say-they-plan-to-get-a-covid-19-vaccine-or-already-have/
23 Ibid.
24 The Hill, WHO official warns global herd immunity from COVID-19 won't happen until 2022, accessed via https://thehill.com/policy/healthcare/533792-who-official-warns-global-herd-immunity-from-covid-wont-happen-until-2022

All socioeconomic data provided in this section were provided by Woods & Poole, Inc. unless otherwise noted. Woods & Poole is an independent vendor and nationally recognized firm that provides expert economic and demographic analysis. Forecasts from Woods & Poole were developed in early 2020, which included estimates for 2020. However, due to COVID-19, there are likely discrepancies between the estimates and the actuals. Therefore, all data presented in this section from Woods & Poole end in 2019. Other sources of data are updated to their most current versions available at the time of the preparation of this document. Additionally, all data provided in dollar values are expressed in real value (i.e. adjusted for inflation).

2.2.1 Economy

2.2.1.1 Relationship of Air Traffic to United States Economy

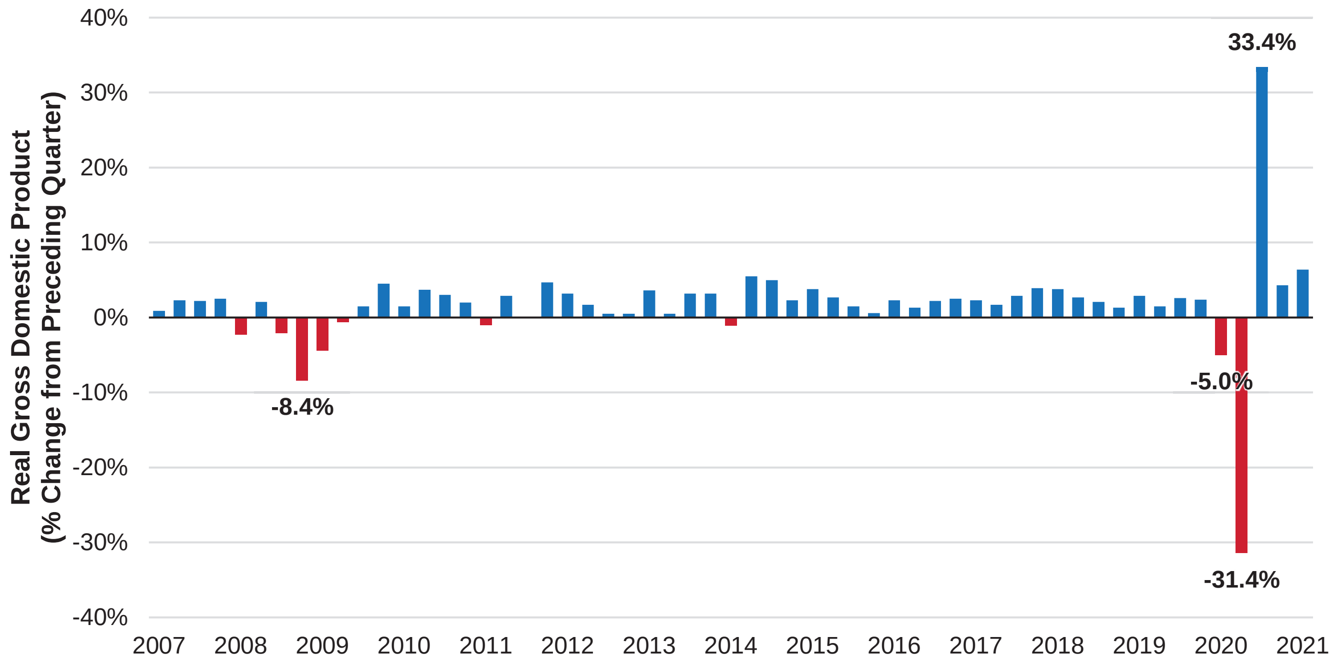
Historically, the United States economy, as measured by gross domestic product (GDP),[25] grew at a relatively steady rate, averaging 3.1% per annum between CY 1960 and CY 2019. The rate of growth had been remarkably stable reflecting both the size and maturity of the United States economy. Individual years have fluctuated around the long-term trend for a variety of reasons including macroeconomic factors, fuel shocks, war, and terrorist attacks.

Prior to 2020, there were two official economic recessions in the United States in the 21st century. The first occurred between March 2001 and November of 2001 and was compounded by the September 11, 2001, terrorist attacks. The negative impact of these events on the airline industry is well documented. The recession itself was short-lived by historical standards and the economy returned to positive growth rates quickly, fueled by a gradual but prolonged reduction in interest rates. The Great Recession occurred between December 2007 and June 2009.[26] As a result of the Great Recession, the nation's unemployment rate rose from 5.0% in December 2007 to a previous high of 10.0% in October 2009.[27]

The outbreak of COVID-19 in early 2020 and the declaration of a pandemic by the WHO on March 11, 2020 coupled with the subsequent travel restrictions have led to disruptions of economies around the world, resulting in dramatic increases in unemployment and significant decreases in air traffic. Business failures, worker layoffs, and consumer business bankruptcies are occurring and are expected to continue into the near future as the COVID-19 global pandemic continues. According to the Bureau of Economic Analysis (BEA), real GDP decreased at an annual rate of 31.4% in the second quarter of 2020 after decreasing by 5.0% in the first quarter of 2020. In comparison, the worst decline in GDP during the Great Recession was 8.4% in the fourth quarter of 2008. There was significant recovery in GDP in the third quarter, increasing 33.4%. Although the growth was significant, real GDP still remained below first quarter 2020. The updated estimate for first quarter of 2021 shows a 6.4% increase. **Figure 2-1** depicts the magnitude of the impact the COVID-19 pandemic has had on the United States economy, thus far, when compared to the Great Recession.

[25] Gross domestic product is a monetary measure of the value of goods and services produced in a country.
[26] National Bureau of Economic Research, United States Business Cycle Expansions and Contractions, September 20, 2010.
[27] National Bureau of Economic Research, United States Business Cycle Expansions and Contractions, September 20, 2010.

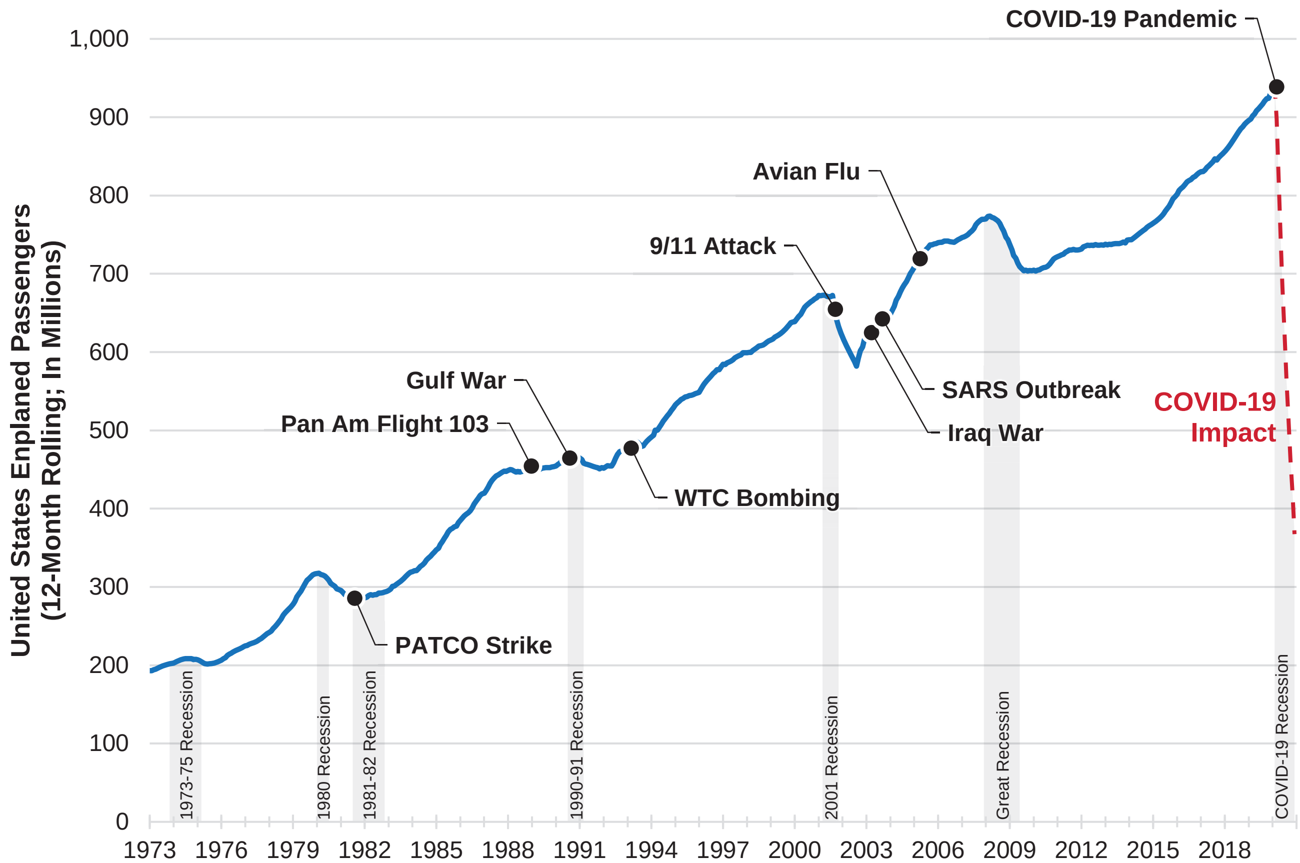
Figure 2-1 United States Economic Impact of the COVID-19 Pandemic



Note: Rates are seasonally adjusted at annual rates.
Source: United States Bureau of Economic Analysis, National Income and Product Accounts.

Figure 2-2 shows the strong correlation between enplaned passenger traffic in the United States and the nation's economy in addition to significant shocks/events. During periods of economic contractions and exogenous events, there is a notable decline in passenger volumes and during the subsequent economic expansions and recovery periods, there is significant growth in passenger volumes. Additionally, exogenous shocks such as terrorist attacks have generally had a short but significant impact on passenger volumes. As presented on this figure, the COVID-19 pandemic has been the most disruptive event to negatively impact aviation in history. There is still much uncertainty on when air traffic will recover to "pre-COVID-19" levels. However, it is assumed that the ultimate ability to control the spread of COVID-19 throughout the world and/or the mass distribution of an effective vaccine or treatment will play a significant role in restoring passenger confidence in air travel and airlines being able to return to pre-COVID-19 load factors. Future waves and/or threats of future waves of COVID-19 or another pandemic including associated travel restrictions and stay-at-home orders, could have a further negative impact on air travel in the future.

Figure 2-2 United States Aviation System Shocks and Recoveries



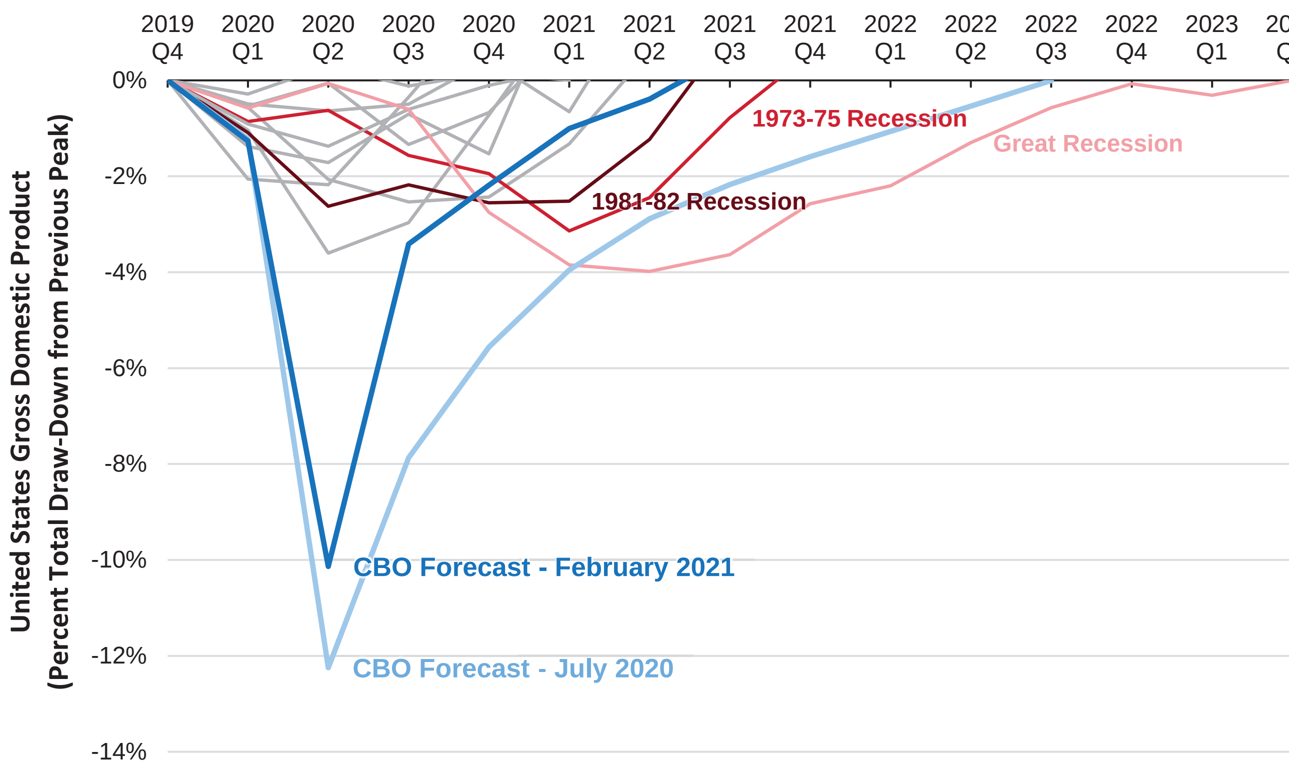
Note: Excludes non-revenue enplaned passengers.

Sources: United States Bureau of Transportation Statistics, United States Air Carrier Traffic Statistics; National Bureau of Economic Research, United States Business Cycle Expansions and Contractions.

Biannually, the Congressional Budget Office (CBO) provides 10-year economic projections which includes output, prices, labor market measures, interest rates, and income. Part of this work includes projections of potential GDP. In July 2020, the CBO released the first update to these projections since the beginning of the pandemic. At the time, the CBO forecast that real United States GDP contracted by 10.1% in the second quarter of 2020, which is equivalent to an annual decline of 34.6%, followed by a 17.0% recovery in the third quarter. The CBO projected that GDP would recover to fourth quarter of 2019 levels by the third quarter of 2022, making the recession the second longest United States recession since 1947.

However, when actual results became available, the real United States GDP contracted by 8.9% in the second quarter of 2020, which is equivalent to an annual decline of 31.4%, before rebounding by 6.7% in the third quarter of 2020. According to the CBO's most recent yearly projections released early February 2021, the United States GDP is estimated to continue rebounding during the fourth quarter of 2020 as concerns about the pandemic diminish and as state and local governments ease stay-at-home orders, bans on public gatherings, and other measures to limit the spread of COVID-19. On an annual basis, the CBO estimates that the United States GDP decreased by 3.4% in 2020 and forecasts that GDP will increase by 4.6% in 2021. The February release projects that GDP would recover to fourth quarter of 2019 levels by the third quarter of 2021. **Figure 2-3** provides a comparison of GDP declines (as of second quarter 2020) to the current CBO forecast (February 2021), the previous release of the forecast, and other major United States recessions since 1947.

Figure 2-3 United States GDP Comparison During Recessions

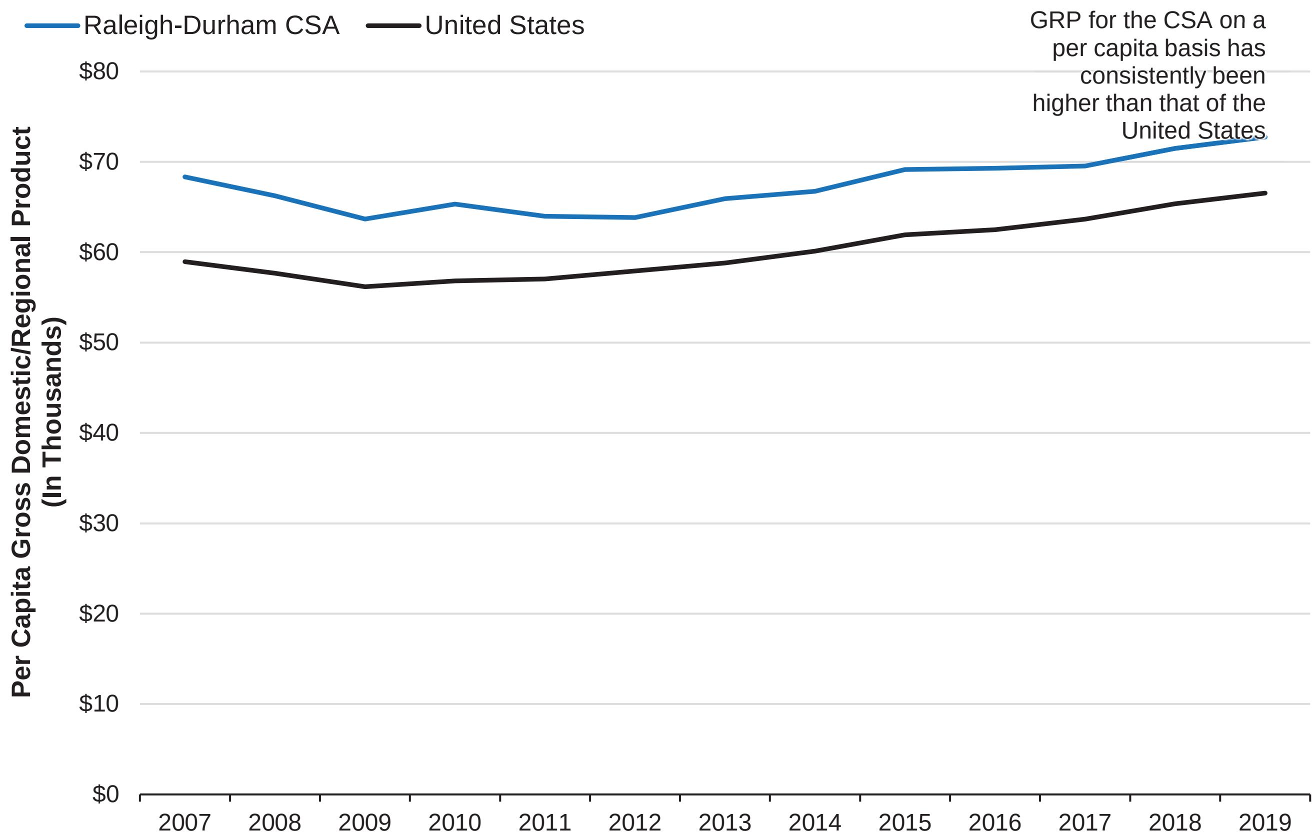


Sources: United States Bureau of Economic Analysis, National Income and Product Accounts; Congressional Budget Office, An Overview of the Budget and Economic Outlook: 2021 to 2031, February 2020.

2.2.1.2 Trends in Regional Economy

GDP and gross regional product (GRP) are measures of the value of all final goods and services produced within a geographic area. These measures are general indicators of the economic health of a geographic area and, consequently, of the area's potential demand for air transportation services. **Figure 2-4** presents the historical GDP for the United States and the GRP for the CSA on a per capita basis from 2007 through 2019 (the latest data available). During the Great Recession, the national economy contracted for three consecutive years. Over the period shown, GRP for the RDU CSA on a per capita basis has consistently been higher than that of the United States.

Figure 2-4 Historical Per Capita Gross Domestic/Regional Product Trends (2007 – 2019)

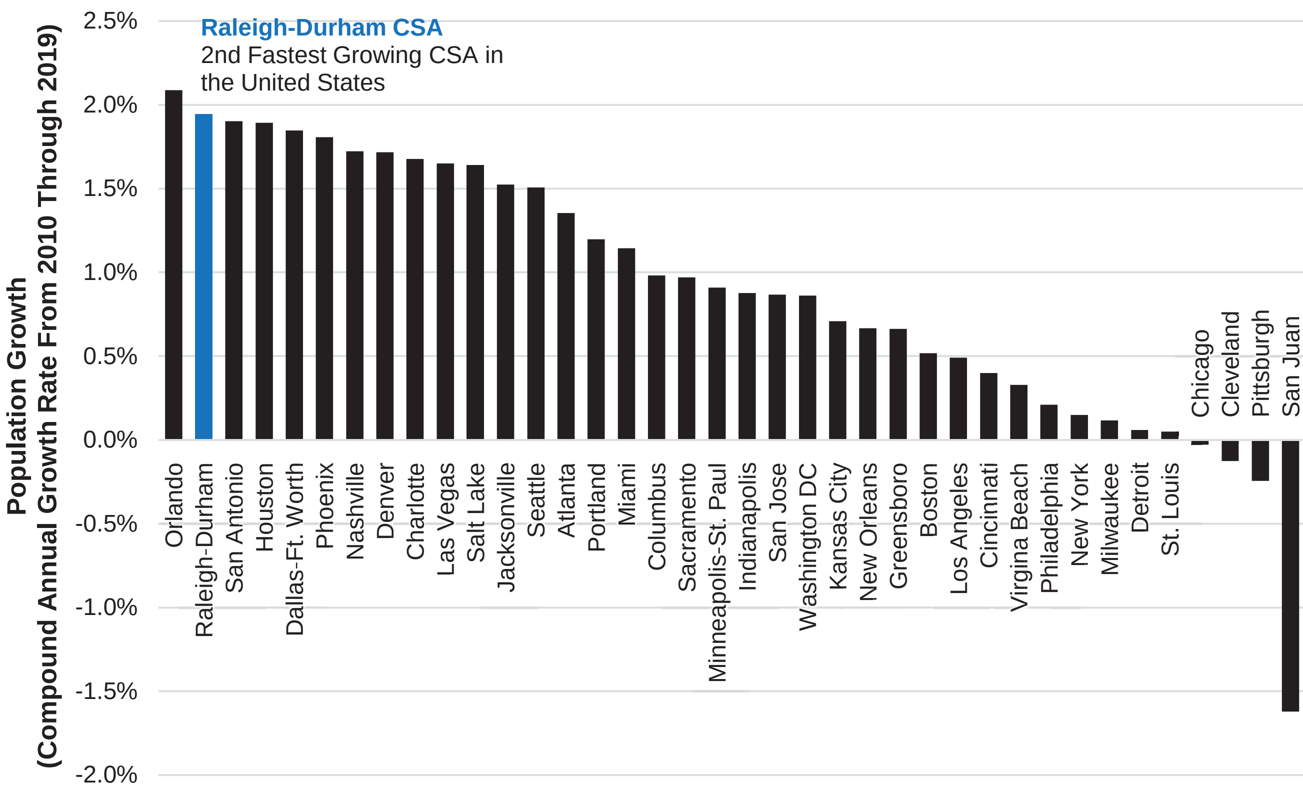


Source: Woods & Poole Economics, Inc., 2020 Complete Economic and Demographic Data Source, April 2020.

2.2.2 Population

There are 38 CSAs in the United States with a population in excess of 1.5 million people, including the Raleigh-Durham CSA. According to the United States Census Bureau, population in the Raleigh-Durham CSA has increased from 1.7 million in 2010 to an estimated 2.1 million in 2019. This relatively rapid growth ranked the Raleigh-Durham CSA as the 2nd fastest growing CSA with a population in excess of 1.5 million people. **Figure 2-5** presents the compound annual growth rate (CAGR) between 2010 and 2019 (the latest data available) for population for the nation's 38 CSAs with populations in excess of 1.5 million.

Figure 2-5 Population Growth in CSAs with Population in Excess of 1.5 Million

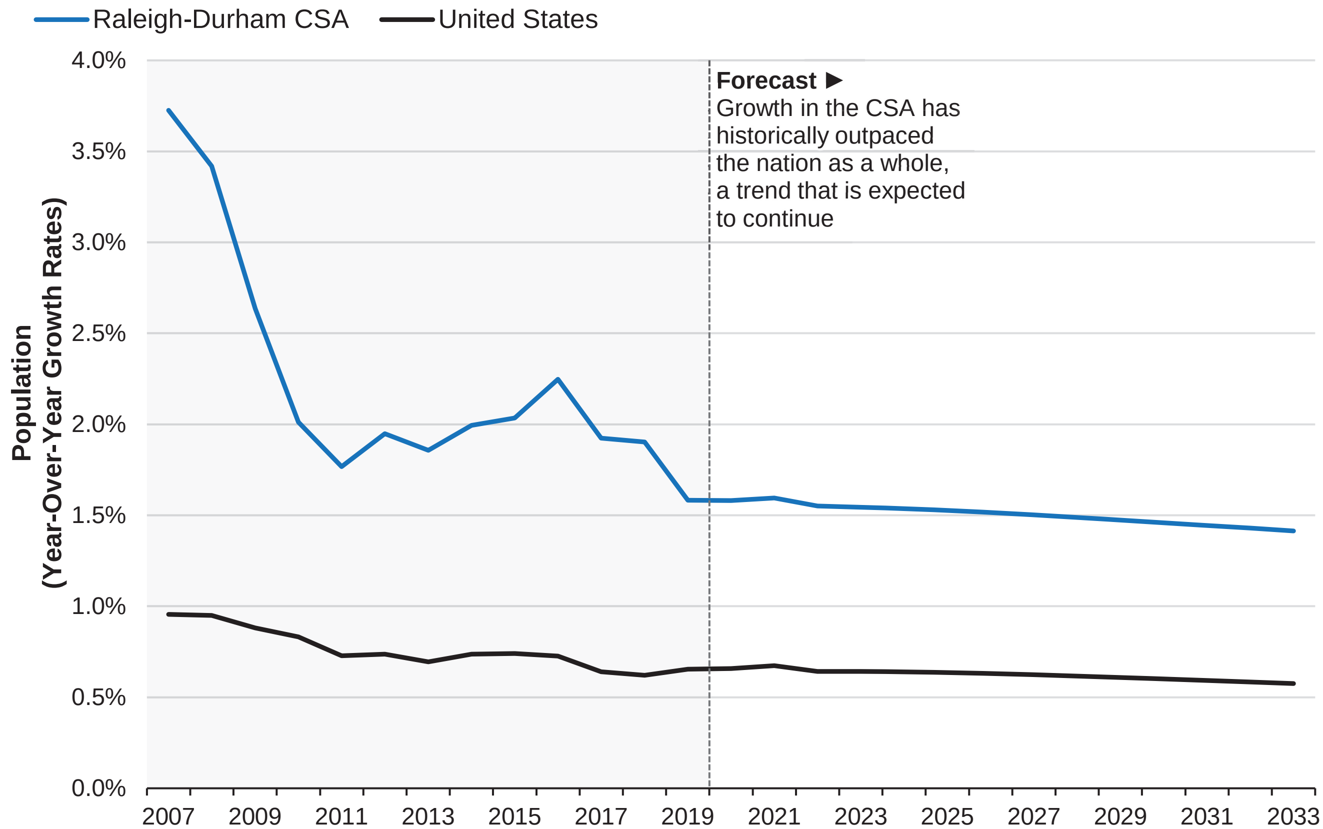


Source: United States Census Bureau, Annual Estimates of Resident Population, accessed via American FactFinder.

2.2.2.1 Trends in Regional Population

Figure 2-6 depicts historical and forecast year-over-year growth of population for the CSA and the United States as a whole. Population growth in the CSA has continually outpaced the nation as a whole. According to Woods & Poole, population in the CSA is forecast to increase from 2.1 million in 2020 (estimated) to 2.9 million in 2033, resulting in a CAGR of 1.5%, which is more than double the rate forecast for national population.

Figure 2-6 Historical and Forecast Population Trends (2007 – 2033)



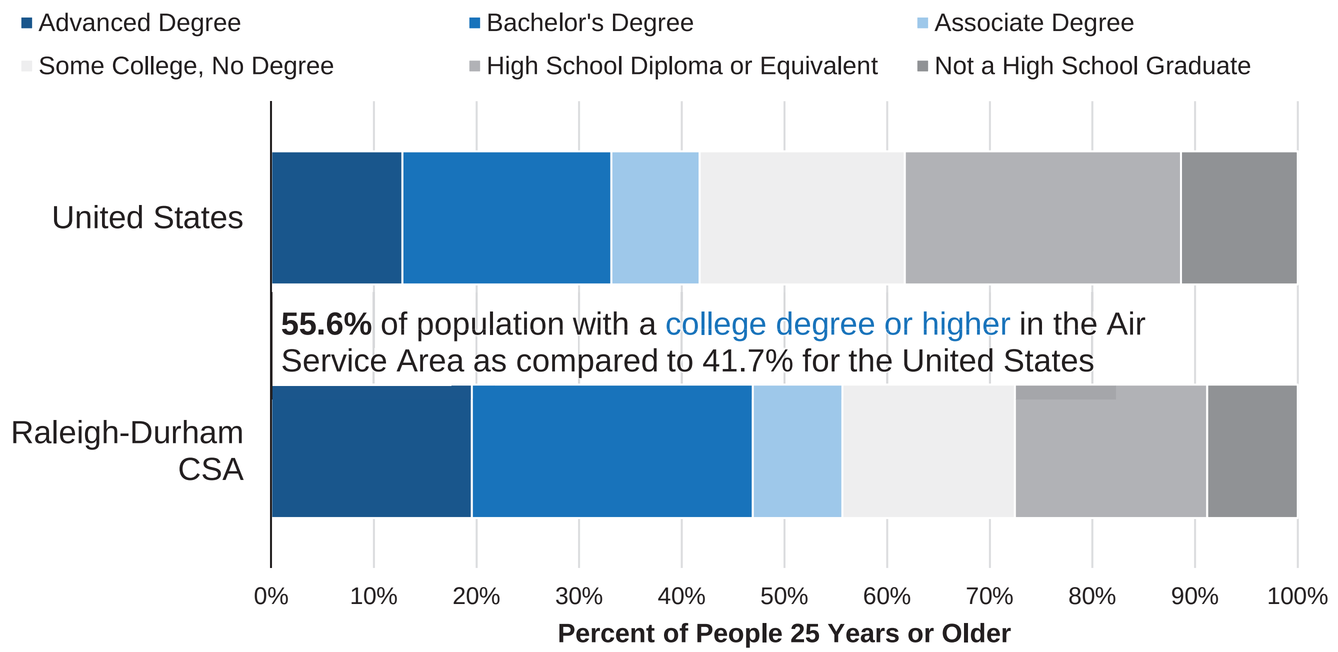
Note: The forecasted year-over-year growth rates were developed prior to the COVID-19 pandemic and may not reflect changes resulting from the pandemic.

Source: Woods & Poole Economics, Inc., 2019 Complete Economic and Demographic Data Source, April 2020.

2.2.2.2 Educational Attainment

People with a college degree have, historically, generated a higher percentage of expenditures on air travel. **Figure 2-7** presents the share of educational attainment for persons aged 25 or older within the CSA and the United States. According to the United States Census Bureau, 55.6% of the population aged 25 or older in the CSA have a college degree or higher. By comparison, only 41.7% of the population aged 25 or older in the United States have a college degree or higher.

Figure 2-7 Educational Attainment (2019)



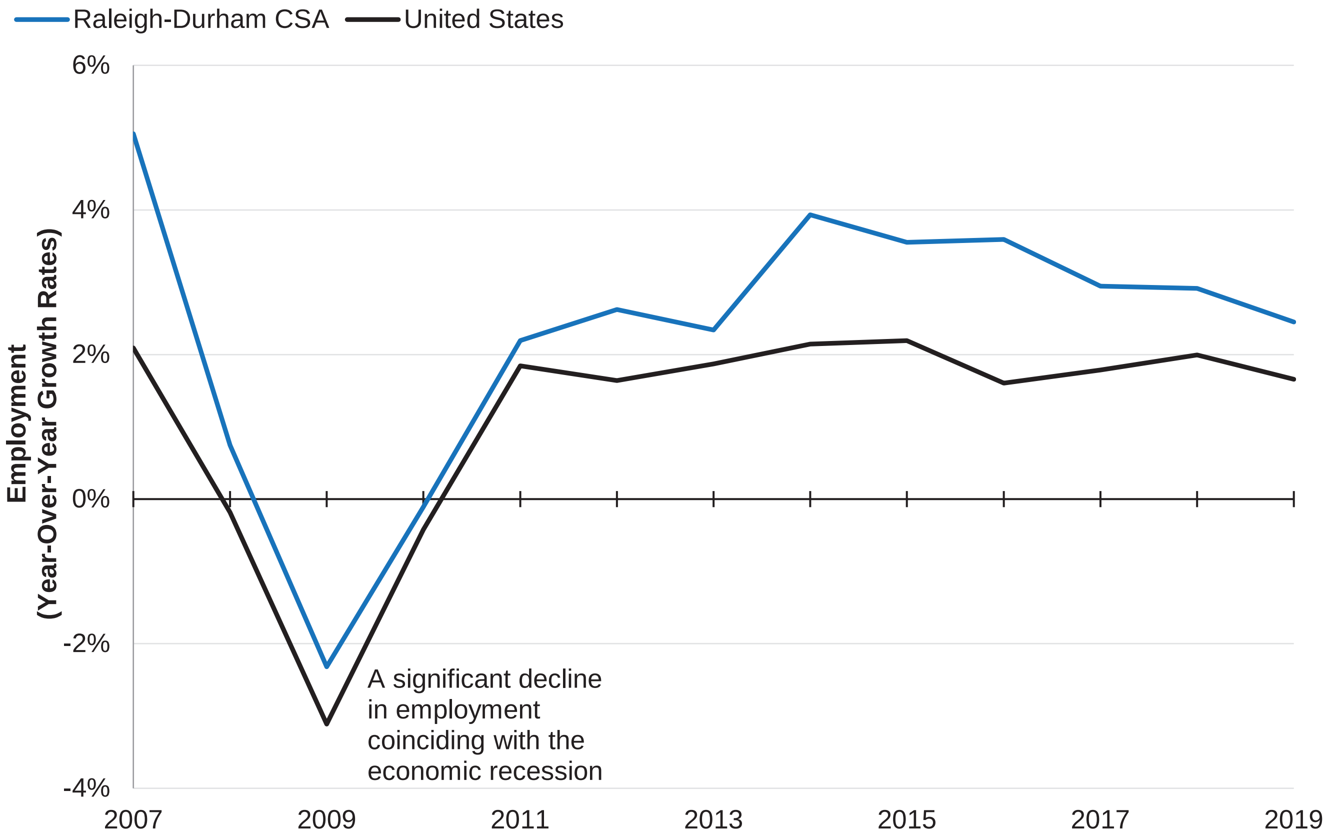
Source: US Census Bureau, 2019: ACS 1-Year Estimates Data Profiles.

2.2.3 Employment

2.2.3.1 Trends in Regional Employment

Growth in employment is an important indicator of the overall health of the local economy. Historically, changes in population and employment tend to be closely correlated as people migrate in and out of areas largely depending on their ability to find work. **Figure 2-8** presents annual growth rates for employment in the CSA and the United States from 2007 through 2019 (before the impacts of the COVID-19 pandemic). Between December 2007 and June 2009, a major financial recession occurred. The recession, often referred to as the 'Great Recession', was the longest recession since the airline industry was deregulated. As shown, from 2008 through 2010 there was a sharp decline in employment in each geographic region. From 2010 through 2019, employment in the CSA increased at a CAGR of 2.9% compared to 1.9% for United States as a whole.

Figure 2-8 Historical Employment Trends (2007 – 2019)

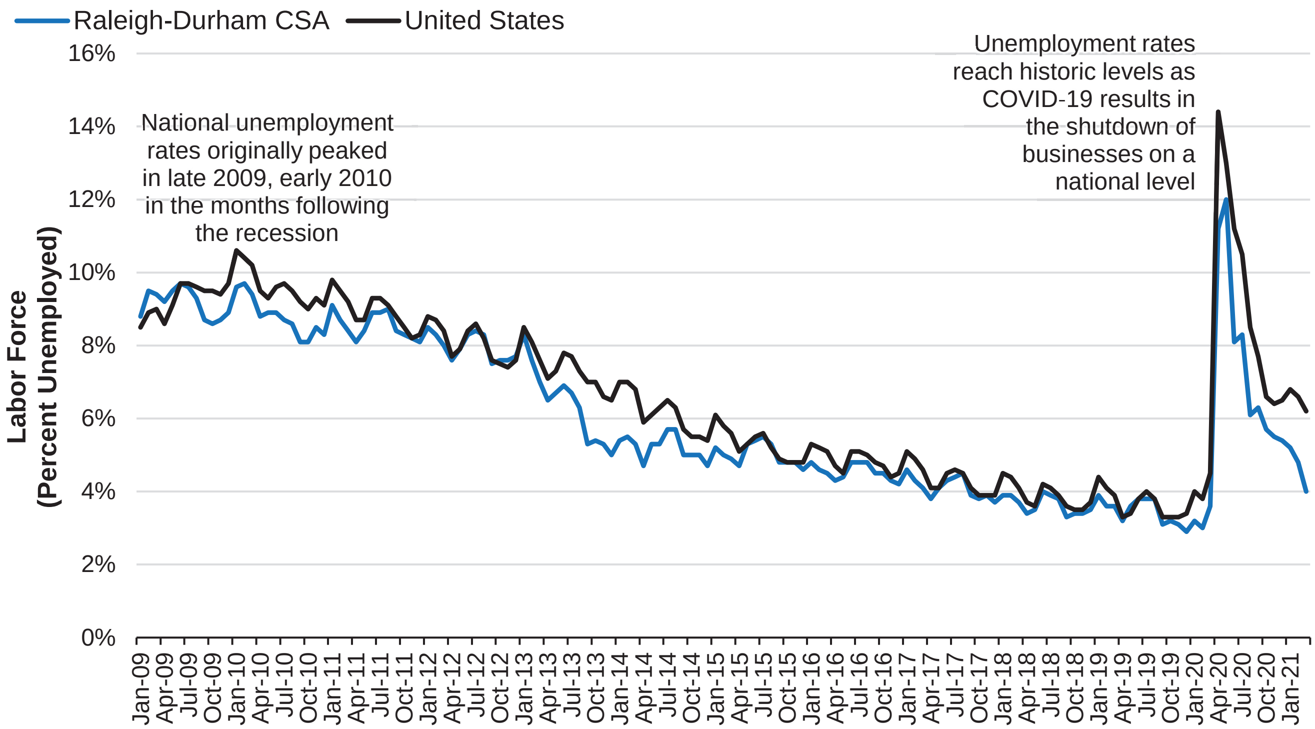


Source: Woods & Poole Economics, Inc., 2020 Complete Economic and Demographic Data Source, April 2020.

2.2.3.2 Unemployment Rates

Unemployment rates are also an indicator of economic health as rates usually decrease as economic activity in the region grows. **Figure 2-9** presents the historical unemployment rates for the CSA and the United States. As shown, from 2009 through 2019, unemployment rates in the CSA trended similar to the national average. During the Great Recession, unemployment for the CSA peaked at 9.7% in January 2010 as compared to the national unemployment peak of 10.6% in the same month. Total employment during 2019 increased at a faster rate than population since the end of the Great Recession, resulting in significant declines in unemployment rates during that time. However, since the impacts associated with the COVID-19 pandemic occurred in the United States starting in March 2020, unemployment rates increased to historic levels as a result of stay-at-home orders and companies hedging for potential losses. In April 2020, the unemployment rate for the CSA reached 11.2% compared to the national rate of 14.4%. While the national unemployment rate has begun a slow decline, the unemployment rate in the CSA Area declined significantly to rates seen as recently as mid-2018. In March 2021, the unemployment rate for the CSA was 4.0%, which was significantly lower than that of the United States at 6.2%.

Figure 2-9 Unemployment Rates (Not Seasonally Adjusted for January 2009 – March 2021)

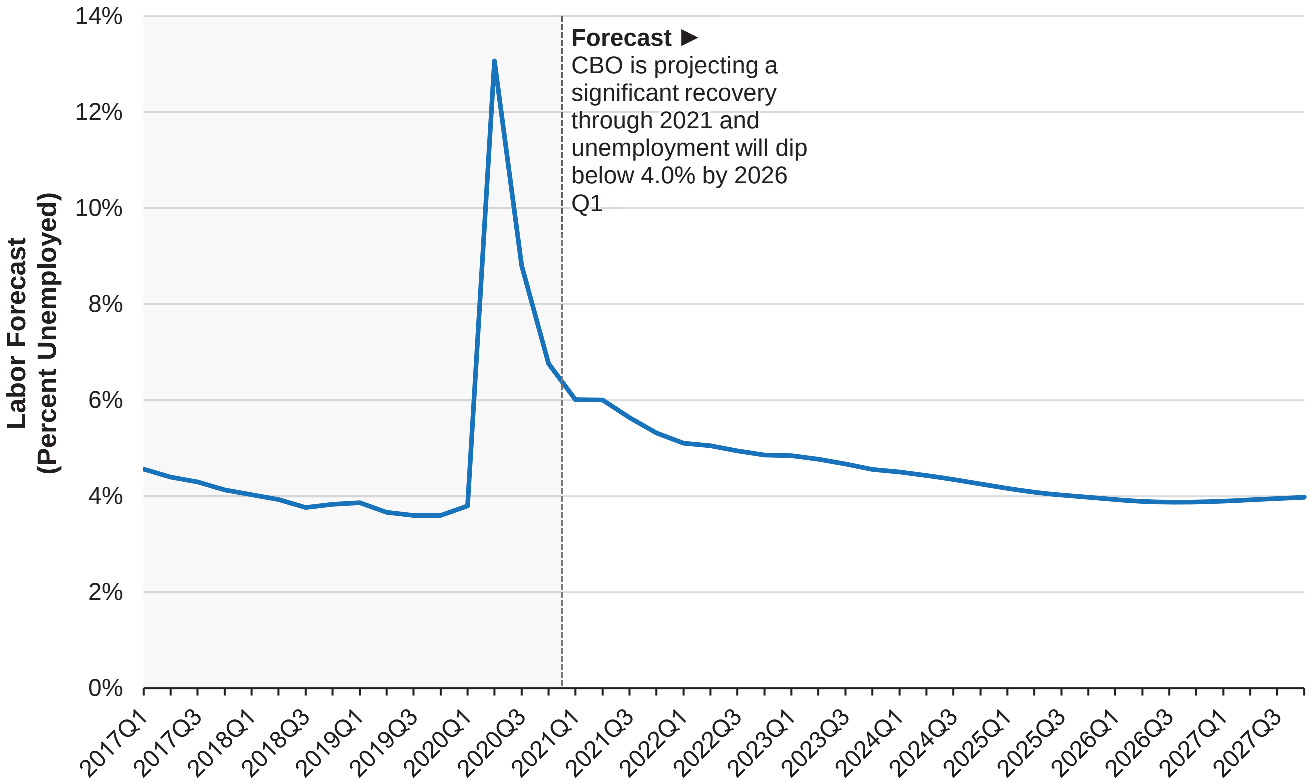


Month	Unemployment Rate	
	United States	Raleigh-Durham CSA
January 2020	4.0%	3.2%
February 2020	3.8%	3.0%
March 2020	4.5%	3.6%
April 2020	14.4%	11.2%
May 2020	13.0%	12.0%
June 2020	11.2%	8.1%
July 2020	10.5%	8.3%
August 2020	8.5%	6.1%
September 2020	7.7%	6.3%
October 2020	6.6%	5.7%
November 2020	6.4%	5.5%
December 2020	6.5%	5.4%
January 2021	6.8%	5.2%
February 2021	6.6%	4.8%
March 2021	6.2%	4.0%

Sources: United States Department of Labor: Bureau of Labor Statistics, Labor Force Statistics from the Current Population Survey, January 2021.

The Congressional Budget Office (CBO) currently forecasts that the national unemployment rate will continue to decline and reach approximately 5.3% in the fourth quarter of 2021, with a slower estimated recovery, thereafter.[28] **Figure 2-10** presents the CBO's long-term forecast for the unemployment rate in the United States. Per the CBO, unemployment rates are not expected to reach levels experienced prior to the impacts associated with the COVID-19 pandemic during the forecast period.

Figure 2-10 Congressional Budget Office Forecast of Unemployment Rates (through 2027 Q4)



Source: Congressional Budget Office, An Overview of the Budget and Economic Outlook: 2021 to 2031, February 2021.

2.2.4 Income

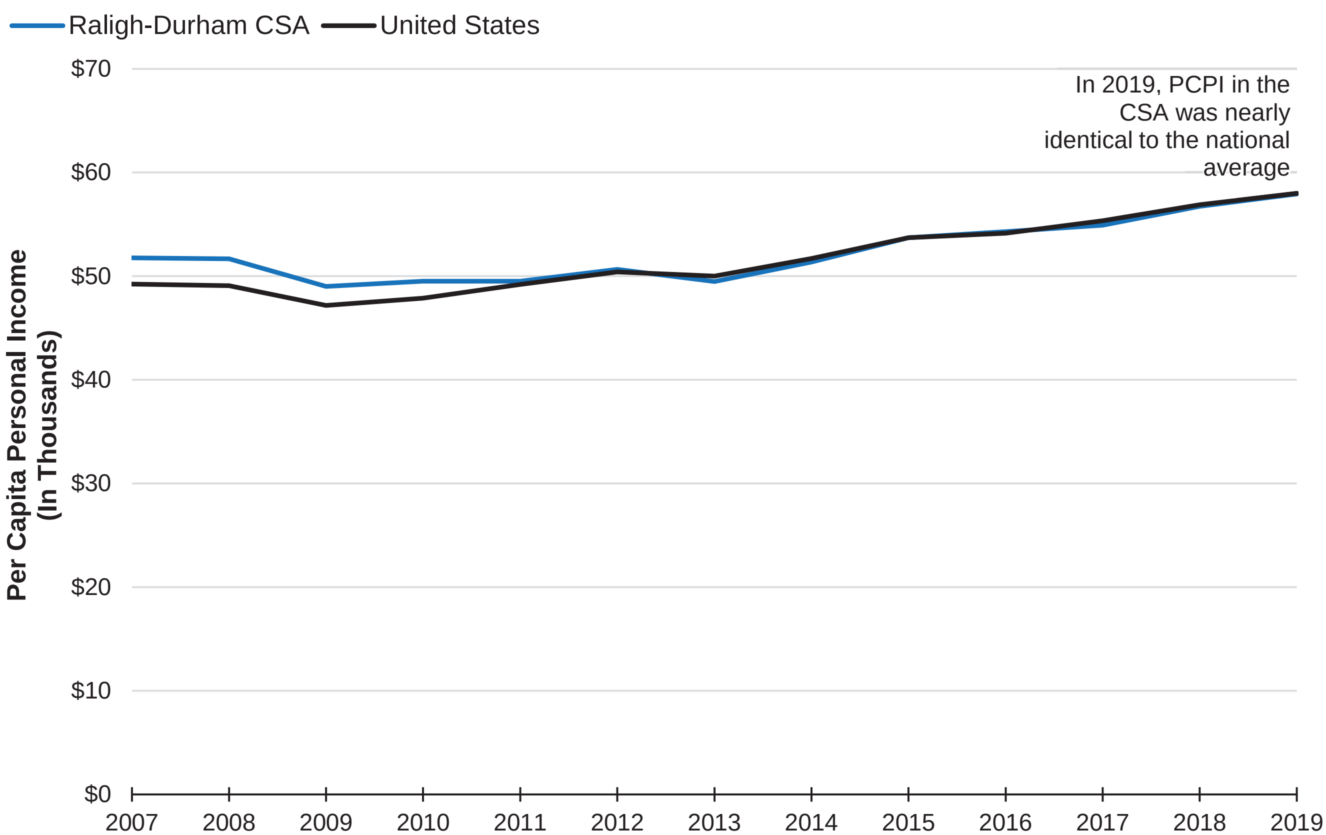
Income statistics are broad indicators of the relative earning power and wealth of an area and provide a measure of the relative affluence of a region's residents and, consequently, of their ability to afford air travel. Income data presented herein provides a general indication of historical trends prior to the impacts associated with the COVID-19 pandemic. Income data since the COVID-19 pandemic was not available at the time of this Report.

28 Congressional Budget Office, An Overview of the Budget and Economic Outlook: 2021 to 2031, February 2021.

2.2.4.1 Trends in Regional Per Capita Personal Income

Per capita personal income (PCPI) corresponds to the income per resident (total income divided by total population). **Figure 2-11** provides the historical PCPI for the CSA and the United States from 2007 through 2019 before the impact of the COVID-19 pandemic. In 2007, PCPI in the CSA was $51,774, which was higher than the national average of $49,240. PCPI for the nation, including the CSA, declined during the Great Recession, recovered between 2010 and 2012, and then decreased slightly in 2013. Since 2013, PCPI in the CSA has increased at a CAGR of 2.7% as compared to a 2.5% CAGR for the United States. The PCPI in the CSA reached an estimated $57,936 in 2019 which was nearly identical to the national average.

Figure 2-11 Historical Per Capita Personal Income Trends (2007 – 2019)



Source: Woods & Poole Economics, Inc., 2020 Complete Economic and Demographic Data Source, April 2020.

2.3 The United States Airline Industry

2.3.1 Airline Profitability

Since 2008, the United States airline industry has decreased capacity, particularly in short-haul markets with smaller, short range aircraft types. The result has been significant improvement in yields, revenue per available seat mile (RASM), and subsequently profitability prior to outbreak of the COVID-19 pandemic. In recent years, the United States airline industry had been at its most stable, profitable point in history. According to the Bureau of Transportation Statistics (BTS), the 23 United States scheduled passenger airlines in the United States reported a pre-tax net operating profit of $15.8 billion in CY 2019, which was a 19.7% increase from 2018 and marked the eleventh consecutive year of pre-tax operating profits. The scheduled passenger airlines reported an operating profit margin of 7.5% in 2019, which was up from 6.3% in 2018.[29] Profitability during this period can also be attributed to airlines unbundling services and increasing the use of ancillary fees such as charges for checked baggage.

As a result of the impacts of the COVID-19 pandemic, United States airlines incurred record losses in 2020 and likely into 2021. Delta reported $12.4 billion in losses for all of 2020[30]. The United States DOT has reported that United States scheduled passenger airlines reported a second straight quarter after-tax net loss. Through the third quarter of 2020, airlines experienced an after-tax net loss of $28.0 billion.[31] The International Air Transport Association (IATA) projects that, globally the airlines are expected to lose $118.5 billion in 2020. In 2021, IATA projects losses to be cut to $38.7 billion as revenues rise to $459 billion.[32] To help support United States air carriers through this crisis, on March 25, 2020 the United States Senate passed the CARES Act. Under Title IV of the CARES Act, Congress approved $500 billion in federal assistance to severely distressed sectors of the economy as part of the larger $2 trillion stimulus package. The approved programs include $61 billion to the airline sector as follows:

- $29 billion in loans and loan guarantees for air carriers,
  FAA Part 145 aircraft repair stations and ticket agents;
- $32 billion in payroll protection grants for air carriers and their contractors; and
- Relief to air carriers from federal excise taxes that apply to transporting passengers and cargo and the purchase of aviation jet fuel.

As of May 12, 2021, 354 passenger carriers, 39 cargo carriers, and 220 contractors have applied for payroll support under CARES Act funds.[33] As a condition of accepting these funds, United States airlines were required to (1) refrain from imposing involuntary furloughs on United States-based employees or reducing employee pay or benefits through September 30, 2020; (2) maintain certain limitations on executive compensation through March 24, 2022; (3) suspend the payment of dividends or other distributions and cease stock buybacks through September 30, 2021; and (4) continue service as is reasonable and practicable under DOT regulations.

As discussed above, it is expected that the airlines will continue to experience financial distress for the foreseeable future until air traffic is able to recover to reasonable levels. It is generally assumed that the airlines will continue to right-size capacity to meet suppressed demand and evolve business models in the near-term to limit the spread of COVID-19.

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29 Bureau of Transportation Statistics, 2019 Annual and 4th Quarter United States Airline Financial Data.
30 AP, A $12 billion loss for 2020, Delta is cautious in early 2021, https://apnews.com/article/travel-air-travel-coronavirus-pandemic-e6304e8edfcf83a42a29ce9b5faee542
31 Bureau of Transportation Statistics, United States Airlines Report Third Quarter 2020 Losses.
32 International Air Transport Association, Deep Losses Continue Into 2021, https://www.iata.org/en/pressroom/pr/2020-11-24-01/
33 Department of the Treasury, Payroll Support Program Payments, https://home.treasury.gov/policy-issues/coronavirus/assisting-american-industry/payroll-support-program-payments

2.3.2 Airline Bankruptcies and Mergers

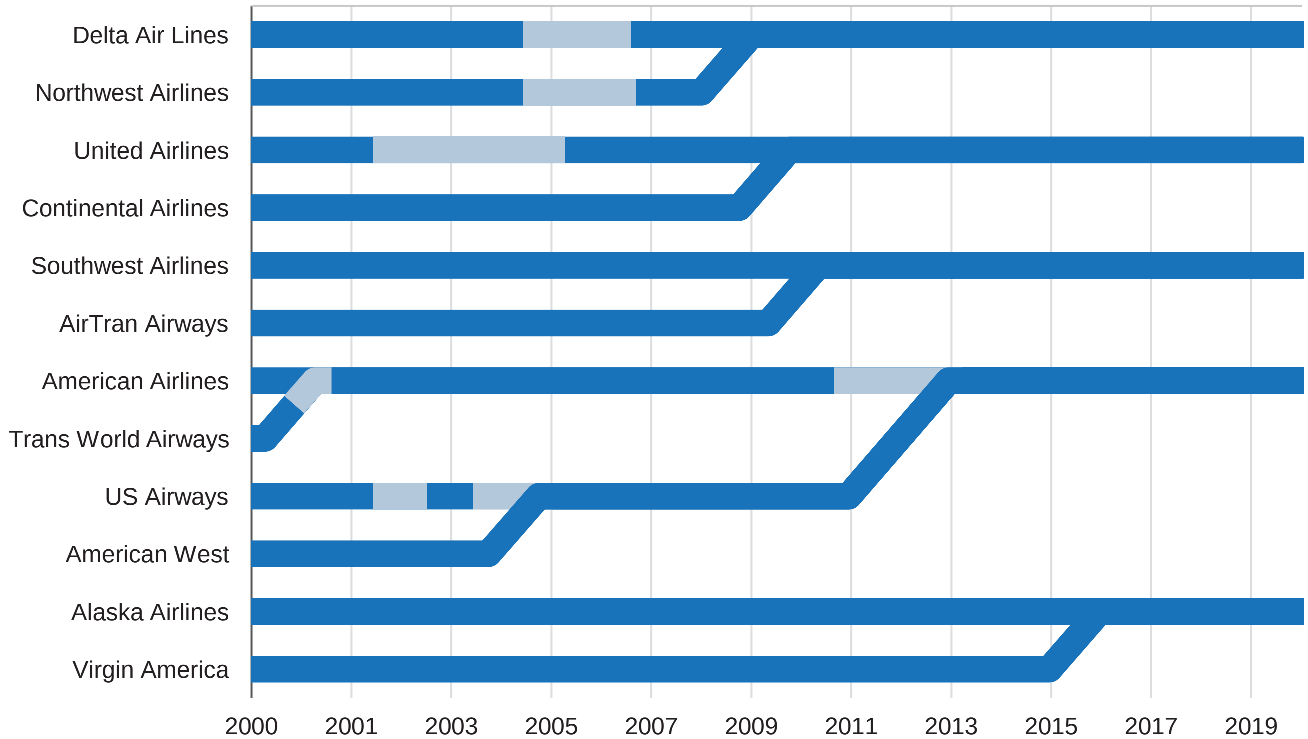
Over the past two decades, the United States airline industry has undergone a significant transformation. Although it has been profitable in recent years prior to the impacts associated with the COVID-19 pandemic, the United States airline industry cumulatively experienced losses of approximately $62 billion from 2000 through 2009 on domestic operations. Many airlines filed for Chapter 11 bankruptcy protection and some ceased operations altogether. During this period, airlines suffered from excess capacity, which drove down yields. Yields adjusted for inflation had dropped by approximately 70%. With oil prices spiking to near $150 per barrel in 2008, industry changes were critical. As a result, all of the major network airlines restructured their route networks and reached agreements with lenders, employees, vendors, and creditors to decrease their cost structure.

Currently, airlines are experiencing significant financial difficulty given the significant passenger decreases caused by the impacts associated with the COVID-19 pandemic. As of April 1, 2021, five United States airlines including three regional carriers and one charter airline have ceased operations primarily as a result of the COVID-19 pandemic.[34] As of April 1, 2021, no United States scheduled mainline passenger airline has filed for Chapter 11 or ceased operations. However, given the ongoing financial struggles and the uncertain recovery of air traffic, it is possible that airlines may file for bankruptcy protection or potentially cease operations in the future primarily as a result of the COVID-19 pandemic.

Industry consolidation has taken place as a result of competitive pressures and economic conditions. Many airlines have merged or been acquired since the turn of the 21st century. **Figure 2-12** provides a graphical representation of the major United States airline mergers during this period. These mergers have resulted in significant economic control of passenger ridership. For FY 2020, the four largest United States airlines (American, Delta, Southwest, and United) account for 79.6% of the domestic seating capacity. The potential impacts associated with consolidation include limited industry seats, limited capacity growth, and increases in fares.

[34] The five United States airlines that have gone bankruptcy in 2020 are the regional carriers: ExpressJet (UA), Trans States Airlines (UA), and Compass Airlines (AA and DL), and the charter carriers: Miami Air International, and Shoreline Aviation. The major carriers served by the regional partner carriers contracted with other carriers to provide regional service.

Figure 2-12 Major United States Airline Mergers of the 21st Century



Note: Shading indicates bankruptcy.
Source: Airlines for America, United States Airline Mergers and Acquisitions.

As of April 1, 2021, there has been no announcement of any United States scheduled mainline passenger airline seeking to acquire or merge with another United States scheduled mainline passenger airline. However, given the ongoing financial struggles and the uncertain recovery of air traffic, it is possible that airlines may seek further industry consolidation in the future primarily as a result of the financial difficulties experienced during the COVID-19 pandemic. It is expected that airlines will continue to enter into partnerships and code-share agreements in attempts to seek competitive advantages. For example, in early 2021, American entered into partnerships with both Alaska Airlines for markets in the western United States and JetBlue Airways for markets in the eastern United States.

2.4 Aviation Fuel

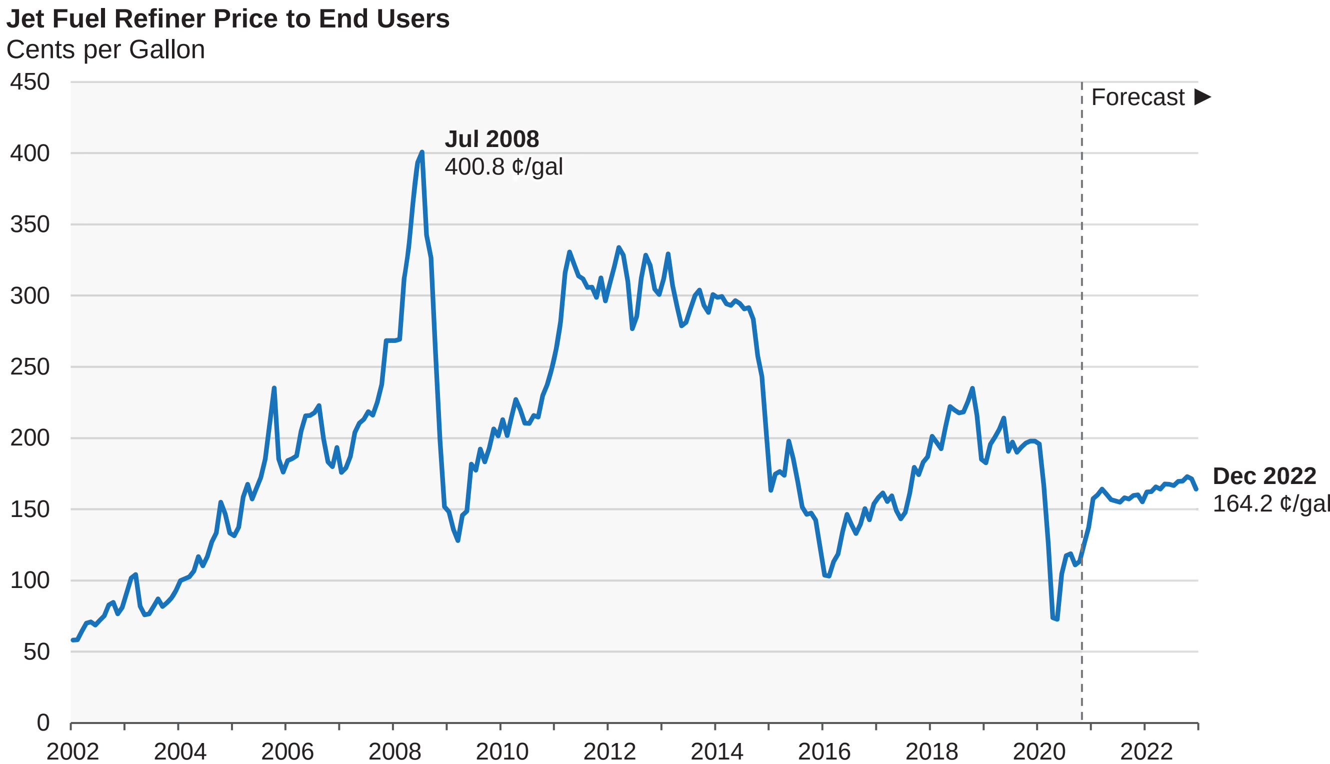
The price of oil and the associated cost of jet fuel has historically been one of the largest operating costs affecting the airline industry. In 2000, jet fuel sold to end users averaged $0.89 per gallon. The average cost of jet fuel climbed steadily through 2007. However, in 2008, crude oil prices and consequently, jet fuel surged in price as a result of strong global demand, a weak United States dollar, commodity speculation, political unrest, and a reluctance to materially increase supply. In July 2008, jet fuel reached an average price of $4.01 per gallon, nearly double the price the year prior. Reduced demand in 2009 stemming from the global financial crisis and subsequent economic downturn resulted in a sharp decline in price. However, as the economic climate improved and political unrest continued in the Middle East, oil prices increased in the subsequent three years. The increase in the price of jet fuel put upwards pressure on airline operating costs. As a result, airlines were faced with cutting capacity or increasing fares, and sometimes both. The average price of jet fuel dropped significantly in 2015 and

2016, reaching a low of $1.03 per gallon in February 2016. Since then, jet fuel prices increased steadily to a peak of $2.25 in October 2018 before falling to $1.70 per gallon in December 2019 due to increased oil supplies. In 2019, jet fuel prices remained fairly stable, averaging approximately $1.90 per gallon from February 2019 through January 2020.

As a result of the COVID-19 pandemic, the global demand for crude oil and fuel decreased dramatically starting in January 2020. As a result, the price of crude oil dropped below $20 per barrel in April 2020. Since then, crude oil supply curtailments have caused oil prices to recover. Prices hovered near $40 per barrel from early June 2020 through December but have increased to nearly $60 per barrel in February 2021.

The United States Energy Information Administration (EIA) provides forecasts of jet fuel refiner price to end users in a report entitled Short-Term Energy Outlook. In the January 2021 release, the EIA projects that jet fuel prices will reach $1.64 per gallon by December 2022. **Figure 2-13** presents the historical price for jet fuel refiner price to end users and the EIA's forecast of that price.

Figure 2-13 Jet Fuel Prices



Source: United States Energy Information Administration, Short-Term Energy Outlook (January 2020).

Although fuel cost is of major importance to the airline industry, future prices and availability are uncertain and fluctuate based on numerous factors. These can include supply-and-demand expectations, geopolitical events, fuel inventory levels, monetary policies, and economic growth estimates. Historically, certain airlines have also employed fuel hedging as a practice to provide some protection against future fuel price increases. While fuel hedging has generally not been used by airlines in recent years, it remains as a potential option to mitigate fuel cost risk.

It is expected that aviation fuel costs will continue to impact the airline industry in the future. If aviation fuel costs increase significantly over current levels, air traffic activity could be negatively affected as airlines attempt to pass costs on to consumers through higher airfares and fees in order to remain profitable. At this time, alternative fuels are not yet commercially cost effective.

2.5 Aviation Security

Since the September 11, 2001, terrorist attacks (9/11), government agencies, airlines, and airport operators have upgraded security measures to guard against threats and to maintain the public's confidence in the safety of air travel. Security measures have included cargo and baggage screening requirements, deployment of explosive detection devices, strengthening of aircraft cockpit doors, the increased presence of armed air marshals, awareness programs for personnel at airports, and new programs for flight crews. Aviation security is under the control of the federal government through the Transportation Security Administration.

The threat of terrorism poses risks to the continued growth of the aviation industry. Although terrorist events targeting aviation interests would likely have negative and immediate impacts on the demand for air travel, the industry and demand have historically recovered from such events. There have been terrorist attacks at airports internationally including at the Brussels Airport in March 2016, the Istanbul Atatürk Airport in June 2016, and the Orly International Airport in March 2017. So long as government agencies continue to seek processes and procedures to mitigate potential risks and to maintain confidence in the safety of aircraft, without requiring unreasonable levels of costs or inconvenience to the passengers, economic influences are expected to be the primary driver for aviation demand as opposed to security and safety.

2.6 National Air Traffic Capacity

The United States aviation system has significant influence on the national economy because it provides a means of transporting people and cargo over long distances in a relatively short period. As demand for air travel increases, the national aviation system must maintain sufficient capacity to allow for travel without unacceptable delays or congestion. It is generally assumed that the required infrastructure improvements needed to maintain capacity will keep pace with demand. Although not likely over the projection period evaluated herein, the inability of the national aviation system to keep pace with demand could create congestion and delays on a national level that could adversely affect the passenger experience and impact future demand.

2.7 Introduction of Ultra-Low-Cost Carriers

Over the last decade the Airport has been served by two LCCs, Southwest Airlines and JetBlue. In May 2021, Sun Country Airlines, another LCC, become the 11th airline at the Airport. However, several ULCCs have begun service at the Airport recently. In 2010, Frontier Airlines began service to General Mitchell International Airport in Milwaukee but the service only lasted two years. However, in 2013, it began scheduled service to Trenton-Mercer Airport in New Jersey and continued to add new services each year following. In 2018, Frontier Airlines increased seating capacity by 187.9% and increased by another 32.8% in 2019. In 2015, Allegiant Air started scheduled service at RDU with flights to Punta Gorda Airport, Orlando Sanford International Airport, and St. Pete-Clearwater International Airport in Florida. Allegiant Air has tested a couple of markets to determine the best destinations. In 2019, Allegiant Air had scheduled seating capacity of 53,340 departing seats. Spirit Airlines began scheduled service at RDU in May 2019. Despite less than a full year of service, Spirit Airlines had scheduled 272,322 departing seats in 2019. In 2010, ULCCs accounted for just 0.2% of the total departing seats at RDU; with high growth in the market that share has increased to 10.8% in 2019.

3 Passenger Activity Forecast

This section presents the forecast of enplaned passengers for RDU through the forecast period as well as a discussion of the methodology used to develop the forecast. The enplaned passenger forecast reflects the historical airline activity trends, the socioeconomic base for air travel, and other factors that may affect the demand for air travel.

3.1 Estimate for 2021

An estimate for 2021 was developed based on available schedule data for commercial passenger operations. All recent or expected airline service announcements were reviewed to ensure that the flights were reflected in the current schedule data. In the wake of the COVID-19 pandemic, airlines have been quick to add scheduled capacity months in advance. However, the airlines have also been removing the capacity as demand dedicates. As such, the schedules can change week-to-week, but capacity has continually been reduced following the original schedules. Therefore, a cancellation factor was applied for the schedules for the months later in the year. Load factors were assumed to increase through the rest of the year.

3.2 Short-Term Forecast

3.2.1 COVID-19 Impacts

3.2.1.1 Reaching Manageable Infection Rates

While developing the enplaned passenger forecasts, two timelines for reaching managing infection rates were developed. The following presents the timelines based on the assumptions made.

- **Rapid-Adoption:** The rapid-adoption timeline assumes that the general public will continue to quickly adopt the vaccine. It is assumed that those wanting to be vaccinated will be by the fourth quarter of 2021 resulting in more manageable infection rates.
- **Slow-Adoption:** The slow-adoption timeline assumes that people are slow to adopt the vaccine for various reasons. It is also assumed that those wanting to be vaccinated will be by the third quarter of 2022 resulting in more manageable infection rates.

Due to the initially slow start to the COVID-19 vaccine rollout, it was originally assumed that the rapid-adoption timeline would be an optimistic scenario. However, now that initial supply issues have largely been resolved. The slow-adoption timeline would likely only happen with a large portion of the population opting not to take the vaccine. The vaccination rate for adults in the United States began to plateau at around 60% in late July 2021. However, pressure from some employers by mandating the vaccine combined with an increase in infection due to the Delta variant and renewed efforts to encourage people to be vaccinated has resulted in an increase in administered doses of the vaccine. Therefore, the slow-adoption timeline represents a more pessimistic scenario. Under baseline conditions, it is assumed that the adoption timeline for the vaccine will be between the two timeframes outlined above for domestic travel.

3.2.1.2 Temporary Loss of Business Travelers

Prior to the Great Recession, airfares did not typically have a significant impact on air travel for business travelers. However, the economic climate after the Great Recession prompted many businesses to seek measures in order to save cost, part of which included shrinking travel budgets. As such, some companies began substituting air travel with telecommunication when the cost to travel becomes too great.

The impacts associated with the COVID-19 pandemic essentially halted all travel in March 2020, which required many business travelers to quickly pivot from in-person meetings to conducting videoconference meetings. Stay-at-home orders required many businesses to shift to work-at-home temporarily with many still operating a hybrid of work at home and in the office. Both of these somewhat acted as an experiment to determine what meetings could be conducted remotely and what jobs can be done effectively from home versus an office setting. The COVID-19 pandemic has been a catalyst for some companies to move to work-at-home on a permanent basis. A survey from July 2020 indicated that 93% of companies believe that their remote working and meeting policies will permanently change.[35]

For business travelers conducting in-person sales or client meetings, air traffic has been recovering quicker and is expected to make a full recovery as face-to-face conversations will continue to be seen as worth the cost of travel. However, internal meetings, training programs, trade shows, and conferences have seen little to no recovery to date. It is possible that if more people work-from-home, in-person internal meetings and training programs previously done in-person will be drastically reduced, with people opting for virtual meetings. There are a number of estimates as to how much business travel will be permanently lost. According to a business travel analyst, the data suggests that between 19% and 36% of all business air traffic are likely to be lost.[36]

Historically, there have been a number of events over the past 20 years, such as the terrorist attacks of September 11, 2001 and the Great Recession, that have prompted theories of an ultimate decline in business air travel. However, the industry has continued to prove resilient and business air travel recovered from both of those events albeit with significant changes in the operating nature of the industry. Therefore, it was assumed that airlines will continue to adapt, and business air travel would fare better than the estimates stated above. In fact, it was assumed that business travelers will eventually return in full with the exception of some intra-company travel. However, the recovery of business travelers will lag behind leisure traffic.

3.2.2 Recovery Assumptions

The short-term enplaned passenger forecast was segmented into three main segments domestic leisure, domestic business, and international.

It was assumed that the recovery in domestic leisure traffic would be driven primarily with the reaching manageable infection rates. There will be a delay between the manageable infection rates and when leisure passengers will recover. Part of this delay is due to leisure traveler’s tendency to plan in advance and are willing to wait for affordable ticket prices. Additionally, some leisure passengers will also wait to travel for other factors like warmer weather and breaks in schooling when deciding to travel. Therefore, it was assumed that recovery in domestic leisure traffic would occur in summer 2022.

[35] BCG, COVID-19 Consumer Sentiment Snapshot #11: Getting to the Other Side, June 2, 2020. Accessed online at https://www.bcg.com/publications/2020/covid-consumer-sentiment-survey-snapshot-6-02-20

[36] The Wall Street Journal, The Covid Pandemic Could Cut Business Travel by 36%—Permanently, December 1, 2020. Accessed online at https://www.wsj.com/articles/the-covid-pandemic-could-cut-business-travel-by-36permanently-11606830490

In addition to reaching manageable infection rates, recovery in business traffic is going to be dictated mostly on the recovery in the economy. The CBO forecast indicates that GDP would recover to fourth quarter of 2019 levels by the third quarter of 2021. Although the overall economy in terms of GDP is expected to recover by the end of 2021, some aspects will be delayed. In April, the consumer price index (CPI) increased by 0.8%, the biggest month increase since 2009, due to the rapid reopening of the United States economy. This increase in the price of goods will prevent some companies to allow for corporate travel as they continue to recover. Additionally, the economic recovery it is not going to be equal between companies. Some companies will recovery faster than others. Additionally, convention goers make a significant portion of business travelers. Conventions require months of planning and it is likely that most conventions will hold off planning until the future is more certain for fear of losing money. Therefore, recovery in business travelers is expected to continue to lag the recovery in leisure traffic.

It was assumed that for international travel (particularly for transoceanic destinations), the adoption timeline will lag behind given the complexities associated with opening borders, varying vaccine distribution, achievement of herd immunity, and other adoption issues. It is also assumed that those wanting to be vaccinated on a global scale will be by the third quarter of 2022 resulting in more manageable infection rates. Additional factors such as recovery in the global economy and the delay between planning and traveling play a part in the recovery of international traffic. Therefore, recovery in international travelers is expected to continue to lag the recovery in domestic traffic.

There are three main segments of international travel at RDU: Latin American, Canadian, and European. Traffic to Latin American countries is nearly entirely leisure passengers from the RDU area. Leisure traffic has already shown to be recovering faster than business travel. Effective August 9, 2021 American citizens that are fully vaccinated will be able to enter Canada for discretionary travel which will jumpstart the recovery for international air travel. European service will be the slowest to recover. However, the western European markets served at RDU are major cities in countries with similar vaccination rates and economic recovery as the United States. These factors combined with the Raleigh, North Carolina Air Service Area's particularly strong socioeconomic base as previously discussed indicates that recovery will likely occur at an accelerated rate compared to other medium hub airports of similar size and international service. Therefore, it was assumed for this forecast that recovery in international traffic would occur by summer 2023.

3.3 Long-Term Forecast

3.3.1 Methodology

Several standard forecasting techniques were considered in order to forecast enplaned passengers such as economic regression modeling, trend analysis, market share, and time series. It was determined that an economic regression model was the most appropriate to forecast enplaned passengers at the Airport. Economic regression modeling quantifies the relationship between enplaned passengers and key socioeconomic variables. This methodology recognizes that key independent variables will change over time and assumes that their fundamental relationships to the dependent variables will remain.

The first step in developing the appropriate model was to test the independent, or explanatory, variables against the dependent variable, enplaned passengers. In order for an economic model to be considered appropriate, the following has to be true:

- Adequate test statistics (i.e. high coefficient of determination (R^2) values and low p-value statistics), which indicate that the independent variables are good predictors of passengers at the Airport.

- The analysis does not result in theoretical contradictions (e.g., the model indicates that GDP growth is negatively correlated with traffic growth).
- The results are not overly aggressive or conservative and are incompatible with historical averages.

Due to the relatively short history of LCCs and ULCCs, the long-term enplaned passenger forecast was developed using two models. One model was used for full-service carriers (FSC) such as Delta Air Lines and the other for LCCs and ULCCs.[37] Data for 2020 was not included in either model due to it being an outlier as a result of the COVID-19 pandemic.

Through the testing of multiple sets of independent variables, a univariate linear model using the Raleigh-Durham-Chapel Hill CSA's PCPI with a historical time frame from 2003 through 2019 was selected to forecast FSC enplaned passengers. The model exhibits strong regression statistics when compared with other combinations of independent variables. The model formula and relevant test statistics are provided below:

Model
Enplaned Passengers = -3.16E6 + 173.7*$PCPI_{CSA}$

Test Statistics
R^2 = 93.0%
Degrees of Freedom = 17
P-value = 0.0

Independent Variables P-Values
Intercept = 0.0
$PCPI_{CSA}$ = 0.0

Through the testing of multiple sets of independent variables, a univariate linear model using the Raleigh-Durham-Chapel Hill CSA's PCPI with a historical time frame from 2009 through 2019 was selected to forecast LCC and ULCC enplaned passengers. The model exhibits strong regression statistics when compared with other combinations of independent variables. The model formula and relevant test statistics are provided below:

Model
Enplaned Passengers = -3.64E6 + 87.0*$PCPI_{CSA}$

Test Statistics
R^2 = 85.2%
Degrees of Freedom = 10
P-value = 0.0

Independent Variables P-Values
Intercept = 0.0
$PCPI_{CSA}$ = 0.0

[37] For the purposes of the forecast models, Southwest Airlines was included in the FSC model. Although Southwest Airlines' business model is primarily based on low-cost pricing built around low operating costs, the airline's fares are higher than typical LCCs and its networking strategy has shifted from a solely point-to-point system to one that incorporates some of aspects of the hub-and-spoke system of traditional FSCs.

Prior to the COVID-19 pandemic, the Airport was experiencing rapid growth, averaging 9.1% growth over the previous four years. Most of this growth was the result of significant expansion of LCC and ULCC offerings at the Airport. Until traffic recovers to 2019 levels, the expansion of new service will be limited as airlines will focus on ensuring adequate loads on current flights to maintain profitability. This will result in a pent-up demand for new service. Therefore, it was assumed that after the initial recovery in 2023, there will be a period of rapid expansion that could not be captured by normal economic models. As such, it was assumed that growth in 2024 and 2025 would exceed that which was determined by the traditional long-term modelling. To account for this pent-up demand, an estimate for the lost traffic due to the COVID-19 was developed. This was done by using the models used in the long-term regression and applying the growth rates to the 2019 enplaned passengers. The regression analysis indicates that by 2023 there would have been 8.2 million enplaned passengers at the Airport, an increase of 1.1 million from the 7.1 million enplaned passengers in 2019. The 1.1 million enplaned passengers were assumed to be lost traffic that would have been realized through natural growth without the COVID-19 pandemic. The Airport is unlikely to recover all of the lost traffic, but it was assumed that approximately two-thirds of the lost traffic would be recovered within the first two years after recovery with a majority of that recovery occurring within the first year.

The model provides a forecast of total enplaned passengers at the Airport but does not distinguish between domestic and international passengers. In 2019, international passengers accounted for 3.6% It was assumed that until new transoceanic service is added, the share of domestic and international passengers would remain constant.

3.3.2 Potential New International Market

As the level of demand increases it is reasonable to assume the Airport would reach a point where there is potential for new international markets. In reviewing O&D demand there are several potential destinations for new international traffic. In the short-term it is reasonable to assume a majority of the growth would be concentrated in the Latin America and Canadian markets. However, as O&D traffic increases for transoceanic international flights, the viability of increased direct transoceanic international service increases, there is an opportunity for a new transoceanic market either in Europe or Asia. The potential of several new transoceanic destinations was examined to determine their likeliness of their service.

Prior to the COVID-19 pandemic, there were two transoceanic flights from RDU. American Airlines operated daily service to London Heathrow Airport and Delta Air Lines operated daily service to Charles de Gaulle Airport in Paris. Both transoceanic flights have been scheduled to return. The return date has been revised several times but these flights are still expected to return to the Airport. .[38] While some of the passenger traffic onboard these flights had their itineraries begin and end at these airports, a majority of the passengers connected to international destinations beyond London and Paris. The connecting traffic is a critical component of the viability of these operations. Therefore, the total O&D demand for transoceanic service, was examined. It was assumed that transoceanic O&D demand would increase at the same rate as the total enplaned passenger forecast. It was also assumed that new international service would be added when the number of new transoceanic O&D enplaned passengers exceed a reasonable level of load factors (approximately 80%) for an assumed amount of annual seating capacity.

[38] Diio Mi, Schedule – Dynamic Table. Landrum & Brown Analysis. August 2021.

Reviewing existing O&D demand, it was determined that the most likely candidate for new service would be a daily transatlantic flight to western Europe. While there are no commitments by any airlines at this time, the service was assumed to be to Frankfurt International Airport using a 293-seat Airbus A350-900 aircraft.[39] This new service would equate to an increase of 106,945 in annual seating capacity. It was assumed that once potential load factors exceed 80%, the new service would begin. Based on these assumptions, it was projected that the new Frankfurt service would begin in 2029. This new service is expected to have a minimal impact on the overall number of passengers at the Airport as it was assumed that most of the passengers have historically been served at the Airport but have flown to gateway airports such as John F. Kennedy International Airport (JFK) prior to their international flight. Therefore, there would be a shift of passengers from the domestic segment to the international segment. It was assumed that 90% of the passengers utilizing this flight would be cannibalized from the domestic segments and the remaining 10% would be stimulated traffic due to the new service. Therefore, there was a slight adjustment to the enplaned passenger forecast to account for the stimulated traffic (and a shift of passengers from the domestic to the international segment.

3.4 Forecast Summary

Based on the assumptions and the models detailed, total enplaned passenger at the Airport are forecast to recover from the COVID-19 pandemic in 2023. Domestic enplaned passengers are forecast to reach 9.6 million in 2033. International enplaned passengers are forecast to reach 362,700 in 2033. **Table 3-1** provides a summary of the enplaned passenger forecast by segment. **Figure 3-1** graphically depicts the total enplaned passenger forecast.

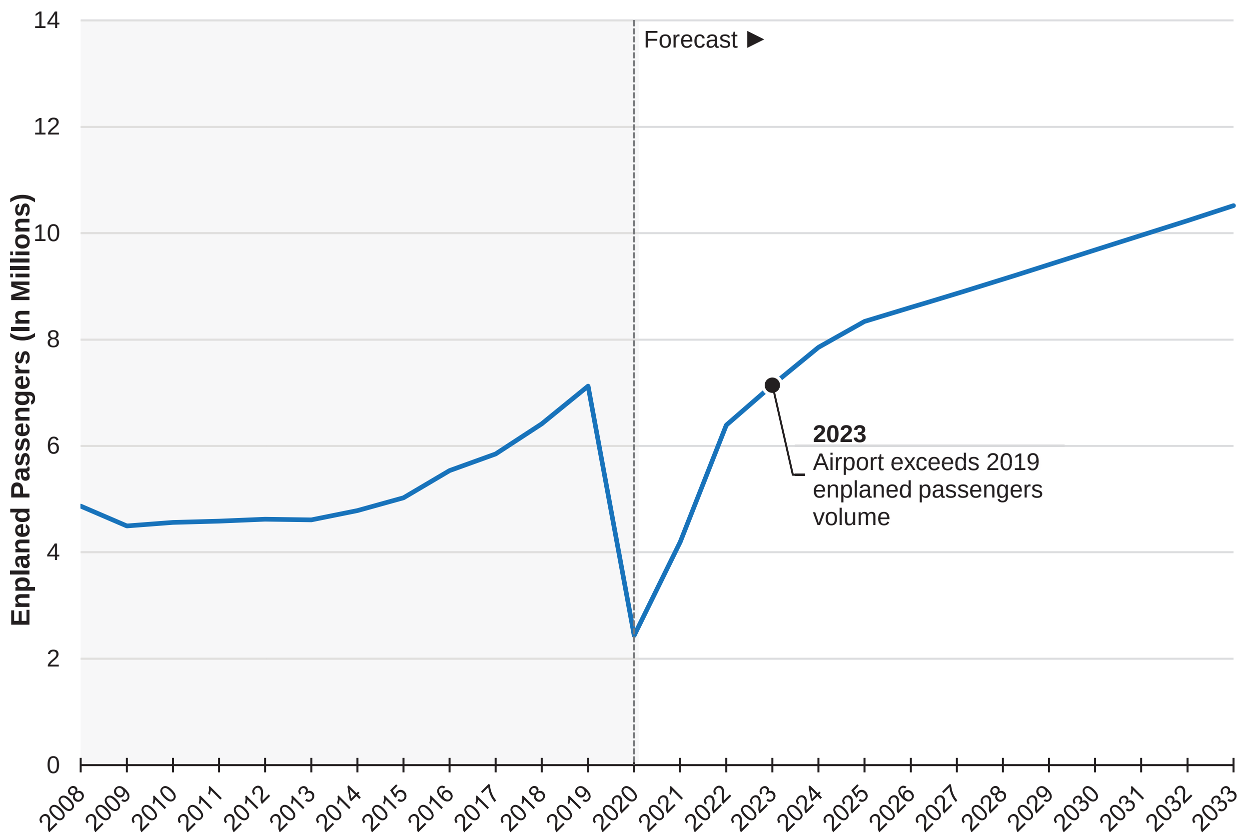
[39] A potential candidate for this service is Lufthansa. The airline currently only utilizes widebody aircraft, like the Airbus A350-900, for transoceanic service. The airline has 28 orders of the A350-900 and once filled, the A350-900 will be the most common widebody aircraft for the airline. The facilities required for such an aircraft are already in place at RDU and the aircraft does not represent the critical aircraft for runway length.

Table 3-1 Enplaned Passenger Forecast Results

Year	Domestic	International	Total
Historical			
2019	6,869,849	253,585	**7,123,434**
2020	2,397,555	38,481	**2,436,036**
Forecast			
2021	4,118,021	78,868	**4,196,889**
2022	6,174,673	216,806	**6,391,479**
2023	6,893,262	252,417	**7,145,679**
2024	7,575,700	277,400	**7,853,100**
2025	8,046,200	294,600	**8,340,800**
2026	8,298,000	303,800	**8,601,800**
2027	8,552,100	313,100	**8,865,200**
2028	8,808,800	322,500	**9,131,300**
2029	8,991,144	417,856	**9,409,000**
2030	9,251,600	430,000	**9,681,600**
2031	9,514,700	442,200	**9,956,900**
2032	9,780,800	454,600	**10,235,400**
2033	10,050,100	467,100	**10,517,200**
Compound Annual Growth Rates			
2020-25	27.4%	50.2%	**27.9%**
2025-33	2.8%	5.9%	**2.9%**
2020-33	11.7%	21.2%	**11.9%**

Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

Figure 3-1 Total Enplaned Passenger Forecast



Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

4 Air Cargo Throughput Forecast

This section presents the forecast of air cargo throughput for RDU through the forecast period as well as a discussion of the methodology used to develop this forecast. In a similar fashion to the enplaned passenger forecast, the air cargo throughput forecast provides the basis for the all-cargo, or freighter, aircraft operations forecast.

4.1 Forecast Methodology

Econometric modeling was explored to forecast domestic air cargo throughput at RDU. However, none of the potential socioeconomic indicators explored produced reasonable test results or realistic forecasts. Therefore, a linear trend model was used to forecast domestic freighter air cargo. The model formula and relevant test statistics are provided below:

Model
Domestic Air Cargo = 1.4E8 + 8.2E6*Time

Test Statistics
R^2 = 88.2%
Degrees of Freedom = 8
P-value = 0.0

Independent Variables P-Values
Intercept = 0.0
Time = 0.0

According to data from the United States Department of Transportation, approximately 93.4% of domestic air cargo has been shipped aboard all-cargo aircraft at the Airport from 2012 through 2019. In 2020, the amount increased to 95.9% due to the reduction in scheduled passenger service as a result of the COVID-19 pandemic. It is assumed that this increase is temporary and, on average, 93.4% of all domestic air cargo will be shipped on all-cargo aircraft through the forecast.

Internationally, air cargo is transported nearly exclusively onboard passenger aircraft. As such, the growth of international air cargo at RDU is dependent on the growth of international passenger traffic. Even more specifically, the international air cargo at RDU is transported on transatlantic passenger operations rather than flights to Central America and Canada. Therefore, the relationship between international air cargo and transoceanic seating configuration was reviewed. American Airlines had 81,450 departing seats to London Heathrow Airport in 2011 which remained relatively constant through 2016. However, in 2017, the airline began phasing out the 209-seat Boeing 767-300 aircraft and replaced it with the 273-seat Boeing 777-200 aircraft. In addition to more seats, the aircraft provides a significantly larger cargo hold and is capable of a higher maximum take-off weight. In 2017, Delta Air Lines began service to Charles de Gaulle Airport in Paris using a 168-seat Boeing 757-200. As part of the airline’s retirement plan for the aircraft, the Boeing 757-200 aircraft was replaced by the larger 211-seat Boeing 767-300ER. A traditional regression model was not capable of capturing the relationship between seating, which is indirectly related to cargo space, due to anomalies in 2013 and 2014. However, the recent changes in the service and fleet for transoceanic flights have coincided with increases in international air cargo. Therefore, a multivariate regression model using transoceanic seating capacity and a dummy variable in 2013 and 2014 to account for the anomalies with a historical time frame of 2009 through 2018 was selected. The model formula and relevant test statistics are provided below:

Model
International Air Cargo = 1.2E6 + 64.6*Seating Capacity$_{transoceanic}$

Test Statistics
R^2 = 75.7%
Degrees of Freedom = 9
P-value = 0.0

Independent Variables P-Values
Intercept = 0.1
Seating Capacity$_{transoceanic}$ = 0.0

For existing service, no changes to the seating configurations were assumed through the forecast period. However, potential new service to Europe would contribute an increase in international air cargo. Therefore, transoceanic seating capacity was held constant except for the years coinciding with the start of the assumed new transoceanic service.

4.2 Forecast Summary

Based on the assumptions and the models previously detailed, total air cargo throughput at the Airport is forecast to increase from 107,302 tons in 2020 to 165,348 tons in 2033. **Table 4-1** provides a summary of the air cargo forecast by segment.

The most recent Boeing World Air Cargo Forecast,[40] is showing a 2.7% cargo ton baseline growth rate for domestic air cargo. Since 2016, all-cargo has increased at a CAGR of 7.5%, well above the national average during that time. These factors combined with the Raleigh, North Carolina Air Service Area's particularly strong socioeconomic base as previously discussed indicates it is reasonable to determine that all-cargo at RDU may increase at 3.0% (2025-33), a rate slightly higher than the forecasted national average.

[40] Boeing, World Air Cargo Forecast: 2020-2039.

Table 4-1 Air Cargo Throughput Forecast Results

Year	Domestic		International	Total
	Belly	All-Cargo		
Historical				
2019	6,460	98,168	6,240	**104,408**
2020	4,553	106,867	435	**107,302**
Forecast				
2021	7,606	108,076	650	**108,726**
2022	7,887	112,058	6,240	**118,297**
2023	8,167	116,040	6,240	**122,279**
2024	8,447	120,021	6,240	**126,261**
2025	8,727	124,003	6,240	**130,243**
2026	9,008	127,985	6,240	**134,225**
2027	9,288	131,967	6,240	**138,207**
2028	9,568	135,949	6,240	**142,189**
2029	9,848	139,931	9,490	**149,420**
2030	10,129	143,913	9,490	**153,402**
2031	10,409	147,895	9,490	**157,384**
2032	10,689	151,876	9,490	**161,366**
2033	10,969	155,858	9,490	**165,348**
Compound Annual Growth Rates				
2020-25	13.9%	3.0%	70.4%	**4.0%**
2025-33	2.9%	2.9%	5.4%	**3.0%**
2020-33	7.0%	2.9%	26.8%	**3.4%**

Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

5 Aircraft Operations Forecast

This section describes the methodology and the results of the aircraft operations forecast at RDU. Aircraft operations, defined as aircraft arrivals plus departures, were projected separately for four major categories: (1) passenger; (2) freighter; (3) GA and air taxi; and (4) military. These components are then aggregated to derive a total aircraft operations forecast.

5.1 Passenger Aircraft Operations

5.1.1 Methodology

The number of passenger aircraft operations at an airport depends on three factors: (1) total passengers; (2) average aircraft size; and (3) average load factors (percent of seats occupied). The relationship is shown in the equation below:

$$\text{Passenger Aircraft Operations} = \frac{\text{Total Passengers}}{\text{Average Load Factor} * \text{Average Aircraft Size}}$$

This relationship permits an infinite set of load factors, average aircraft size, and operations to accommodate a given number of passengers. The enplaned passenger forecast was used to derive the passenger aircraft operations. The enplaned passenger forecast was used as the numerator in the formula above with assumed values for the load factors and average aircraft size to determine passenger aircraft departures. To calculate total operations, the total number of departures was multiplied by a factor of two.

In order to develop reasonable load factor and average number of seats per aircraft assumptions, enplaned passengers and passenger aircraft departures were disaggregated into categories of activity (i.e. air carrier and regional activity for both domestic and international service). Load factors and the average aircraft size, or average seats per departure (ASPD), at every airport is inherently different due to differences in how airlines choose to service the demand for air travel to, from, and over each airport. These differences may result from a strategic focus on unit revenue versus unit costs or an emphasis on a hub and spoke system versus a point-to-point system.

Several sources were used to develop the historical passenger aircraft operations, load factors, and the ASPD for the Airport. Official airline schedules; FAA's Operations Network (OPSNET); and the United States Department of Transportation (DOT, and Air Carrier Statistics database (T-100) were used to develop total departures and seats for each segment. ASPD for each of the major groups of passenger activity was calculated from total departures and total departing seats. Aircraft load factors were calculated for each group of passenger aircraft operations by dividing the total enplaned passengers by total departing seats.

5.1.2 Passengers Per Operation

5.1.2.1 Domestic Passenger Aircraft Operations

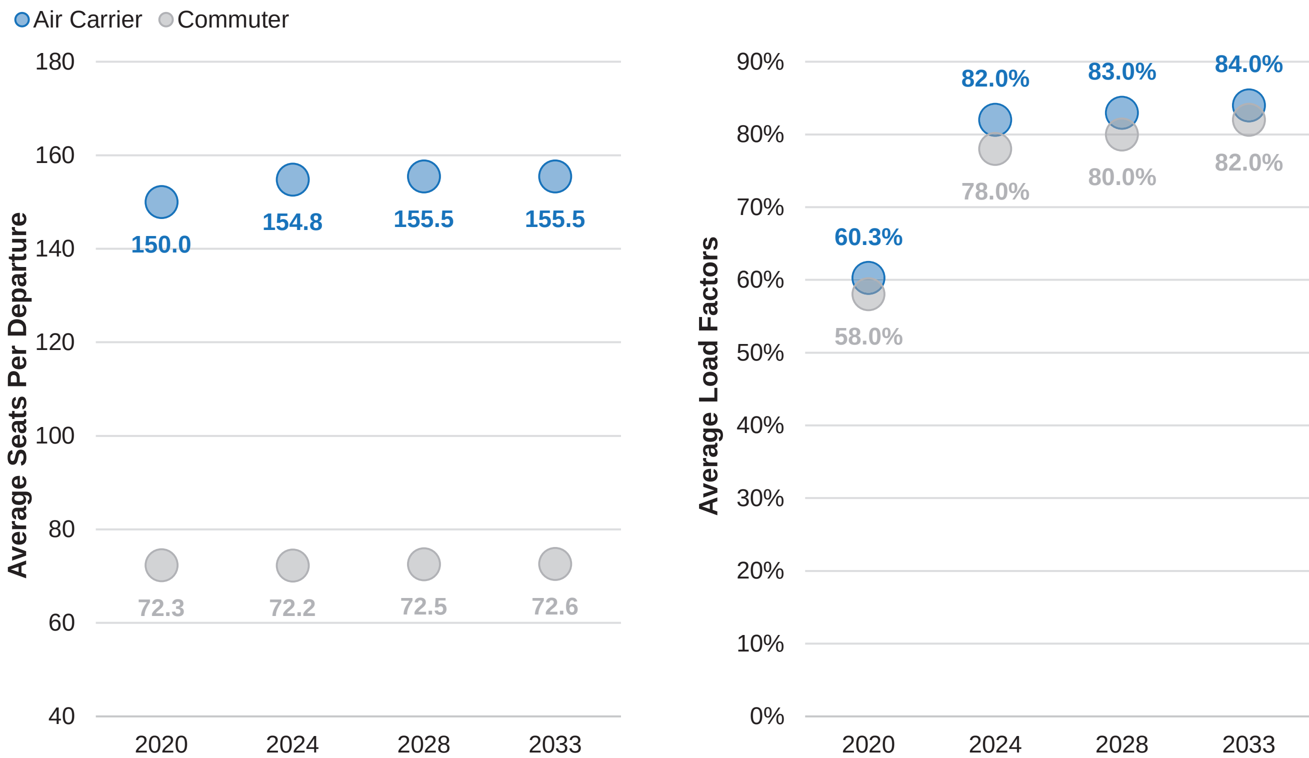
The average number of seats per aircraft for each category of activity is directly related to the type of aircraft being used at the Airport. Most of the domestic passenger traffic is handled by the network carriers. Therefore, in order to estimate the future average number of seats per aircraft, the fleet plans for these carriers were examined. The following is a description of the current fleet plans for each of the major carriers and LLCs with a focus on potential changes at RDU.

- **Delta Air Lines:** Delta Air Lines primarily uses a mix of the Boeing 717-200, Boeing 737-800, Airbus A319-100, Airbus A320-200, and Airbus A321-200, The Boeing 717-200 aircraft are relatively old by aircraft standards. The airline currently has 42 unfilled orders for the Airbus A220-300 aircraft which is assumed to be the Boeing 717-200s replacement with the shift occurring as orders are delivered. Delta Air Lines has 125 Airbus A321s on order. These aircraft will be added to the fleet where applicable.
- **American Airlines:** Currently, American Airlines utilizes a mix of the Boeing 737-800, Airbus A319-200, Embraer E190, Airbus A320-200, and Airbus A321 aircraft for domestic air carrier operations at RDU. The Embraer E190 was retired during the COVID-19 pandemic. American Airlines has 38 unfilled orders for the Airbus A321neo. Additionally, the airline has 50 unfilled orders for the Airbus A321XLR and 59 unfilled orders for the Boeing 737 Max 8.
- **Southwest Airlines:** A majority of Southwest Airlines' flights at RDU utilize the Boeing 737-700 aircraft and Boeing 737-800 aircraft. Currently, Southwest Airlines has a number of Boeing 737 Max 8 and Boeing 737 Max 7 aircraft on order which are expected to replace older Boeing 737-700 aircraft.
- **United Airlines:** United Airlines deploys a relatively even mix of the Airbus A319, Airbus A320, and Boeing 737-800 aircraft with some flights with the Boeing 737-900 aircraft at RDU. United Airlines has orders for the Boeing 737 Max 9 and Boeing 737 Max 10 aircraft, which will be utilized at the Airport as the aircraft are delivered.
- **Low-Cost Carriers:** Frontier Airlines uses Airbus A320 aircraft for a majority of its operations at RDU. Frontier Airlines has a number of Airbus A320neo and Airbus A321neo aircraft on order. It is expected the Airbus A320neo will handle some of the flights at RDU currently being operated by the current model Airbus A320. JetBlue primarily uses the Embraer E190 aircraft at RDU. JetBlue has orders for 68 Airbus A220-300 aircraft which is expected to be the replacement for the Embraer E190. Spirit Airlines primarily uses a mix of Airbus A319 and Airbus A320 aircraft for its operations with some flights using the Airbus A320neo. It is expected that as Spirit Airlines receives more deliveries of the Airbus A320neo, it will incorporate the aircraft in more flights at the Airport.

Delta Air Lines, United Airlines, and American Airlines all use regional affiliates to accommodate a majority of their passenger traffic. These regional airlines exclusively use aircraft with fewer than 76 seats, which are called regional jets. Small regional jets (aircraft with 50 or fewer seats) are being retired at an accelerated rate as airlines believe these aircraft are too expensive to fly. Some of the small regional aircraft have already been eliminated from routes at RDU. It is expected that all the regional partners of the mainline carrier will replace the majority of the small regional aircraft with larger regional aircraft (aircraft with at least 65 seats) at RDU within the next ten years. Bombardier ended production of Canadair regional jets (CRJ) in March 2021 which will prevent growth of these aircraft in future years. The average age for the CRJ-700 for the regional airlines is in excess of 15 years, so some replacements will likely be required by the end of the forecast. However, the CRJ-900 has an average age of around 10 years, which indicates the aircraft will likely be available through the forecast period. It is expected that comparable Embraer regional jets will fill the need for future growth in regional jet traffic and act as a replacement when necessary. The CRJ-550 is 50-seat conversion of the CRJ-700 with some of these aircraft are still in the process of being converted. Once the conversion is complete the availability of 50-seat aircraft will remain constant. The CRJ-550 is the only 50-seat aircraft assumed to remain in service through the forecast and its operations will remain at the forecasted 2024 levels during this time.

In 2020, domestic air carrier aircraft operations had a scheduled ASPD of 150.0 and an estimated average load factor of 60.3%. Based on the fleet plans for airlines providing domestic service at RDU, the ASPD for domestic air carrier flights is projected to increase to 155.5 by 2033. The average load factor is currently at an all-time low due to the COVID-19 pandemic but they are expected to recover to an average of 84.0%. In 2020, domestic commuter aircraft operations had a scheduled ASPD of 72.3 and an estimated average load factor of 58.0%. Based on the anticipated reduced utilization of small regional aircraft for domestic service at RDU, the ASPD for domestic commuter flights is projected to increase to 72.6 by 2033 and average load factors for domestic commuter flights are expected to recover to 82.0%. **Figure 5-1** provides the ASPD and load factors used to calculate domestic passenger aircraft operations by air carrier and commuter aircraft categories.

Figure 5-1 Domestic Passengers Per Aircraft Operation Assumptions



Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. U.S. Department of Transportation, Air Carrier Statistics database (T-100). Diio Mi, Schedule – Dynamic Table. Landrum & Brown Analysis.

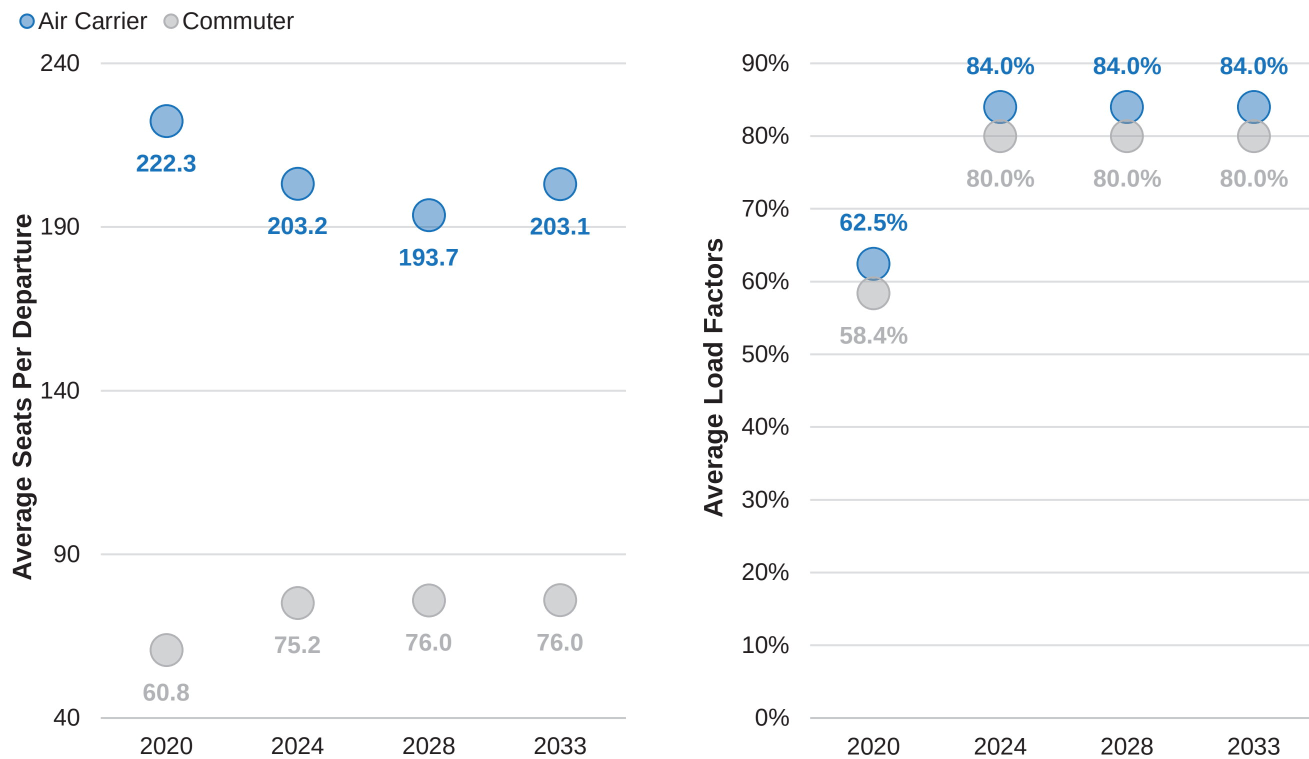
5.1.2.2 International Passenger Aircraft Operations

There are three international regions currently being served at the Airport: Canada, Latin America, and Europe. Each region has distinct carriers that employ specific aircraft for each region. The following is a summary of the anticipated changes to the fleet for each region.

- **Canada:** Canadian markets are served solely by regional affiliates of Air Canada. Combined, these affiliates utilize Embraer E175, Bombardier CRJ200, and Bombardier CRJ900. The Bombardier CRJ200 in the Air Canada fleet have all been in service in excess of 16 years and will be reaching the end of their useful age by the end of the forecast. Although, there are currently no plans to completely remove the smaller regional jets from the fleet, it is anticipated that all Bombardier CRJ200 aircraft will be retired by 2033.
- **Latin America:** In 2020, there were only three Latin American destinations: Cancun, Mexico; Montego Bay, Jamaica; and Punta Cana, Dominican Republic. These flights are handled by a mix of airlines, but all the airlines use a narrow-body aircraft, such as the Airbus A320-200, Embraer E190 and Boeing 737-800 aircraft. JetBlue currently has 68 orders for the Airbus A220-300 which the airline will use as a replacement for the Embraer E190 aircraft.
- **Europe:** Prior to the suspension of the service, Delta Air Lines was using the Boeing 767-300 aircraft for flights to Paris. The airline is expected to retire the Boeing 767-300 aircraft by 2025. The airline has 28 orders for Airbus A330-900neo to be the replacement for the Boeing 767-300 aircraft. American Airlines uses the Boeing 777-200 aircraft for flights to London. The airline currently has 30 orders for Boeing 787-9 aircraft, which will be the replacement for the older Boeing 777-200 aircraft starting in 2023. New transatlantic service to Frankfort Airport is assumed to begin in 2029. It was assumed that Airbus for -900 aircraft would be used for these flights and would not change over the forecast period.

In 2020, international air carrier aircraft operations had a scheduled ASPD of 222.3 and an estimated average load factor of 62.5%. Based on the fleet plans for airlines providing international service at RDU, and the potential for new service, the ASPD for international air carrier flights is projected to decrease to 20.1 by 2033 and average load factors are expected to increase to an average of 84.0%. In 2020, international commuter aircraft operations had a scheduled ASPD of 60.8 and an estimated average load factor of 58.4%. Based on the anticipated reduced utilization of small regional aircraft for domestic service at RDU, the ASPD for international commuter flights is project to increase to 76.0 by 2033 and average load factors for international commuter flights are expected to recover to 80.0%. **Figure 5-2** provides the ASPD and load factors used to calculate international passenger aircraft operations by air carrier and commuter aircraft categories.

Figure 5-2 International Passengers Per Aircraft Operation Assumptions



Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. U.S. Department of Transportation, Air Carrier Statistics database (T-100). Diio Mi, Schedule – Dynamic Table. Landrum & Brown Analysis.

5.1.3 Forecast Summary

Based on the foregoing assumptions regarding load factors and ASPD, passenger operations will increase from 66,316 in 2020 to 198,280 in 2033. **Table 5-1** presents the results of the domestic and international passenger aircraft operations forecast.

Table 5-1 Passenger Aircraft Operations Forecast

Year	Domestic	International	Total
Historical			
2019	139,632	4,466	**144,098**
2020	65,278	1,038	**66,316**
Forecast			
2021	101,296	2,010	**103,306**
2022	123,200	3,580	**126,780**
2023	137,260	4,120	**141,380**
2024	149,280	4,640	**153,920**
2025	157,720	4,980	**162,700**
2026	161,800	5,140	**166,940**
2027	165,880	5,320	**171,200**
2028	169,940	5,540	**175,480**
2029	172,880	6,680	**179,560**
2030	177,300	6,840	**184,140**
2031	181,720	7,000	**188,720**
2032	186,160	7,140	**193,300**
2033	190,640	7,300	**197,940**
Compound Annual Growth Rates			
2020-25	19.3%	36.8%	**19.7%**
2025-33	2.4%	4.9%	**2.5%**
2020-33	8.6%	16.2%	**8.8%**

Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

5.1.4 Passenger Airline Fleet Mix

The fleet mix forecasts were developed to match the ASPD assumptions for each segment and the fleet plans of the major carriers. The fleet mix forecasts allowed for the calibration of the ASPD and load factor assumptions and, where appropriate, modifications were made prior to finalizing the ASPD and load factor assumptions. The allocation of passenger departures by aircraft type is shown in **Table 5-2** for domestic departures and **Table 5-3** for international departures.

Table 5-2 Domestic Passenger Fleet Mix Forecast

Aircraft	Departures				
	2019	2020	2024	2028	2033
Air Carrier	**52,071**	**24,944**	**52,234**	**59,154**	**65,955**
Boeing 757-200	119	31	0	0	0
Airbus A321	1,734	885	1,798	2,057	2,320
Boeing 737-900	1,421	1,004	3,601	4,119	4,642
Boeing 737-800	8,228	4,940	12,245	14,004	15,791
Airbus A320	9,346	3,987	7,831	8,955	10,095
Boeing (Douglas) MD-90	496	226	0	0	0
Boeing (Douglas) MD-80	1,759	392	0	0	0
Boeing 737-700	9,176	4,566	4,960	5,671	6,394
Airbus A220-300	0	0	6,627	8,661	9,765
Airbus A319	4,301	2,222	9,741	11,143	12,563
Boeing 717-200	3,230	1,190	465	0	0
Embraer E190	5,255	1,769	482	0	0
Canadair Regional Jet 900	7,006	3,732	4,484	4,544	4,385
Regional	**17,745**	**7,695**	**22,406**	**25,816**	**29,365**
Embraer E175	6,454	4,596	13,899	16,393	18,892
Embraer E170	1,290	1,019	5,054	6,865	8,811
Canadair Regional Jet 700	5,136	1,222	2,089	1,413	519
Canadair Regional Jet 550	0	0	1,142	1,145	1,143
Canadair Regional Jet 200	3,274	611	161	0	0
Embraer E135/E140/E145	1,591	247	61	0	0
Total	**69,816**	**32,639**	**74,640**	**84,970**	**95,320**

Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

Table 5-3 International Passenger Fleet Mix Forecast

Aircraft	Departures				
	2019	2020	2024	2028	2033
Air Carrier	**972**	**329**	**1,673**	**2,022**	**2,799**
Airbus A350-900	0	0	0	0	365
Boeing 787-900	0	0	365	365	365
Boeing 777-200	360	75	0	0	0
Boeing 767-300	315	56	316	316	316
Airbus A321	0	11	0	0	0
Boeing 737-900	9	0	7	8	12
Boeing 737-800	19	17	57	70	102
Airbus A320	136	24	116	202	279
Airbus A220-300	0	0	156	313	431
Airbus A319	0	11	200	246	360
Embraer E190	0	0	23	0	0
Canadair Regional Jet 900	128	135	433	502	569
Boeing 737-700	5	0	0	0	0
Regional	1,261	190	647	748	851
Embraer E175	179	0	613	746	851
Canadair Regional Jet 200	1,082	190	34	2	0
Total	**2,233**	**519**	**2,320**	**2,770**	**3,650**

Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

5.2 Freighter Aircraft Operations

5.2.1 Methodology

The freighter aircraft operations forecast was derived from the air cargo throughput forecast in a similar fashion as passenger aircraft operations are derived from the passenger forecast. The freighter aircraft operations are a product of the cargo throughput forecast, excluding belly cargo, forecast and an assumed average air cargo tons per operation.

5.2.2 Tons Per Operation

A majority of the air cargo at the Airport is handled by FedEx and UPS. The following is a summary of the anticipated changes to the fleet for each carrier.

- **FedEx:** FedEx uses a mix of wide-body, some narrow-body, and small regional jets for its operations. At RDU, the carrier predominately uses a mix of the Boeing 767-300 and the Cessna 208 aircraft. Currently, FedEx has 101 Boeing 767-300 in service and an order for an additional 31 aircraft. Additionally, FedEx has 45 Boeing 777 in service and another 13 on order. The new aircraft will be used as a replacement for the carrier's Airbus A300-600, Airbus A310-300, and variants of the McDonnell Douglas MD-10 and MD-11 aircraft. The carrier also has 29 ATR 72-600 and 50 Cessna 408 aircraft on order. The Cessna 408 will be used in place of the Cessna 208 for higher demand markets.
- **UPS:** Currently, UPS has 280 aircraft in service. The Boeing 757-200 is the most common aircraft in the carrier's fleet followed closely by the Boeing 767-300. The carrier has a number of McDonnell Douglas MD-11 and Airbus A300-600 but does not have any retirement plans for these aircraft. However, it is assumed that the airline will use the Boeing 767-300 to act as a replacement for some of the older aircraft.

Historically, tons per aircraft operation have been on a slight decline, decreasing from 18.4 tons in 2012 to 16.1 tons in 2019. In 2020, there was an increase to 16.8 tons. Due to the anticipated changes in the fleet mix, the average tons per aircraft operation is expected to increase over the forecast. As such, the tons per aircraft operation for the airline is expected to increase to 17.0 by 2033.

5.2.3 Forecast Summary

Freighter aircraft operations are forecast to increase from 6,362 in 2020 to 9,170 in 2033. **Table 5-4** provides the number of freighter aircraft operations through 2033.

Table 5-4 Freighter Aircraft Operations Forecast

Year	All-Cargo Tonnage	Freighter Operations	Tons/ Operation
Historical			
2019	98,168	6,110	16.1
2020	106,867	6,362	16.8
Forecast			
2021	108,076	6,430	16.8
2022	112,058	6,660	16.8
2023	116,040	6,890	16.8
2024	120,021	7,120	16.8
2025	124,003	7,350	16.9
2026	127,985	7,580	16.9
2027	131,967	7,810	16.9
2028	135,949	8,040	16.9
2029	139,931	8,260	16.9
2030	143,913	8,490	16.9
2031	147,895	8,720	17.0
2032	151,876	8,940	17.0
2033	155,858	9,170	17.0
Compound Annual Growth Rates			
2020-25	3.0%	2.9%	
2025-33	2.9%	2.8%	
2020-33	2.9%	2.9%	

Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

5.2.4 Freighter Fleet Mix

As previously mentioned, FedEx is expected to replace its Airbus A300-600, Airbus A310-300, and variants of the McDonnell Douglas MD-10 and MD-11 aircraft with Boeing 767-300 and Boeing 777 aircraft. FedEx will also introduce the Cessna 408 to replace the Cessna 208 in higher demand markets. While UPS does not have any current retirement plans for its McDonnell Douglas MD-11 and Airbus A300-600, they are anticipated to be replaced by Boeing 767-300 aircraft. **Table 5-5** provides the allocation of freighter aircraft operations by aircraft type.

Table 5-5 Freighter Fleet Mix Forecast

Aircraft	Departures				
	2019	2020	2024	2028	2033
Air Carrier	**1,680**	**1,750**	**1,958**	**2,210**	**2,519**
Wide-Body	**1,649**	**1,717**	**1,922**	**2,169**	**2,473**
Boeing 767-300	972	1,011	1,321	1,668	1,990
Airbus A300-600	413	431	361	306	261
Boeing 777	0	0	105	195	222
Boeing (Douglas) MD-11	231	241	135	0	0
Boeing (Douglas) DC-10	33	34	0	0	0
Narrow-Body	**31**	**33**	**36**	**41**	**46**
Boeing 757-200	29	31	34	39	44
Other	2	2	2	2	2
Regional	**1,375**	**1,431**	**1,602**	**1,810**	**2,066**
Cessna 208 Caravan	1,354	1,409	1,561	1,746	1,982
Cessna 408 SkyCourier	0	0	16	36	52
Other	21	22	25	28	32
Total	**3,055**	**3,181**	**3,560**	**4,020**	**4,585**

Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

5.3 Other Aircraft Operations

It was assumed that GA and air taxi aircraft operations would increase at a rate consistent with the national trends. The average annual growth rate (AAGR) for active GA and air taxi hours flown from the FAA Aerospace Forecast for each category (jets, turboprops, pistons, and helicopters) were applied to the number of aircraft operations in 2020. **Table 5-6** presents the air taxi and GA aircraft operations forecast by aircraft type.

Table 5-6 Air Taxi and General Aviation Fleet Mix Forecast

Aircraft	Example Aircraft	Departures				
		2019	2020	2024	2028	2033
Jets	Cessna Citation V Cessna Excel Bombardier Challenger 300	26,005	21,404	28,716	33,402	38,943
Turboprops	Beech 200 Super King Pilatus PC-12 Socata TBM-850	9,037	7,198	8,662	9,466	10,631
Pistons	Cirrus SR 22 Piper PA-28 Cherokee Diamond Star DA40	32,128	24,799	26,723	26,344	26,023
Other/Helicopters	Eurocopter EC-145 Bell 407 Agusta AB-139	1,667	1,341	1,679	1,888	2,153
Total		**68,837**	**54,742**	**65,780**	**71,100**	**77,750**

Note: Example aircraft represents the most common aircraft for each category operating at the Airport.
Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

Military aircraft operations make up a very small share of the aircraft operations at the Airport. In 2020, there were 2,990 military aircraft operations. Changes in military operations are driven by state and federal policy, such as a base closure, rather than the socioeconomic characteristics of a region. Currently, no details for plans to expand or contract the operating level of military operations at RDU have been announced. Therefore, the military aircraft operations were held constant at 2,990 through the forecast period.

5.4 Aircraft Operations Forecast Summary

The total aircraft operations forecast is the aggregation of the passenger, freighter, air taxi and GA, and military aircraft operations forecast. Total aircraft operations are projected to increase from 130,410 in 2020 to 288,190 in 2033. **Table 5-7** presents the aircraft operations forecast by segment through the forecast period.

Table 5-7 Total Aircraft Operations Forecast

Year	Passenger			Freighter	Air Taxi/ General Aviation	Military	Grand Total
	Domestic	International	Total				
Historical							
2019	139,632	4,466	**144,098**	6,110	68,837	2,581	**221,626**
2020	65,278	1,038	**66,316**	6,362	54,742	2,990	**130,410**
Forecast							
2021	101,296	2,010	**103,306**	6,430	61,790	2,990	**174,516**
2022	123,200	3,580	**126,780**	6,660	63,120	2,990	**199,550**
2023	137,260	4,120	**141,380**	6,890	64,450	2,990	**215,710**
2024	149,280	4,640	**153,920**	7,120	65,780	2,990	**229,810**
2025	157,720	4,980	**162,700**	7,350	67,110	2,990	**240,150**
2026	161,800	5,140	**166,940**	7,580	68,440	2,990	**245,950**
2027	165,880	5,320	**171,200**	7,810	69,770	2,990	**251,770**
2028	169,940	5,540	**175,480**	8,040	71,100	2,990	**257,610**
2029	172,880	6,680	**179,560**	8,260	72,430	2,990	**263,240**
2030	177,300	6,840	**184,140**	8,490	73,760	2,990	**269,380**
2031	181,720	7,000	**188,720**	8,720	75,090	2,990	**275,520**
2032	186,160	7,140	**193,300**	8,940	76,420	2,990	**281,650**
2033	190,640	7,300	**197,940**	9,170	77,750	2,990	**287,850**
Compound Annual Growth Rates							
2020-25	19.3%	36.8%	**19.7%**	2.9%	4.2%	0.0%	**13.0%**
2025-33	2.4%	4.9%	**2.5%**	2.8%	1.9%	0.0%	**2.3%**
2020-33	8.6%	16.2%	**8.8%**	2.9%	2.7%	0.0%	**6.3%**

Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Landrum & Brown Analysis.

6 Peak Period Forecast

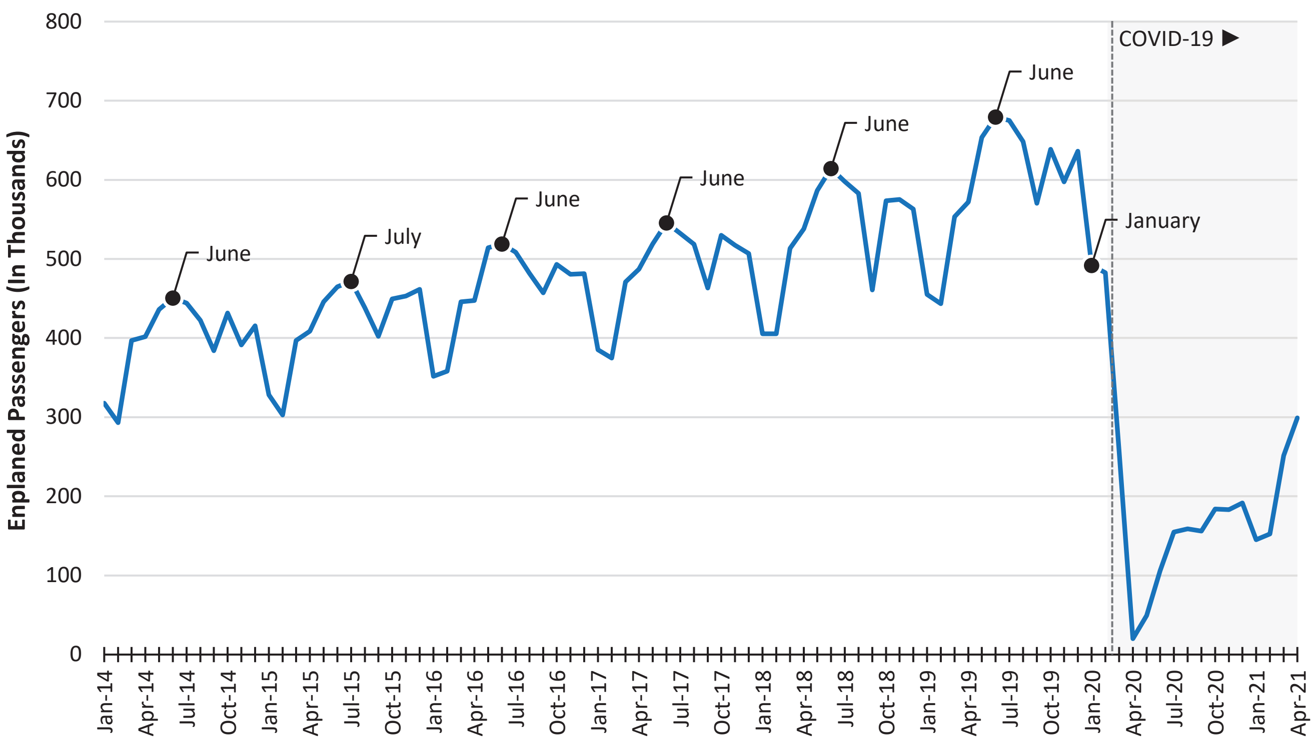
The traffic demand patterns imposed upon an airport are subject to seasonal, monthly, daily, and hourly variations. Peaking characteristics are critical in the assessment of existing facilities and airfield components to determine their ability to accommodate forecast increases in passenger and operational activity throughout the forecast period.

The annual passenger and aircraft operations forecasts for RDU were converted into monthly, daily, and peak hour equivalents. The peak period aircraft operations forecasts were developed for passenger, all-cargo, air taxi, GA, military, and total operations.

6.1 Monthly Seasonality

The monthly passenger data from the Airport was used to determine the peak month for passengers. The Airport's busy period for passengers occurs during the summer months of June and July. From 2014 through 2019, June was the peak month for five years and July was the peak month for one year. During this period, the months of June and July accounted for 9.4% and 9.3% of the passengers at RDU respectively. January was the peak month of 2020 due to the impacts from the COVID-19 pandemic. **Figure 6-1** graphically depicts the monthly seasonality for passengers at the Airport.

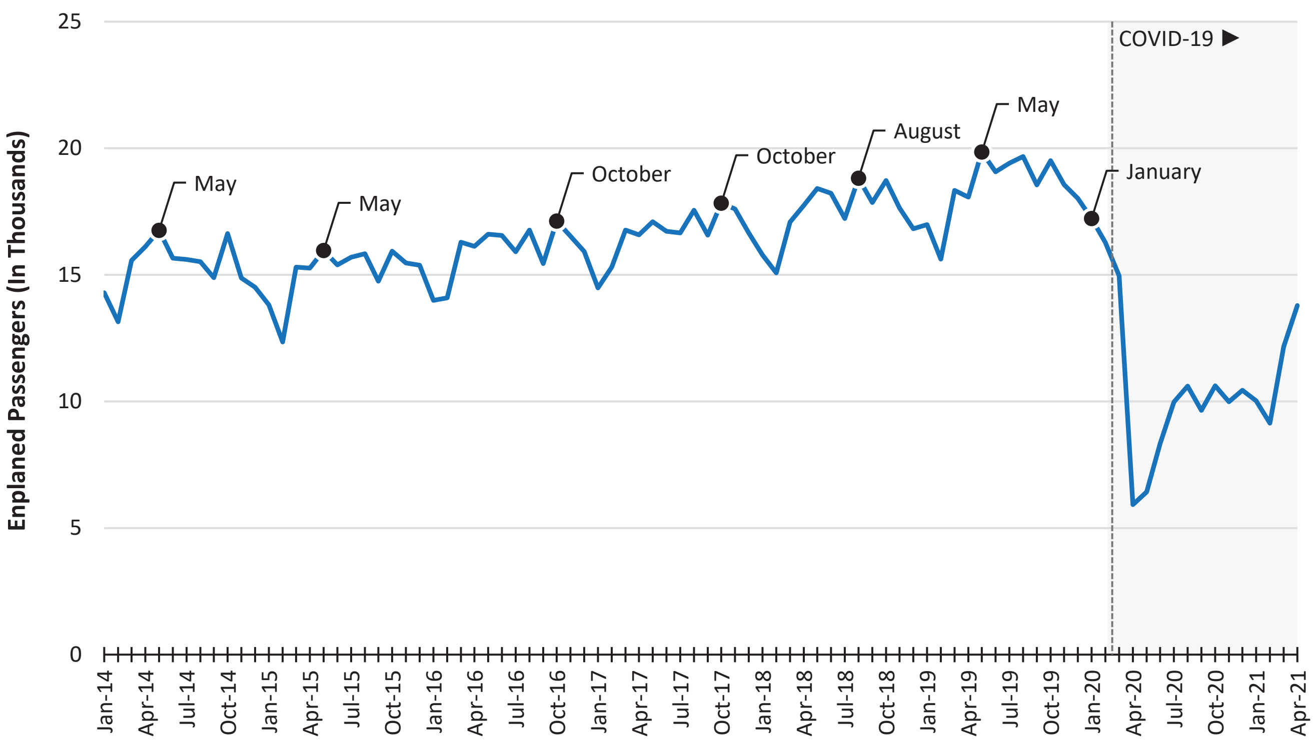
Figure 6-1 Monthly Passengers



Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics.

Although June is the peak month for passengers it has not been the peak month in terms of aircraft operations over the past five years. Unlike passengers which have a consistent peak month, total aircraft operations tend to vary from month to month. Commercially, airlines will increase the average gauge of their aircraft during the summer months to accommodate increased demand and freighter operations tend to increase in the fourth quarter to meet demand for the holiday season. Additionally, GA and air taxi service tends to be more random than commercial service, so although they account for a smaller percent of the overall traffic, they tend to have a more significant impact in the seasonality of aircraft operations. January was the peak month of 2020 due to the impacts from the COVID-19 pandemic. **Figure 6-2** graphically depicts the monthly seasonality for aircraft operations at the Airport.

Figure 6-2 Monthly Aircraft Operations



Source: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics.

6.2 Daily Variation

The FAA recommends the use of the average day of the peak month, typically referred to as the peak month average day (PMAD), for purposes of physical planning such as developing gate requirements. As an alternative, the peak month average weekday (PMAWD) can be used at airports that have domestic service as the predominant activity and at airports where weekend activity is consistently less than weekday activity.

As demonstrated, June has been consistently ranked as the highest month for passengers. However, passengers in July has been within one percent of the traffic in June for four of the past five years despite traffic slowing during the Fourth of July holiday. If evaluating traffic on passengers per weekday, excluding holidays, July has consistently had higher traffic. Therefore, July was selected as the peak month for the purposes of physical planning at the Airport.

Seating information from scheduling data was used as a proxy to determine the 2019 PMAWD, as passenger data was not available at the daily level. PMAWD was used as the design day at RDU because the average weekday had 12.1% more scheduled seats than the average weekend. Operations at RDU were significantly lower on the Fourth of July holiday than the rest of the month and were removed from the analysis for determining the PMAWD. Wednesday July 31, 2019 was selected as the PMAWD as it most closely resembles the average weekday for the month.

6.3 Design Day Flight Schedule

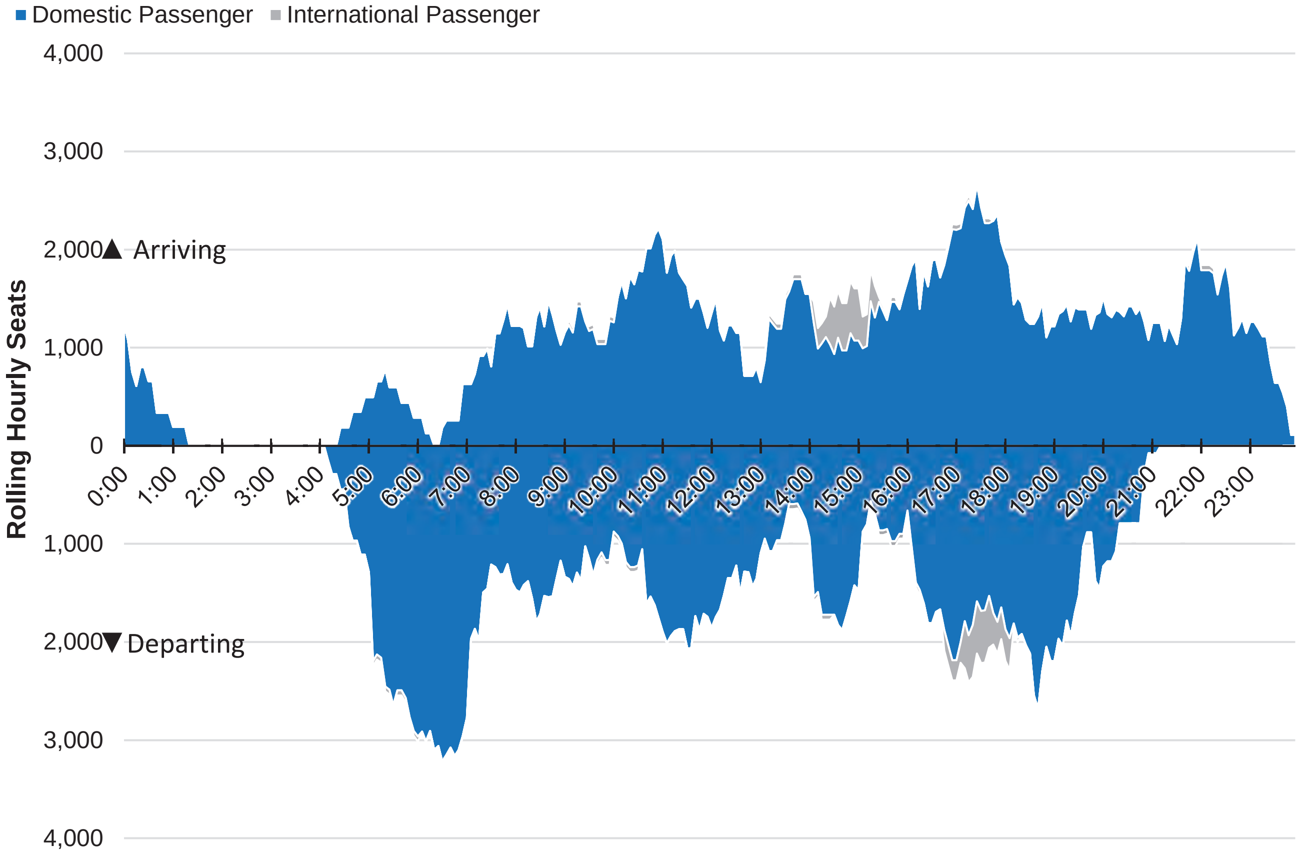
A design day flight schedule (DDFS) for 2019 was developed to determine the hourly profile of traffic at the Airport. In order to develop the DDFS, that was representative of the traffic at the Airport and to include scheduled and unscheduled service, a combination of the published flight schedule and historical radar data was used.

Published flight schedules for the design day provided the scheduled passenger aircraft operations. The passenger aircraft operations were supplemented with radar data for cargo, air taxi, and GA aircraft operations. Accurate military data was not available in the radar data so additional flights were added to the DDFS to account for the average day.

6.4 Hourly Profiles

The DDFS for 2019 was analyzed to determine the hourly profile at the Airport to identify the periods of time where traffic was most concentrated. Using a clock hour as the basis for peak periods does not allow for peak periods of traffic that occurs across clock hours to be identified, i.e. traffic occurring late in the first hour combined with the traffic at the beginning of the next hour. Therefore, a rolling 60-minute hour approach was used to determine the design day profile. In this case, aircraft operations were categorized into one of 288 five-minute buckets, or bins, that occur during the given day. The sum of twelve sequential buckets represents a rolling 60-minute hour. In 2019, the peak for departing seats occurred during the morning departure push while the arrival peak occurred during the afternoon. **Figure 6-3** graphically presents the rolling 60-minute hour profile for scheduled passenger seats in the DDFS for 2019.

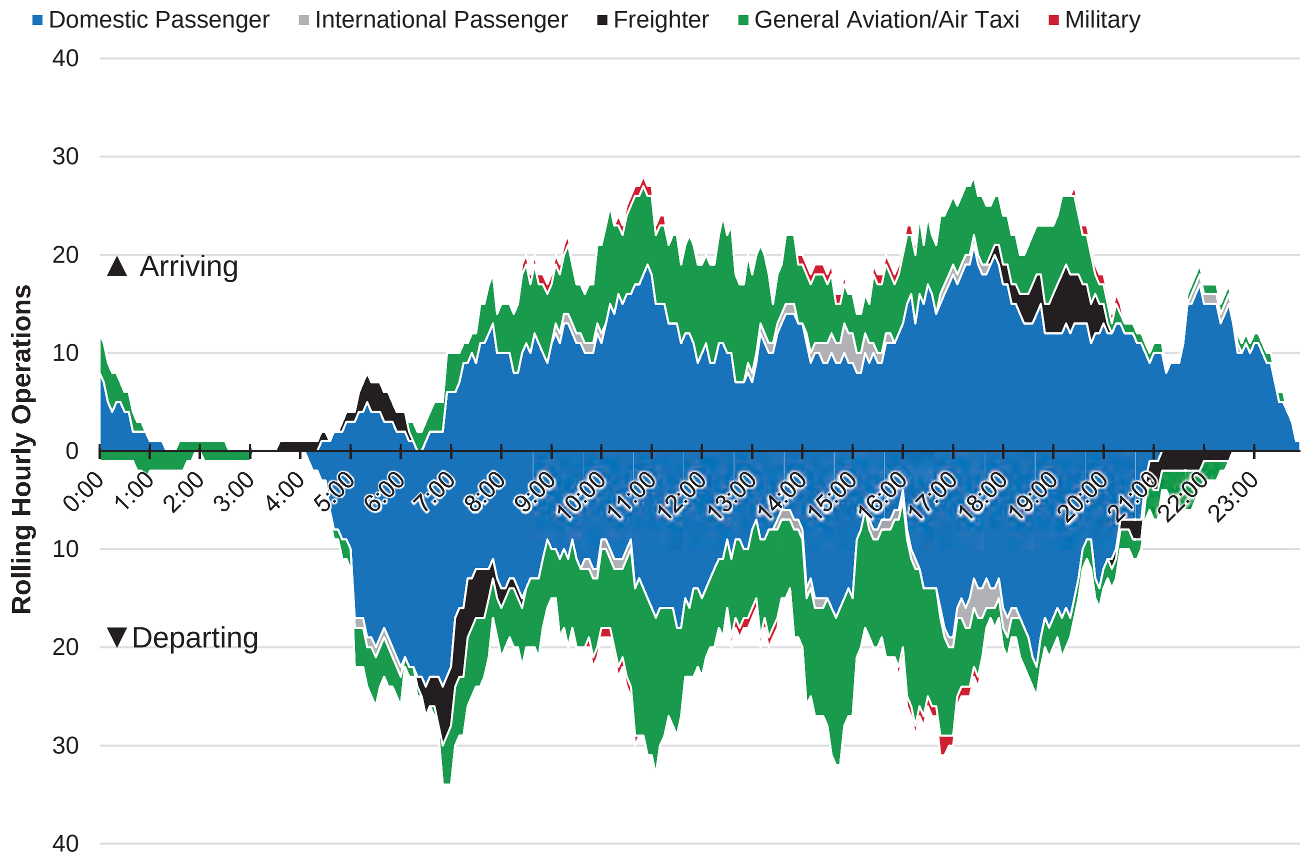
Figure 6-3 Rolling 60-Minute Seating Profile (July 31, 2019)



Sources: Diio Mi, Schedule – Dynamic Table. Landrum & Brown.

Figure 6-4 graphically presents the total aircraft operations (including scheduled passengers, cargo, air taxi, GA, and military) for the rolling 60-minute hours for the 2019 DDFS. As shown in the profile, the peaks for aircraft operations are dependent on passenger operations as the arrival peak occurs in the afternoon and the departure peak is during the morning departure peak. There are smaller peaks throughout the day as a result of GA and air taxi operations.

Figure 6-4 Rolling 60-Minute Operations Profile (July 31, 2019)



Sources: Diio Mi, Schedule – Dynamic Table. Landrum & Brown.

6.5 Peak Period Forecast Summary

Information regarding peak month, average day, and peak hour from the DDFS was used to formulate metrics to determine the peak period forecast. These metrics include the peak month as a percent of the annual, the design day as a percent of the peak month, and the peak hour as a percent of the design day.

6.5.1 Aircraft Operations Forecast

Annual aircraft operations were divided by the peak month aircraft operations, peak month aircraft operations were divided by the design day aircraft operations, and the design day aircraft operations were divided by the peak hour aircraft operations to determine the peak period factors. Peak period factors were expressed for each of the segments (scheduled passenger, cargo, GA and air taxi, and military).

It was assumed that the peak month and design day factors would remain relatively unchanged through the forecast period. However, the expansion of service at the Airport to meet future demand would result in a more evenly distributed profile across the day. As a result, the peak hour factors were adjusted to account for these changes. The annual, monthly, daily, and peak hour aircraft operations forecasts are presented in **Table 6-1**. The total of annual, monthly, and design day aircraft operations is the aggregation of the individual segments. However, each of the individual segments peak at different periods of the day. As a result, peak hour total aircraft operations are not equal to the sum of the categories.

6.5.2 Passenger Forecast

Peak hour passengers were calculated using a similar methodology as peak hour aircraft operations. The annual and monthly passengers were determined from the Airport's records. The design day passengers are based on the scheduled seats for the design day as a share of the scheduled seats for the month. Peak hour passengers were calculated from the aircraft seating configurations in the DDFS and assumed load factors from the annual passenger aircraft operations forecast. **Table 6-2** presents the peak hour passenger forecasts for RDU.

Table 6-1 Peak Period Aircraft Operations Forecast

Segment	Time Frame	2019	2024	2028	2033
Domestic Passenger	Annual	139,632	149,280	169,940	190,640
	Peak Month	12,642	13,516	15,386	17,260
	Design Day	436	466	531	595
	PH Arrivals	21	23	26	28
	PH Departures	24	26	29	32
	PH Total	37	40	45	50
International Passenger	Annual	4,466	4,640	5,540	7,300
	Peak Month	442	457	536	679
	Design Day	14	14	17	22
	PH Arrivals	3	3	3	3
	PH Departures	3	3	3	3
	PH Total	4	4	4	4
Total Passenger	Annual	144,098	153,920	175,480	197,940
	Peak Month	13,084	13,973	15,922	17,939
	Design Day	450	480	548	617
	PH Arrivals	22	24	27	29
	PH Departures	24	26	29	32
	PH Total	39	42	47	52

Table 6-1 Peak Period Aircraft Operations Forecast (continued)

Segment	Time Frame	2019	2024	2028	2033
Freighter	Annual	6,110	7,120	8,040	9,170
	Peak Month	504	587	663	756
	Design Day	24	28	32	36
	PH Arrivals	6	7	8	9
	PH Departures	7	8	9	11
	PH Total	7	8	9	11
Air Taxi/ General Aviation	Annual	68,837	65,780	71,100	77,750
	Peak Month	5,537	5,291	5,719	6,254
	Design Day	220	210	227	248
	PH Arrivals	13	12	14	15
	PH Departures	16	15	17	18
	PH Total	25	24	26	28
Military	Annual	2,581	2,990	2,990	2,990
	Peak Month	279	323	323	323
	Design Day	9	10	10	10
	PH Arrivals	1	1	1	1
	PH Departures	2	2	2	2
	PH Total	2	2	2	2
Grand Total	Annual	221,626	229,810	257,610	287,850
	Peak Month	19,404	20,174	22,627	25,272
	Design Day	703	728	817	911
	PH Arrivals	28	29	33	35
	PH Departures	34	36	40	45
	PH Total	58	59	65	72

Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Diio Mi, Schedule – Dynamic Table. Flight Track Data for 2019. Landrum & Brown.

Table 6-2 Peak Period Passenger Forecast

Segment	Time Frame	2019	2024	2028	2033
Domestic Passenger	Annual	13,709,580	15,151,400	17,617,600	20,100,200
	Peak Month	1,308,511	1,443,008	1,677,824	1,914,240
	Design Day	44,387	48,946	56,967	64,920
	PH Arrivals	2,265	2,559	2,955	3,236
	PH Departures	2,733	3,054	3,479	3,905
	PH Total	3,763	4,196	4,821	5,449
International Passenger	Annual	509,041	554,800	645,000	934,200
	Peak Month	51,620	56,194	64,177	89,361
	Design Day	1,348	1,422	1,681	2,392
	PH Arrivals	490	516	502	552
	PH Departures	490	516	502	552
	PH Total	536	564	549	604
Total Passenger	Annual	14,218,621	15,706,200	18,262,600	21,034,400
	Peak Month	1,360,131	1,499,202	1,742,001	2,003,601
	Design Day	45,735	50,368	58,648	67,312
	PH Arrivals	2,311	2,605	3,001	3,282
	PH Departures	2,733	3,054	3,479	3,905
	PH Total	4,253	4,686	5,311	5,939

Sources: Raleigh-Durham Airport Authority, Raleigh-Durham International Airport: Activity Statistics. Diio Mi, Schedule – Dynamic Table. Flight Track Data for 2019. Landrum & Brown.

7 Comparison to the TAF

The FAA publishes its own forecast annually for each U.S. airport, including RDU. The Terminal Area Forecast (TAF) is "prepared to assist the FAA in meeting its planning, budgeting, and staffing requirements. In addition, state aviation authorities and other aviation planners use the TAF as a basis for planning airport improvements."[41]

If the EA Forecast is used for FAA decision-making, such as key environmental issues (for example purpose and need, air quality, and land use), noise capability planning, airport layout plan, and initial financial decisions, the FAA requires that the EA forecast is compared to the most recent TAF to determine if they are consistent. For all classes of airports, forecasts for total passenger enplanements, based aircraft, and total aircraft operations are considered consistent with the TAF if they meet the following criterion:[42]

- Forecasts differ by less than 10% in the five-year forecast period
- Forecasts differ by less than 15% in the ten-year forecast period

If the EA forecast is not consistent with the TAF, differences must be resolved before proceeding.

The TAF is prepared on a U.S. Government Fiscal Year (FY) basis (October through September) rather than calendar year. The forecast presented herein was developed on a calendar year basis. When an airport's traffic is growing rapidly, a timing difference between the FY base year and the calendar base year can be significant. This timing difference distorts a straight future year comparison between the two forecasts. Therefore, all forecasts presented in this report have been converted to a FY basis to be able to make valid comparisons.

The Final 2020 TAF includes historical information on aircraft operations from FY1990 through FY2019 and forecasts for FY2020[43] to FY2045. At airports with FAA towers like RDU, historical aircraft operations data is provided by FAA air traffic controllers, which count landings and take-offs. These aircraft operations are recorded as either air carrier, commuter and air taxi, GA, or military. Air carrier is defined as an aircraft with seating capacity of more than 60 seats or a maximum payload capacity of more than 18,000 pounds carrying passengers or cargo for hire or compensation. Commuter and air taxi aircraft are designed to have a maximum seating capacity of 60 seats or a maximum payload capacity of 18,000 pounds carrying passengers or cargo for hire or compensation.

The enplaned passenger information in the Final 2019 TAF includes historical values from FY1976 through FY2020 and forecasts from FY2021 to FY2045. Historical enplaned passenger data is obtained through the DOT T-100 Reports. The enplaned passengers provided in the TAF exclude non-revenue passengers and military charter passengers. These non-revenue passengers were removed from the enplaned passenger forecast in this report to make apt comparisons.

The Final 2020 TAF projects that aircraft operations at RDU will increase from 159,242 in FY2020 to 264,470 in 2030. In FY2020, there were 3.7 million enplaned passengers at RDU, which is 3.8% higher than the 3.6 million for FY2019 in the Final 2020 TAF. The Final 2020 TAF projects that enplaned passengers will increase from 3.6 million in FY2020 to 8.8 million in FY2030.

41 Federal Aviation Administration, Terminal Area Forecast Summary: Fiscal Years 2020-2045, May 2021.
42 Federal Aviation Administration, Review and Approval of Aviation Forecasts, June 2008.
43 Operations data for FAA towers and Federal contract towers for 2018 are actual.

The FAA provides templates in order to compare forecasts prepared by airport sponsors to the TAF. These templates are provided in Appendix B and C from the FAA Office of Aviation Policy and Plans (APO) document, *Forecasting Aviation Activity by Airport*. According the APO document, the appendices are encouraged to be completed in order to facilitate the review and approval of the forecasts submitted to the FAA. The templates for Appendix B and C have been compared to the EA forecast and provided in **Table 7-1** and **Table 7-2** respectively.

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Table 7-1 FAA TAF Forecast Comparison – Appendix B

A. Forecast Levels and Growth Rates	Activity Levels					Growth Rates			
	Base Year	Base Year + 1 year	Base Year + 5 years	Base Year + 10 years	Base Year + 15 years	Base Year to + 1 year	Base Year to + 5 years	Base Year to + 10 years	Base Year to + 15 years
	2020	2021	2025	2030	2035	2020-2021	2020-2025	2020-2030	2020-2035
Passenger Enplanements									
Air carrier	2,903,098	2,617,687	6,466,387	7,504,401		-9.8%	17.4%	10.0%	
Commuter	710,065	600,865	1,519,593	1,765,340		-15.4%	16.4%	9.5%	
Total Enplanements	***3,613,163***	***3,218,552***	***7,985,980***	***9,269,741***	-	***-10.9%***	***17.2%***	***9.9%***	
Operations									
Itinerant									
Air carrier	69,394	58,139	107,075	122,304		-16.2%	9.1%	5.8%	
Commuter/air taxi	35,200	39,456	71,542	79,593		12.1%	15.3%	8.5%	
Total Commercial Operations	***104,594***	***97,595***	***178,617***	***201,897***	-	***-6.7%***	***11.3%***	***6.8%***	
General aviation	51,412	51,155	55,434	60,821		-0.5%	1.5%	1.7%	
Military	3,236	3,236	3,236	3,236		0.0%	0.0%	0.0%	
Local									
General aviation	0	0	0	0					
Military	0	0	0	0					
Total Operations	***159,242***	***151,986***	***237,287***	***265,954***	-	***-4.6%***	***8.3%***	***5.3%***	
Instrument Operations									
Peak Hour Operations									
Cargo/Mail (Enplaned + Deplaned Tons)	107,302	108,800	130,243	153,719		1.4%	4.0%	3.7%	
Based Aircraft									
Single Engine (Nonjet)	99								
Multi Engine (Nonjet)	30								
Jet Engine	17								
Helicopter	6								
Other	23								
Total Based Aircraft	***175***								

Table 7-1 FAA TAF Forecast Comparison – Appendix B (continued)

B. Operational Factors	Activity Levels					Growth Rates			
	Base Year	Base Year + 1 year	Base Year + 5 years	Base Year + 10 years	Base Year + 15 years				
	2020	2021	2025	2030	2035				
Average aircraft size (seats)									
Air carrier	150.7	150.4	156.1	157.0					
Commuter	72.0	71.9	72.4	72.7					
Average enplaning load factor									
Air carrier	60.3%	65.1%	82.3%	83.4%					
Commuter	58.1%	67.3%	78.5%	80.8%					
GA operations per based aircraft	294								

Source: Landrum & Brown.

Table 7-2 FAA TAF Forecast Comparison – Appendix C

Segment	Forecast Year	Sponsor Forecast	2020 FAA TAF	% Variance Sponsor vs 2018 TAF
Passenger Enplanements				
Base year	2020	3,613,163	3,613,163	0.0%
Base year + 5 years	2025	7,985,980	7,329,278	9.0%
Base year + 10 years	2030	9,269,741	8,814,433	5.2%
Base year + 15 years	2035		10,066,356	n.a.
Commercial Operations*				
Base year	2020	104,594	104,594	0.0%
Base year + 5 years	2025	178,617	169,193	5.6%
Base year + 10 years	2030	201,897	200,286	0.8%
Base year + 15 years	2035		226,536	n.a.
Total Operations				
Base year	2020	159,242	159,242	0.0%
Base year + 5 years	2025	237,287	233,194	5.6%
Base year + 10 years	2030	265,954	264,470	0.8%
Base year + 15 years	2035		285,649	n.a.

Notes: Commercial operations includes operations by passenger airlines, all-cargo airlines, and air taxi operators.
Sources: Federal Aviation Administration, 2020 Terminal Area Forecast; Landrum & Brown.

Table 7-2 demonstrates the EA forecast is consistent with the TAF in both the five-year forecast period and the ten-year forecast period.

U.S. Department
of Transportation
**Federal Aviation
Administration**

Memphis Airports District Office
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Memphis, TN 38118

Phone: 901-322-8180

December 7, 2021

Mr. William C. Sandifer
Senior Vice President & COO
Raleigh-Durham Airport Authority
P.O. Box 80001
RDU Airport, North Carolina 27623

**RDU Runway 5L-23R Environmental Assessment – Aviation Activity Forecast Review
Raleigh-Durham International Airport
Raleigh, North Carolina**

Dear Mr. Sandifer:

We have reviewed the aviation activity forecast of aviation activity as presented in the RDU Envirornnmental Assesment Aviation Acitivity Forecast dated September 2021. Based on our review, our only comment conditional to the approval of the forecast is the caveat that the start of Airbus A350 service to Frankfurt is for conceptual planning only. This is due to no airline having indicated any firm plans to start this service. Please note that FAA approval for use in decision making is normally based on a specific commitment from an operating airline in writing.

This forecast was prepared at the same time as the evolving impacts of the COVID-19 public health emergency. Forecast approval is based on the methodology, data, and conclusions at the time the document was prepared. However, consideration of the impacts of the COVID-19 public health emergency on aviation activity is warranted to acknowledge the reduced confidence in growth projections using currently-available data.

Accordingly, FAA approval of this forecast does not consititue justification for future projects. Justification for future projects will be made based on activity levels at the time the project is requested for development. Documentaiton of actual activity levels meeting planning activity levels will be necessary to justiy AIP funding for eligible projects.

If you have any questions or need additional information regarding this matter, please feel free to contact me.

Sincerely,

L. Bernard Green
Airport Planner
Memphis Airport District Office

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Runway Length Analysis

Raleigh-Durham International Airport

September 2021

PREPARED FOR

Raleigh-Durham Airport Authority

PRESENTED BY

Landrum & Brown, Incorporated

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1 Introduction

The following runway length analysis was conducted in order to understand the range of runway length needed for the proposed Replacement 5L/23R project at the Raleigh-Durham International Airport (RDU or Airport). This runway length analysis serves as the basis for the development of runway alternatives formulated for screening and evaluation in the Environmental Assessment (EA). For an alternative to meet the purpose and need of the EA, it must meet the needed runway length range demonstrated in this analysis.

The runway length is established in accordance with the take-off and landing runway length requirements for the most demanding aircraft type(s) contained in the RDU Aviation Activity Forecast.[1] The existing and future aircraft fleet mix was used to evaluate the runway length needs. The use of this existing and projected future fleet ensures that the runway system will be capable of accommodating the aircraft users of the Airport through the forecast range. Without adequate runway length configured to serve the current and anticipated aircraft fleet mix, the existing capacity of the overall airfield may be compromised.

This runway length analysis provides both takeoff and landing distances needed. The runway length requirements for aircraft takeoffs typically exceed the requirements for aircraft landings. Therefore, the ability to operate a particular aircraft type at an airport is typically limited by the available departure length of its runways.

2 Takeoff Length Requirements

Takeoff length requirements were calculated following the recommended guidance in Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5325-4B, *Runway Length Requirements for Airport Design*. These guidelines establish a five-step process needed to determine an adequate runway length recommendation. These guidelines establish the process and considerations to assess existing runways and determine adequate runway length recommendations at a planning level. It should be noted that the results of these calculations can differ from more detailed analysis that aircraft operators are capable of performing. The aircraft operators' analysis usually are more detailed calculations based on specific aircraft operational configurations and specific airline procedures.

2.1 Step #1 Identify Critical Design Airplanes

The first step according to FAA AC 150/5325-4B is to identify the list of critical design airplanes that will make regular use of the proposed runway for an established planning period of at least five years. The aircraft types that are currently operating and are projected to operate at an airport are critical components to determining runway length requirements. The passenger and

[1] Raleigh-Durham Airport Authority. Aviation Activity Forecast, Preliminary Draft May 2021.

freighter aircraft types that are currently operating or are forecast to operate at RDU and have at least 500 or more annual itinerant operations (landings and takeoffs are considered as separate operations) are listed in **Table 1, *Critical Design Airplanes with 500 Operations***.

TABLE 1 CRITICAL DESIGN AIRPLANES WITH 500 ANNUAL OPERATIONS

Aircraft	2020 (Existing) Annual Operations	2028 (Forecast) Annual Operations	2033 (Forecast) Annual Operations
Airbus A220-300	0	17,948	20,392
Airbus A300-600	862	612	522
Airbus A319	4,466	22,778	25,846
Airbus A320	8,022	18,314	20,748
Airbus A321	1,792	4,114	4,640
Airbus A330-900	0	632	632
Airbus A350-900	0	0	730
Boeing 737-700	9,132	11,342	12,788
Boeing 737-800	9,914	28,148	31,786
Boeing 737-900	2,008	8,254	9,308
Boeing 767-300	2,134	3,336	3,980
Boeing 787-900	0	730	730
Canadair Regional Jet 550	0	2,950	3,286
Canadair Regional Jet 700	2,444	5,936	6,608
Canadair Regional Jet 900	7,734	12,450	13,878
Cessna 208	2,818	3,492	3,964
Embraer E170	2,038	10,390	11,566
Embraer E175	9,192	31,710	35,342

Source: RDU Aviation Activity Forecast, Preliminary Draft May 2021

2.2 Step #2 Identify Critical Design Airplanes that Require Longest Runway Lengths

The purpose of Step #2 is to identify the airplanes that will require the longest runway lengths at maximum certificated takeoff weight (MTOW) as a baseline for establishing runway length requirements per FAA AC150/5325-4B. The aircraft types from Table 1 were reviewed and aircraft that had the greatest MTOW are provided in **Table 2, *Critical Design Airplanes MTOW***.

TABLE 2 CRITICAL DESIGN AIRPLANES MTOW

Aircraft	Aircraft Approach Category (AAC) Airplane Design Group (ADG)	Maximum Takeoff Weight (MTOW) in Pounds (lbs)
Airbus A220-300	C III	156,307
Airbus A300-600	C IV	375,888
Airbus A319	C III	166,449
Airbus A320	C III	171,961
Airbus A321	C III	206,132
Airbus A330-900	D V	533,519
Airbus A350-900	D V	617,295
Boeing 737-700	C III	154,500
Boeing 737-800	D III	174,200
Boeing 737-900	D III	174,200
Boeing 767-300	C IV	350,000
Boeing 787-900	D V	560,000

Source: A330 Airbus Airport Planning Manual, June 2020. A350-900/-1000 Airbus Airport Planning Manual, April 2021. B737 Boeing Airplane Characteristics for Airport Planning Manual, September 2020. B767 Boeing Airplane Characteristics for Airport Planning Manual, May 2011. B787-9/-9/-10 Boeing Airplane Characteristics for Airport Planning Manual, March 2018. Great Circle Mapper, 2021. AC 150/5300-13A, and Landrum & Brown analysis, 2021.

2.3 Step #3 Determine Method for Establishing Recommended Runway Length

This step compares the aircraft identified in Step #2 with Table 1-1 in FAA AC 150/5325-4B. All of the potential aircraft listed in Table 2 are greater than 60,000 pounds. Therefore, runway length requirements should be determined using the airplane manufacturers Airport Planning Manuals (APMs) for specific individual airplanes.

2.3.1 Aircraft / Destination Used for Runway Length Analysis

In order to determine specific individual airplanes for detailed analysis, the critical aircraft and forecast document were reviewed to determine the aircraft's furthest destinations that made up at least 500 annual operations. The analysis was paired down to six aircraft that had the potential to be determined the critical aircraft for runway length at RDU. The aircraft analyzed in this analysis are both narrowbody passenger aircraft traveling domestically to the west coast and widebody passenger aircraft traveling to international European destinations. Domestically, Alaska Airlines currently operates a Boeing 737-900 to Seattle, Washington. In addition, Delta Airlines operates a Boeing 737-800 to Los Angeles International Airport from RDU.

Internationally, the Boeing 767-300 to Paris Charles de Gaulle Airport (CDG) is expected to be in service until 2025 and will then be replaced with the A330-900 on this route. The Boeing 787-900 aircraft is expected to replace the B777-200 to London Heathrow Airport (LHR) in the next couple of years and was analyzed in the runway length analysis. However, the B777-200 was not included due to its near-term retirement in the fleet and due to its aircraft characteristics would likely not be the critical aircraft to determine runway length for RDU. Finally, as assumed in the forecast, transatlantic service is expected to begin to Frankfort Airport (FRA) with the A350-900 by 2026 and was incorporated into the runway length analysis. The specific aircraft and the distance to those destinations in nautical miles are provided in **Table 3, *Aircraft / Destination Used for Runway Length Analysis***.

TABLE 3 AIRCRAFT / DESTINATION USED FOR RUNWAY LENGTH ANALYSIS

Aircraft	Type	Operation	Furthest Destination	Distance from RDU (NM)[1]
Airbus 350-900 (A350-900)	International Passenger	Forecast	FRA	3,717
Boeing 767-300 (B767-300)	International Passenger	Existing	CDG	3,521
Airbus 330-900 (A330-900)	International Passenger	Forecast	CDG	3,521
Boeing 787-900 (B787-900)	International Passenger	Existing	LHR	3,364
Boeing 737-800 Winglets (B737-800W)	Domestic Passenger	Existing	LAX	1,945
Boeing 737-900 Extended Range (B737-900ER)	Domestic Passenger	Existing	SEA	2,046

[1] CDG- Paris Charles de Gaulle Airport, FRA- Frankfort Airport, LAX- Los Angeles International Airport, LHR- London Heathrow Airport, SEA- Seattle-Tacoma International Airport

Note: NM stands for nautical mile.

Source: RDU Aviation Activity Forecast, Preliminary Draft May 2021

2.3.2 Airport Planning Manuals (APMs)

Runway takeoff length requirements based on airplane manufacturers APMs were calculated using a payload/range analysis with 100 percent payload, where possible, to the furthest destination for each aircraft in the fleet mix.

2.3.3 Density Altitude

As defined by the FAA, density altitude is pressure altitude corrected for nonstandard temperature. It is a function of the combination of an airport's elevation and temperature. The higher the elevation of the Airport, the less efficient an aircraft wing is at producing lift, thus requiring higher airspeeds to produce a comparable amount of lift. This creates higher density altitude. Because higher density altitude decreases an aircraft's operational performance, longer runway distances are required for takeoffs and landings at airports with a greater elevation and/or in hotter climates.

2.3.3.1 Airfield Elevation

Airfield elevation is used as an input factor on the takeoff charts from the aircraft manufacturers' airport planning manuals to determine accurate takeoff and landing requirements. The Airport elevation at RDU is 435.2 feet above Mean Sea Level (MSL).[2]

2.3.3.2 Temperature

The aircraft manufacturers' manuals contain charts to calculate takeoff runway length requirements based on temperature. Takeoff length requirements may be calculated based on standard day (defined as 59 degrees Fahrenheit or 15 degrees Celsius) or a hot day . The hot day charts in the aircraft manufacturers' manuals vary the conditions on what they consider a hot day. Hot day charts can vary by aircraft manufacturer and sometimes even by aircraft type. Most Airbus and Boeing airport planning manuals offer one "hot day" chart, which utilizes 86 degrees Fahrenheit. However, "hot day" charts can vary from 70 degrees Fahrenheit to over 100 degrees Fahrenheit. Some manuals may include more than one "hot day" chart too.

The determination of which temperature chart to use depends upon the average or typical weather conditions for a particular airport. FAA guidance prescribes the use of an airport's mean-max temperature for runway length calculations, which would indicate the use of the "hot day" charts, where possible. The mean-max temperature is defined as the average daily maximum temperature of the hottest month. The mean daily maximum temperature at RDU is 90.8 degrees Fahrenheit or 33 degrees Celsius and is representative of the month of July.[3]

FAA AC 150/5325-4B states that takeoff length calculations for a "hot day" analysis must be within three degrees Fahrenheit of the "hot day" charts available in the Airport Planning Manuals. The B767-300 airport planning manual offered a 90-degree Fahrenheit "hot day" chart so that was used as the preferred method of temperature adjustment in this analysis. The only "hot day" charts for the A330-900, A350-900, B737-800W, B737-900ER, and B787-900 are 86-degree Fahrenheit charts. With a mean daily maximum temperature of 90.8 degrees Fahrenheit, this does not fall within the 3-degree window of acceptability according to the FAA's AC. The AC states that if the aircraft manufacturers do not offer charts within the 3-degree window for takeoff length analysis, the consultant should reach out to the manufacturer to determine the takeoff length needed.

The consulting team reached out to both Boeing[4] and Airbus[5] in regard to "hot day" charts and have not received any further analysis from the manufacturers at this time. This has been

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2 FAA Aeronautical Information Services-Airport Data, 2021.

3 Airport mean-max temperature defined by the National Oceanic & Atmospheric Administration (NOAA), Summary of Daily Normals 1991-2020, July.

4 Evanicio Costa, Airport Compatibility Engineer, Boeing, RE: Performance charts for the B787-9 and B777X at temperatures higher than ISA+15C, Email June 8th, 2021.

5 Olivier Chauvet, Airbus, RE: aircraft performance data, Email dated June 8. 2021.

common with other runway length analyses conducted and therefore, a temperature adjustment was used for the aircraft under consideration. ICAO Document 9157, Aerodrome Design Manual, Part 1- Runways, Fourth Edition 2020 was used to assist in the calculation of the hot day runway length requirements for the A330-900, A350-900, B737-800W, B737-900ER, and B787-900. ICAO states that the runway length determined on a standard day chart may be increased at the rate of 1 percent for every 1 degree Celsius above the standard atmospheric condition (15 degrees Celsius or 59 degrees Fahrenheit). Using the daily maximum temperature at RDU of 33 degrees Celsius, this resulted in a difference of 18 degrees Celsius or an 18 percent increase in runway length from the standard day chart.

2.3.4 A330-900

The A330-900 APM provides a payload range and takeoff length chart at International Standard Atmosphere (ISA)[6]. Using the payload range chart, it was determined that the A330-900 traveling to CDG had a takeoff weight (TOW) of 515,000 pounds. The A330-900 payload range chart is provided in **Figure 2**. The A330-900 would be able to depart with maximum payload to CDG. Using the takeoff length chart and the TOW, it was determined the A330-900 needed 8,200 feet for takeoff length. The takeoff length was then revised to 9,656 feet for takeoff length due to ICAO temperature adjustment. The A330-900 takeoff length chart is provided in **Figure 3**.

2.3.5 Boeing 767-300

The Boeing 767-300 APM provides charts at the standard day (59 F) + 31 F temperature. Using the payload range chart, it was determined that the Boeing 767-300 traveling to CDG had a MTOW of 350,000 pounds. The Boeing 767-300 payload range chart is provided in **Figure 4**. The Boeing 767-300 payload must be reduced due to the structural capabilities of this aircraft flying from RDU to CDG. The B767-300 can only take 88% of its total payload capability, sacrificing 12% of its payload in order to fly to CDG, regardless of the amount runway length available for takeoff. Using the takeoff length chart and the TOW resulted in the Boeing 767-300 needing 8,400 feet for takeoff length. The Boeing 767-300 takeoff length chart is provided in **Figure 5**. Because the B767-300 airport planning manual offered a 90-degree Fahrenheit “hot day” chart no temperature adjustment was needed.

2.3.6 Boeing 787-900

The Boeing 787-900 APM provides charts at the standard day temperature. Using the payload range chart, it was determined that the Boeing 787-900 traveling to LHR had a TOW of 502,000 pounds. The Boeing 787-900 payload range chart is provided in **Figure 6**. The Boeing 787-900 would be able to depart with maximum payload to LHR. Using the takeoff length chart and

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Karl Czekus, Aircraft Performance Service Development Manager, NAVBLUE, RE: Performance data for the A330-900 and the A350-900 at temperatures higher than ISA+15C Email June 8th, 2021.

Charles Thornberry, Head of Airport & Airspace Sales at NAVBLUE. Phone conversation June 16, 2021. Airbus and NAVBLUE do not share performance data for free.

[6] ISA represents the standard sea level pressure/temperature of 59 degrees Fahrenheit.

TOW, the Boeing 787-900 needed 7,800 feet for takeoff length. The takeoff length then was revised to 9,179 feet for takeoff length due to ICAO temperature adjustment. The 787-900 takeoff length chart is provided in **Figure 7**.

2.3.7 A350-900

The A350-900 APM provides charts at the ISA. Using the payload range chart, it was determined that the A350-900 traveling to FRA had a TOW of 532,212 pounds. The A350-900 payload range chart is provided in **Figure 8**. The A350-900 would be able to depart with maximum payload to FRA. Using the takeoff length chart, the Boeing A350-900 needed 6,890 feet for takeoff length. The takeoff length was then revised to 8,110 feet for takeoff length due to ICAO temperature adjustment. The A350-900 takeoff length chart is provided in **Figure 9**.

2.3.8 Boeing 737-800W

The Boeing 737-800W APM provides charts at the standard day temperature. Using the payload range chart, it was determined that the Boeing 737-800W traveling to LAX had a TOW of 173,000 pounds. The Boeing 737-800W payload range chart is provided in **Figure 10**. The Boeing 737-800W would be able to depart with maximum payload to LAX. Using the takeoff length chart, the Boeing 737-800W needed 7,850 feet for takeoff length. The takeoff length then was revised to 9,242 feet for takeoff length due to ICAO temperature adjustment. The Boeing 737-800W takeoff length chart is provided in **Figure 11**.

2.3.9 Boeing 737-900ERW

The Boeing 737-900ERW APM provides charts at the standard day temperature. Using the payload range chart, it was determined that the Boeing 737-900ERW traveling to SEA had a TOW of 187,000 pounds. The Boeing 737-900ERW payload range chart is provided in **Figure 12**. The Boeing 737-900ERW must sacrifice payload due to the critical destination distance from RDU to SEA. Further destinations require more fuel, which in turn, may require trading payload weight for more fuel. The B737-900ER can only take 92% of its total payload capability (includes both passengers and belly cargo), sacrificing 8% of its payload in order to fly to SEA. This payload hit is a direct representation to the physical limits of the aircraft regardless of the amount of runway length available for takeoff. Using the ISA takeoff length chart from the manual, the Boeing 737-900ERW needed 10,100 feet for takeoff length. However, the takeoff length then was revised to 11,886 feet for takeoff length using an ICAO temperature adjustment to account for “hot day” conditions. The B737-900ERW takeoff length chart is provided in **Figure 13**.

2.3.10 Summary of Step #3

The standard day and hot day takeoff length requirements to the furthest destination for each aircraft are presented in **Table 4, *Takeoff Length Requirements***.

TABLE 4 TAKEOFF LENGTH REQUIREMENTS

Aircraft[1]	Furthest Destination For this Aircraft Type[2]	Standard Day Takeoff Length Requirement (feet)	Hot Day Takeoff Length Requirement (feet)
A350-900	FRA	6,890	8,110
B767-300	CDG	N/A[3]	8,400
B787-900	LHR	7,800	9,179
B737-800W	LAX	7,850	9,242
A330-900	CDG	8,200	9,656
B737-900 ERW	SEA	10,100	11,886

1 ICAO Document 9157, Aerodrome Design Manual, Part 1- Runways, Fourth Edition 2020 was used to calculate hot day runway length requirements for the A330-900, A350-900, B737-800W, B737-900ER, and B787-900.

2 CDG- Paris Charles de Gaulle Airport, FRA- Frankfort Airport, LAX- Los Angeles International Airport, LHR- London Heathrow Airport, SEA- Seattle-Tacoma International Airport

3 N/A stands for not applicable. The B767-300 planning manual contained a 90-degree Fahrenheit hot-day chart that meets FAA AC 150/5325-4B for determining hot day takeoff lengths at RDU since the hot day temperature at RDU is 90.8 (within 3 degrees of the manufacturers hot-day chart).

2.4 Step #4 Select the Recommended Runway Length

All of the takeoff length requirements identified in Table 4 were selected to proceed to Step #5.

2.5 Step #5 Adjustments

Step #5 adds any necessary adjustment to the runway lengths to obtain a final recommended runway length range.

2.5.1 Runway Slope

The runway length charts in the aircraft manufacturers manuals are based on a runway slope of zero. An aircraft taking off on an uphill gradient requires more runway length than it does on a flat or downhill slope. FAA AC 5325-4B recommends an adjustment for non-zero effective runway gradients.[7] At RDU, there is a positive slope on existing Runway 05L takeoffs, an elevation change of nearly 41.8 feet (existing Runway 05L: 366.8 feet and existing Runway 23R: 408.6 feet). For this reason and per the FAA AC 5325-4B, 418 feet was added to the required takeoff length analysis for each aircraft analyzed. This adjustment for slope was provided if the proposed Replacement 5L/23R project would need to have the same slope as the existing Runway 5L/23R. In addition, FAA AC 150/5325-4B states that analyses should round lengths of 30 feet and over to the next 100-foot interval.

2.6 Summary of Takeoff Length Requirements

The takeoff length requirements adjusted for runway slope and rounded are presented in **Table 5, *Adjusted Takeoff Length Requirements***. Takeoff length requirements ranged from 8,500 feet (A350-900) to 12,300 feet (B737-900 ERW).

TABLE 5 ADJUSTED TAKEOFF LENGTH REQUIREMENTS

Aircraft	Furthest Destination[1]	Hot Day Takeoff Length Requirement (with slope adjustment in feet)[2, 3, 4]	Rounded Hot Day Takeoff Length Requirement (with slope adjustment in feet)[2, 3,]
A350-900	FRA	8,528	8,500
B767-300	CDG	8,818	8,800
B787-900	LHR	9,597	9,600
B737-800 W	LAX	9,660	9,700
A330-900	CDG	10,074	10,100
B737-900 ERW	SEA	12,304	12,300

1 CDG- Paris Charles de Gaulle Airport, FRA- Frankfort Airport, LAX- Los Angeles International Airport, LHR- London Heathrow Airport, SEA- Seattle-Tacoma International Airport

2 AC 150/5325-4B, Runway Length Requirements for Airport Design, 2005 states that Runway lengths are increased at the rate of 10 feet (3 meters) for each foot (0.3 meters) of elevation difference between the high and low points of the runway centerline.

3 ICAO Document 9157, Aerodrome Design Manual, Part 1- Runways, Fourth Edition 2020 was used to calculate hot day runway length requirements for the A330-900, A350-900, B737-800W, B737-900ER, and B787-900.

Source: A330 Airbus Airport Planning Manual, June 2020. A350-900/-1000 Airbus Airport Planning Manual, April 2021. B737 Boeing Airplane Characteristics for Airport Planning Manual, September 2020. B767 Boeing

7 AC 150/5325-4B states that runway lengths are increased at the rate of 10 feet (3 meters) for each foot (0.3 meters) of elevation difference between the high and low points of the runway centerline.

Airplane Characteristics for Airport Planning Manual, May 2011. B787-9/-9/-10 Boeing Airplane Characteristics for Airport Planning Manual, March 2018. Great Circle Mapper, 2021. Landrum & Brown analysis, 2021.

3 Landing Length Requirements

Runways that are subject to frequent surface contaminants such as rain and snow often require longer landing lengths than dry surfaces. Some aircraft manufacturers have designated landing length charts for contaminated surfaces, while others do not. Boeing landing charts offer contaminated landing length charts, while Airbus did not. In this analysis, 15 percent was added to each dry landing length calculation where a contaminated chart did not exist per section 508 of FAA AC 5325-4B.

The MD-11 aircraft did not contain at least 500 annual operations per year. However, this type of aircraft is currently being operated by UPS at RDU and in 2020 there were 482 annual operations. Because the annual number of operations were very close to the threshold of 500, it was included in this analysis.

3.1 Summary of Landing Length Requirements

The landing length requirements are presented in **Table 6, *Landing Length Requirements***. Landing length requirements ranged from 6,100 feet (B767-300) to 9,600 feet (MD-11). As stated, the runway length requirements for aircraft takeoffs exceed the requirements for aircraft landings.

TABLE 6 LANDING LENGTH REQUIREMENTS

Aircraft	Maximum Landing Weight (lbs)	Landing Length (feet) Dry Conditions	Landing Length (feet) Wet Conditions
Airbus A350-900	456,357	6,600	7,600
Boeing 767-300	300,000	5,300	6,100
Boeing 787-900	425,000	6,200	7,200
B737-800 W	147,300	5,650	6,500
Airbus 330-900	421,083	6,500	7,500
B737-900 ERW	146,300	5,800	6,700
MD-11	471,500	8,300	9,600

[1] Landing length requirements were calculated using contaminated runway input (wet charts where available and additional 15 percent where only dry charts were available).

Note: lbs stands for pounds.

Source: A330 Airbus Airport Planning Manual, June 2020. A350-900/-1000 Airbus Airport Planning Manual, April 2021. B737 Boeing Airplane Characteristics for Airport Planning Manual, September 2020. B767 Boeing Airplane Characteristics for Airport Planning Manual, May 2011. B787-9/-9/-10 Boeing Airplane

Characteristics for Airport Planning Manual, March 2018. Great Circle Mapper, 2021. Landrum & Brown analysis, 2021.

4 Airline Coordination

This runway length analysis was provided to airlines operating at RDU for their review and comment. All comments received from the airlines were considered in this analysis. **Table 7**, ***Airline Comments*** provides a summary of the comments received.

TABLE 7 AIRLINE COMMENTS

Airline	Comment Date	Summary of Comment
Alaska Airlines	August 12, 2021	It bears emphasis that the obstacles beyond the runway are critical to whether airport users actually benefit from increased runway length. An analysis that ignores this could lead to significant wasted cost and environmental impact. However, if we assume that obstacles off the new runway allow us to use the length built, then we do benefit from a runway longer than the existing 10,000 feet up to a length of 11,600 feet. The 12,300-foot design length in the draft analysis is not disadvantageous, especially if it forces the runway thresholds further from obstacles, but it's unnecessary if the obstacles allow use of 11,600 feet. We understand this analysis is the basis for developing alternatives and noted the statement that obstacle limitations and OEI planning would be taken into account during the final design of the project. Given that, we support the analysis at this stage of the planning process and look forward to working with the Airport as you develop and refine alternatives.
American Airlines	June 22, 2021	No comments from American Airlines.
Delta Airlines	June 25, 2021	Delta reviewed RDU's presentation and has no outstanding questions or concerns with the analysis or a 10,000-foot replacement runway. We evaluated a few fleet/route combinations that did not work on a 10,000-foot runway, but those instances were limited and in the most material case the combination was unlikely to be scheduled by our network planning team.
Frontier Airlines	June 22, 2021	Frontier has reviewed the study and done our analysis based on stage length and aircraft type. We have found no impact on payload or performance. Having said that Frontier does agree with United's assessment that the study does not address obstacle clearance requirements, specifically OEI (One Engine Inoperative). The takeoff flight path must meet

Airline	Comment Date	Summary of Comment
		specified obstacle clearance requirements in the event of an engine failure. Payload is only part of the equation when considering runway suitability. Ensuring a safe departure path is available that meets all regulatory and safety requirements should be considered. These two factors will provide the most optimum maximum takeoff weight.
Southwest Airlines	August 18, 2021	Southwest's engineers reviewed and had no comments.
United Airlines	June 7, 2021	I took a quick look at our 763 performance on the current 05L, assuming calm winds, standard day and 30C/86F. MTOW of the 767-300 is limited by obstacles for the current runway which is of 10,000 ft length. I am not certain if there is an intent to study the obstacles that must be cleared on takeoff, and which could control the takeoff weight (depending on temperature/pressure/wind), but it could affect the other aircraft. For our 787-9, we are limited by the takeoff field length. In either case, I don't think there will be a maximum passenger payload issue but did want to make sure there was an understanding of obstacle clearance and that each carrier, although following one of two sets of rules, will have internal operational restrictions that may result in different a different max takeoff weight.
United Airlines	June 28, 2021	The study ignores obstacle clearance requirements under 14 CFR 121. According to the study, a 767-300 can takeoff in 8800 ft of runway length at an adequate weight to get to Europe considering a structural limited takeoff. On the United side, the current 05L runway is somewhat longer than 8800 ft, and even at 20C, does not support a full structural takeoff weight. I did not calculate the payload but want to make sure the design accounts for the reduced capability vis a vis obstacle limitation.

4.1 Obstruction Analysis / One Engine Out Analysis Considerations

This runway length analysis serves as the basis for the development of runway alternatives formulated for screening and evaluation in the EA. This runway length analysis does not take into account any displaced landing thresholds to address obstruction issues or to comply with runway safety area, object free area, or runway protection zone criteria. At this planning level, obstacle limitations using obstacle clearance limited takeoff weights per AC Guidance 150/5325-4B are not accounted for. Obstacle limitations and One Engine Inoperative (OEI) planning would be taken into account during the final design of the project.

5 Summary of Assumptions

This runway length analysis serves as the basis for the development of runway alternatives formulated for screening and evaluation in the EA. The following summarizes the assumptions used in this analysis.

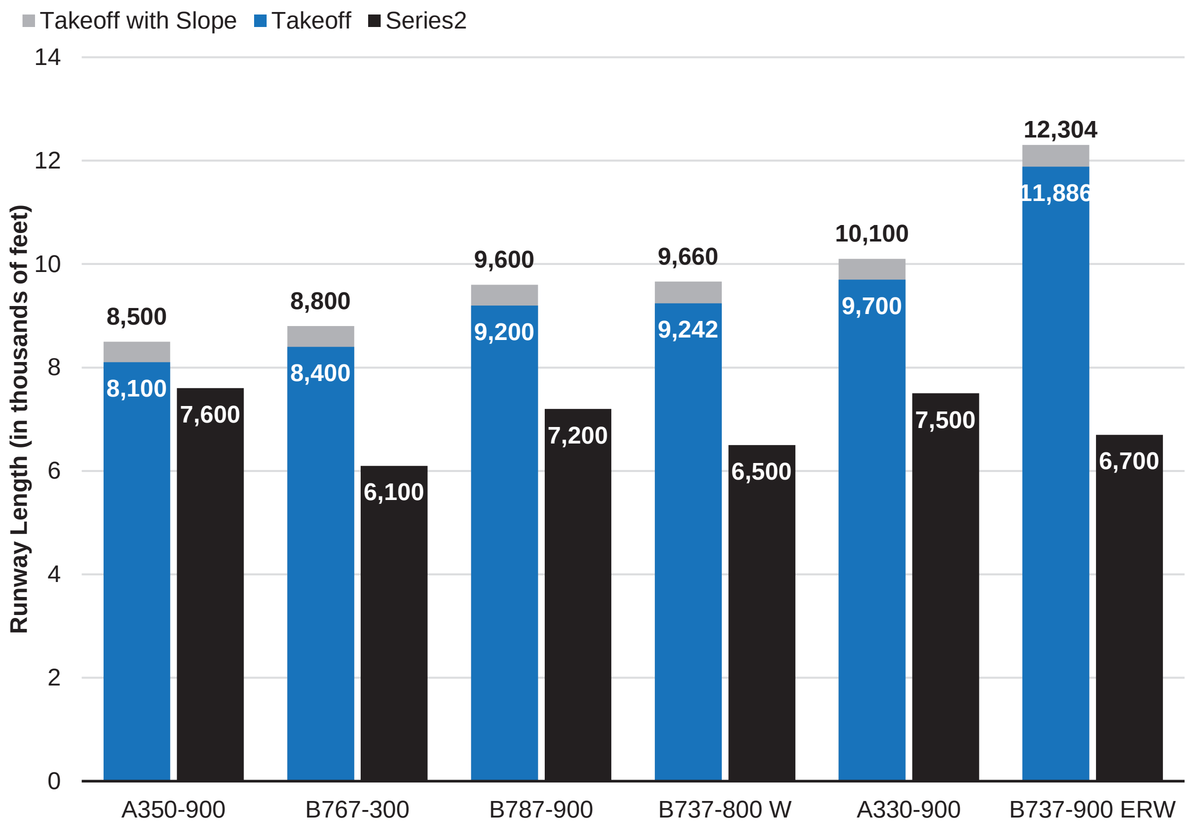
- Takeoff length requirements were calculated following the recommended guidance in FAA AC 150/5325-4B.
- This runway length analysis does not consider any displaced landing thresholds to address obstruction issues or to comply with runway safety area, object free area, or runway protection zone criteria.
- A temperature adjustment per ICAO was used because the Boeing and Airbus Airport Planning Manuals do not offer takeoff length charts for 90.8 degrees Fahrenheit and correspondence was not returned from the manufacturers as requested in FAA AC 150/5325-4B, *Runway Length Requirements for Airport Design.*
- At RDU, there is a positive slope on existing Runway 05L takeoffs, an elevation change of nearly 41.8 feet (existing Runway 05L: 366.8 feet and existing Runway 23R: 408.6 feet) therefore 418 feet was added to the required takeoff length analysis for each aircraft analyzed.
- 15 percent was added to each dry landing length calculation where a contaminated chart did not exist per FAA AC 5325-4B, *Runway Length Requirements for Airport Design*
- Runway length requirements for aircraft takeoffs exceed the requirements for aircraft landings. Landing length requirements ranged from 6,100 feet (B767-300) to 9,600 feet (MD-11).
- Per FAA AC 150/5325-4B, *Runway Length Requirements for Airport Design* runway lengths were rounded to the next 100-foot interval if greater than 30 feet.

6 Recommended Runway Length Range

All takeoff and landing lengths are summarized in **Figure 1**, ***Summarized Runway Length Requirements***. The critical aircraft for runway length at RDU is the B737-900ERW traveling to SEA per FAA AC 150/5000-17, Critical Aircraft and Regular Use Determination. While the runway length requirement for the B737-900 ERW to Seattle is recommended at 12,300 feet, Alaska Airlines is currently operating this aircraft to this destination on the existing 10,000-foot runway at RDU. Therefore, for an alternative to meet the purpose and need of the EA, it must have a runway takeoff length of between 10,000 feet to 12,300 feet to act as the primary runway at RDU.

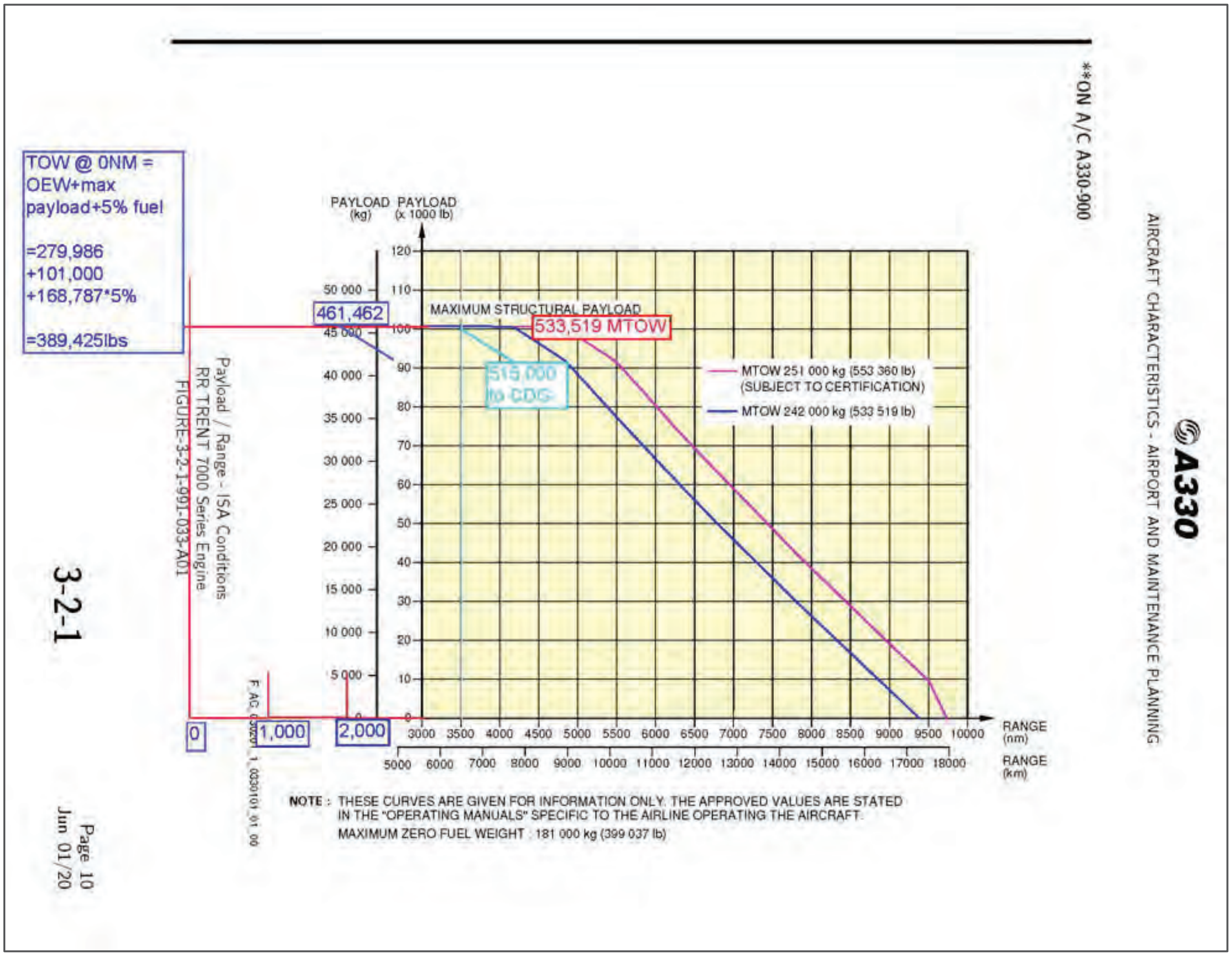
On a standard day, it appears that the B737-900ERW can operate on the existing runway without restrictions. Additionally, on a hot day a B737-900ERW traveling to its furthest destination in the forecast fleet, would still be able to take 90 to 95% of their passenger load without additional belly cargo. This equates to a passenger seating sacrifice of 10 to 15 seats assuming the current Alaska Airlines B737-900ER seating configurations.

FIGURE 1 SUMMARI ED RUNWAY LENGTH REQUIREMENTS



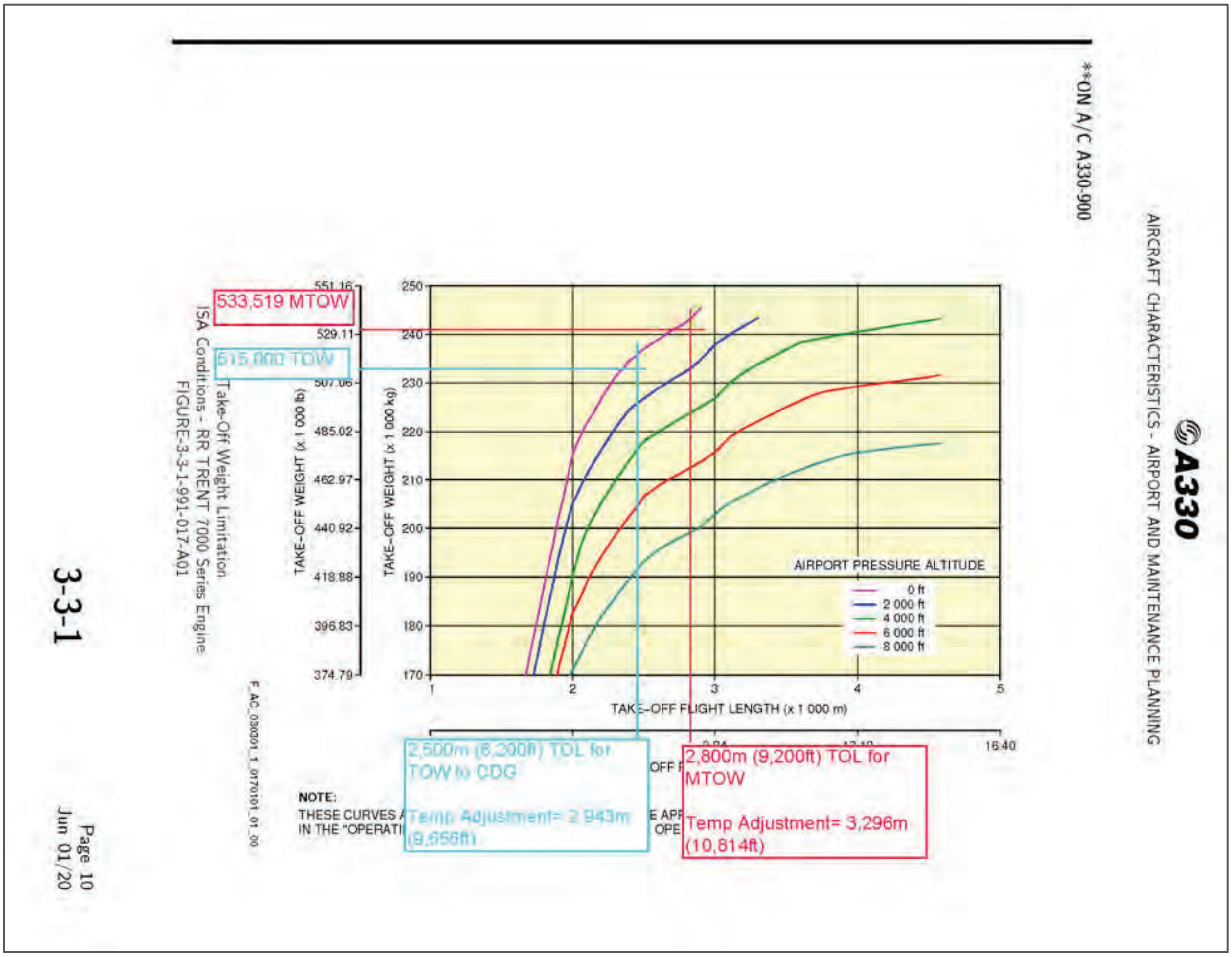
Source: Landrum & Brown analysis, 2021.

FIGURE 2 A330-900 PAYLOAD-RANGE CHART



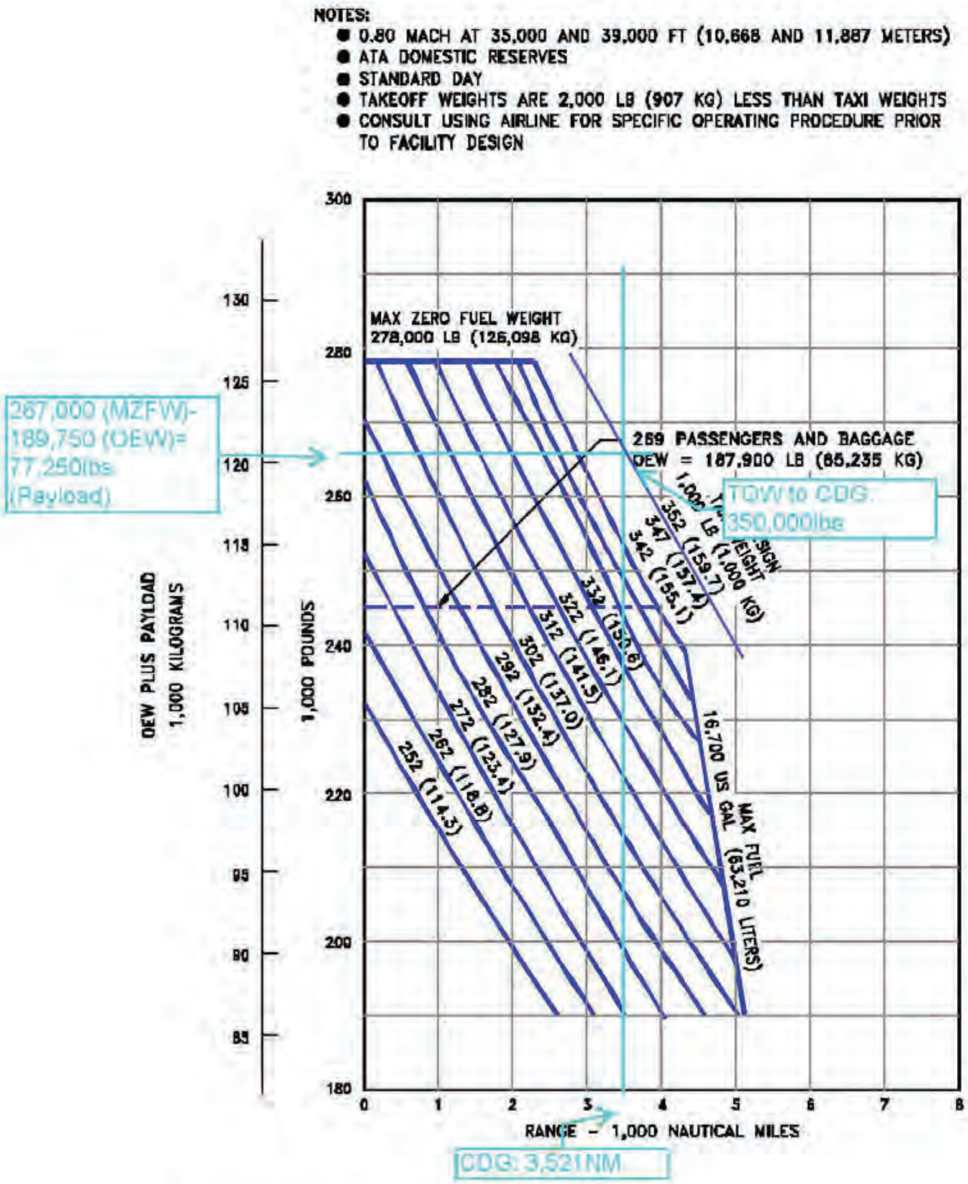
Source: A330 Airbus Airport Planning Manual, June 2020. Landrum & Brown analysis, 2021.

FIGURE 3 A330-900 TAKEOFF LENGTH CHART



Source: A330 Airbus Airport Planning Manual, June 2020. Landrum & Brown analysis, 2021.

FIGURE 4 B767-300 PAYLOAD-RANGE CHART



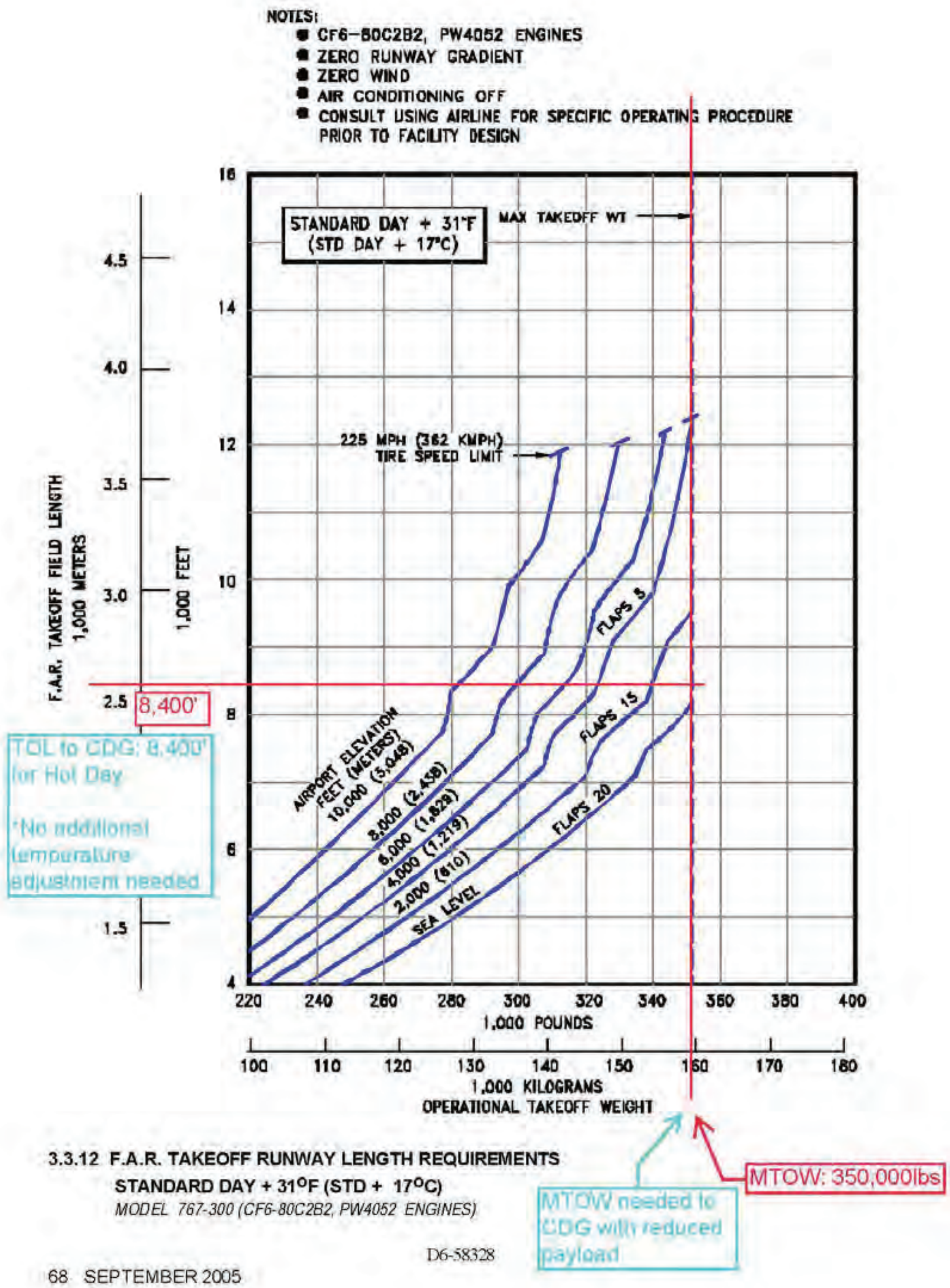
3.2.3 PAYLOAD/RANGE FOR LONG-RANGE CRUISE
MODEL 767-300

D6-58328

SEPTEMBER 2005 49

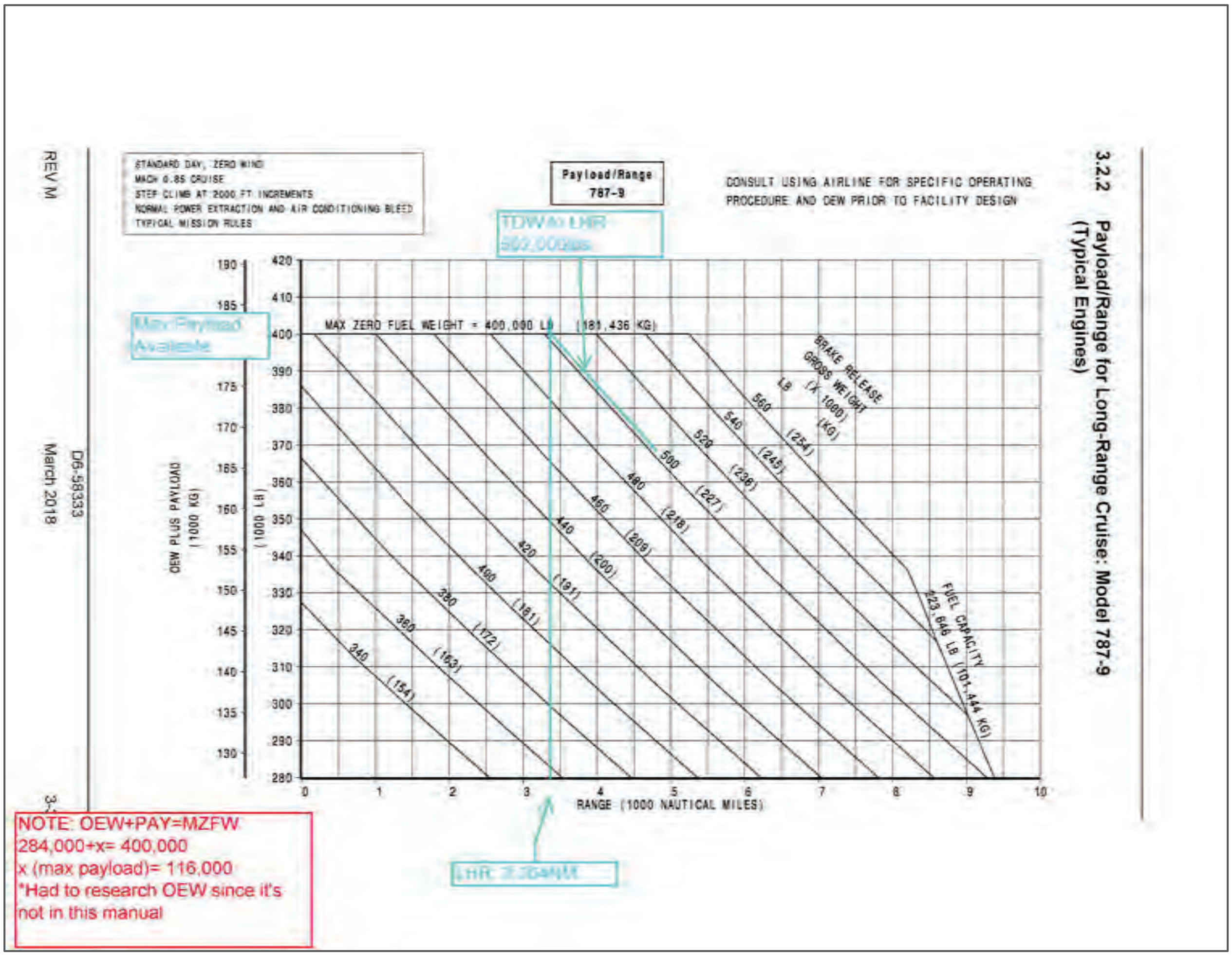
Source: B767 Boeing Airplane Characteristics for Airport Planning Manual, May 2011. Landrum & Brown analysis, 2021.

FIGURE 5 B767-300 TAKEOFF LENGTH CHART



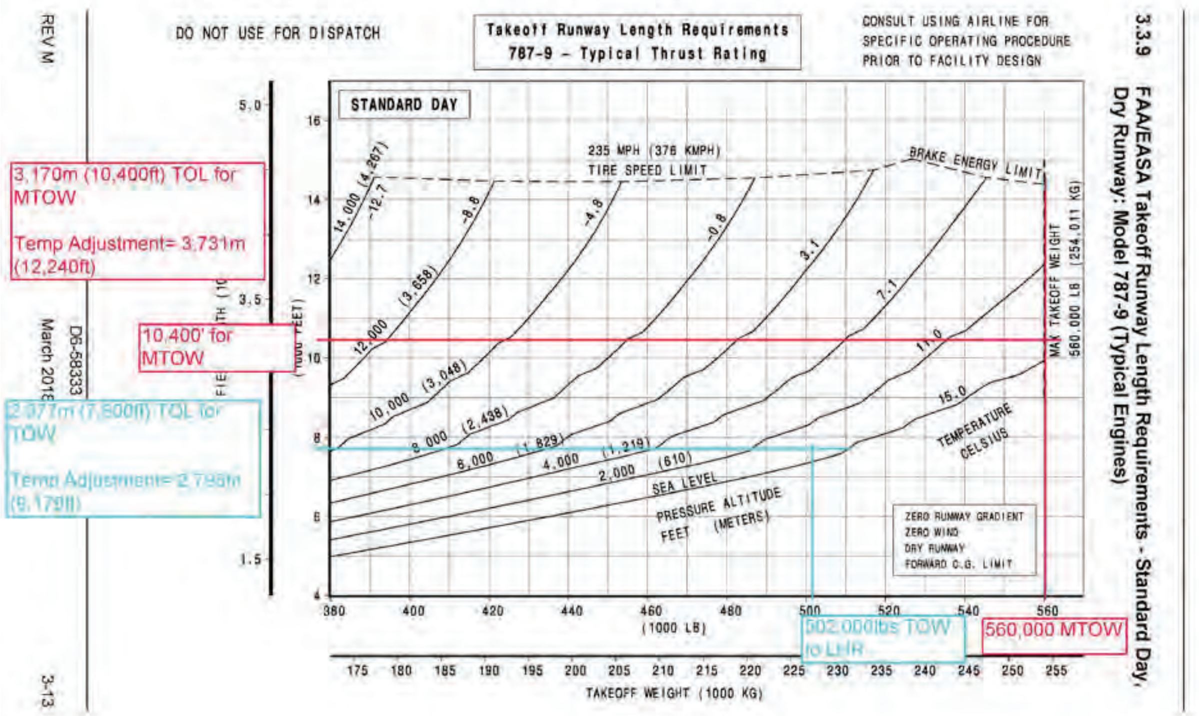
Source: B767 Boeing Airplane Characteristics for Airport Planning Manual, May 2011. Landrum & Brown analysis, 2021.

FIGURE 6 B787-900 PAYLOAD-RANGE CHART



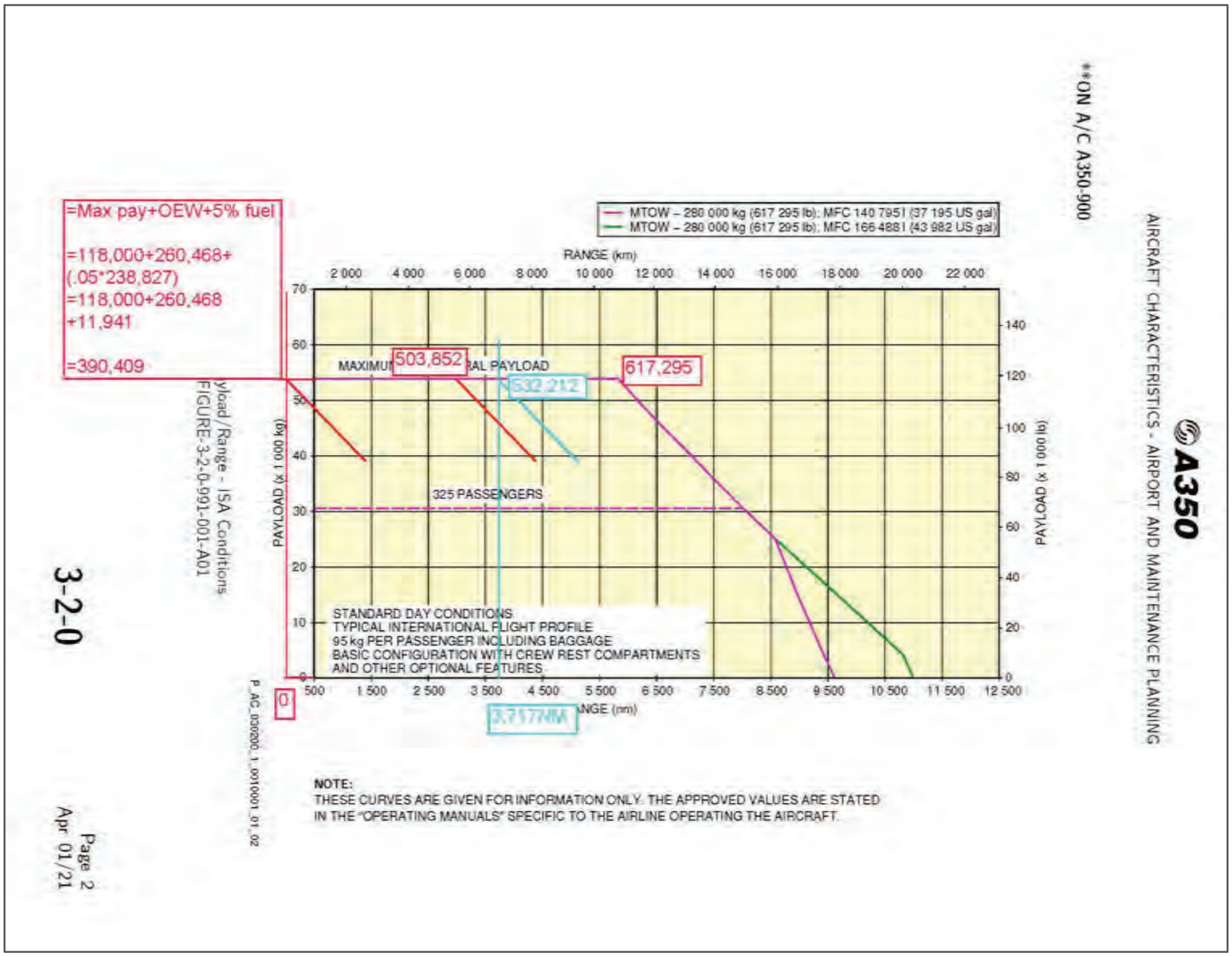
Source: B787-9/-9/-10 Boeing Airplane Characteristics for Airport Planning Manual, March 2018. Landrum & Brown analysis, 2021.

FIGURE 7 B787-900 TAKEOFF LENGTH CHART



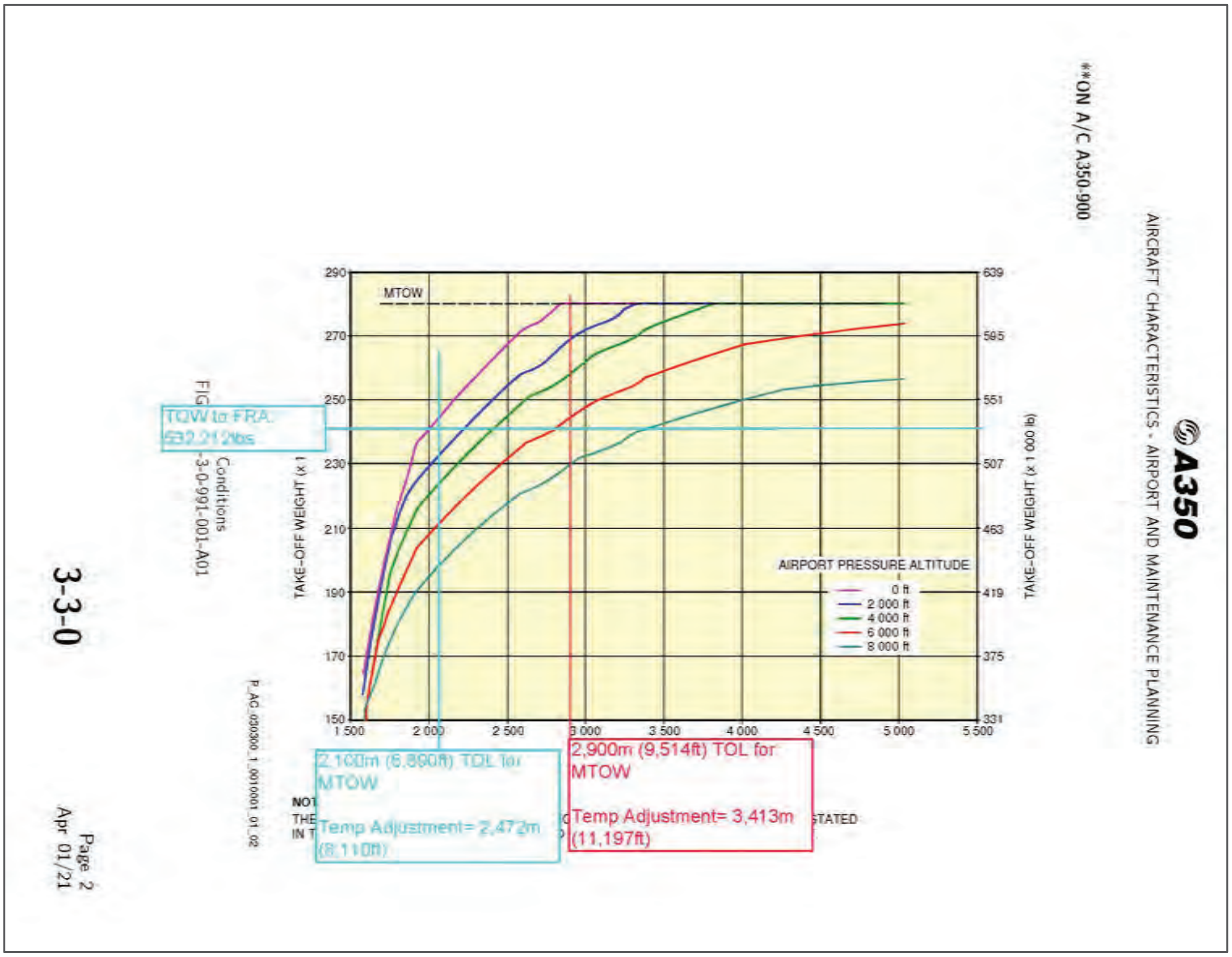
Source: B787-9/-9/-10 Boeing Airplane Characteristics for Airport Planning Manual, March 2018. Landrum & Brown analysis, 2021.

FIGURE 8 A350-900 PAYLOAD-RANGE CHART



Source: A350-900/-1000 Airbus Airport Planning Manual, April 2021. Landrum & Brown analysis, 2021.

FIGURE 9 A350-900 TAKEOFF LENGTH CHART



Source: A350-900/-1000 Airbus Airport Planning Manual, April 2021. Landrum & Brown analysis, 2021.

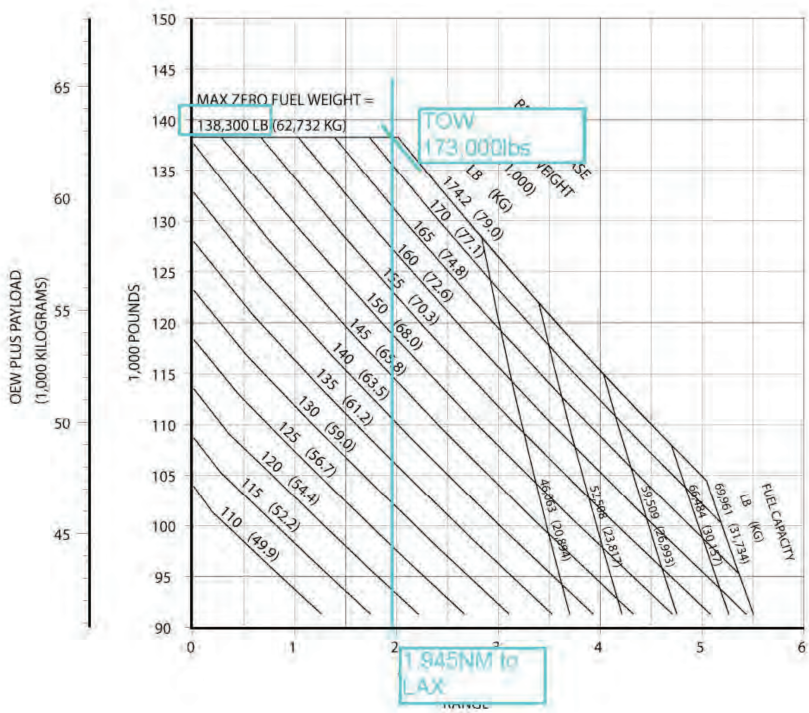
FIGURE 10 B737-800W PAYLOAD-RANGE CHART

3.2.12 Payload/Range for Long Range Cruise: Model 737-800

DO NOT USE FOR DISPATCH

Payload/Range
737-800/800W/BBJ2 (CFM56-7B Series)

- STANDARD DAY, ZERO WIND
- CRUISE MACH = LRC
- NORMAL POWER EXTRACTION AND AIR CONDITIONING BLEEDS
- TYPICAL MISSION RULES
- NON-WINGLET PERFORMANCE SHOWN. WINGLET AIRCRAFT WILL HAVE SLIGHTLY GREATER RANGE.
- CONSULT USING AIRLINE FOR SPECIFIC OPERATING PROCEDURE AND OEW PRIOR TO FACILITY DESIGN.



D6-58325-6

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Source: Boeing 737 Airplane Characteristics for Airport Planning, September 2020. Landrum & Brown analysis, 2021.

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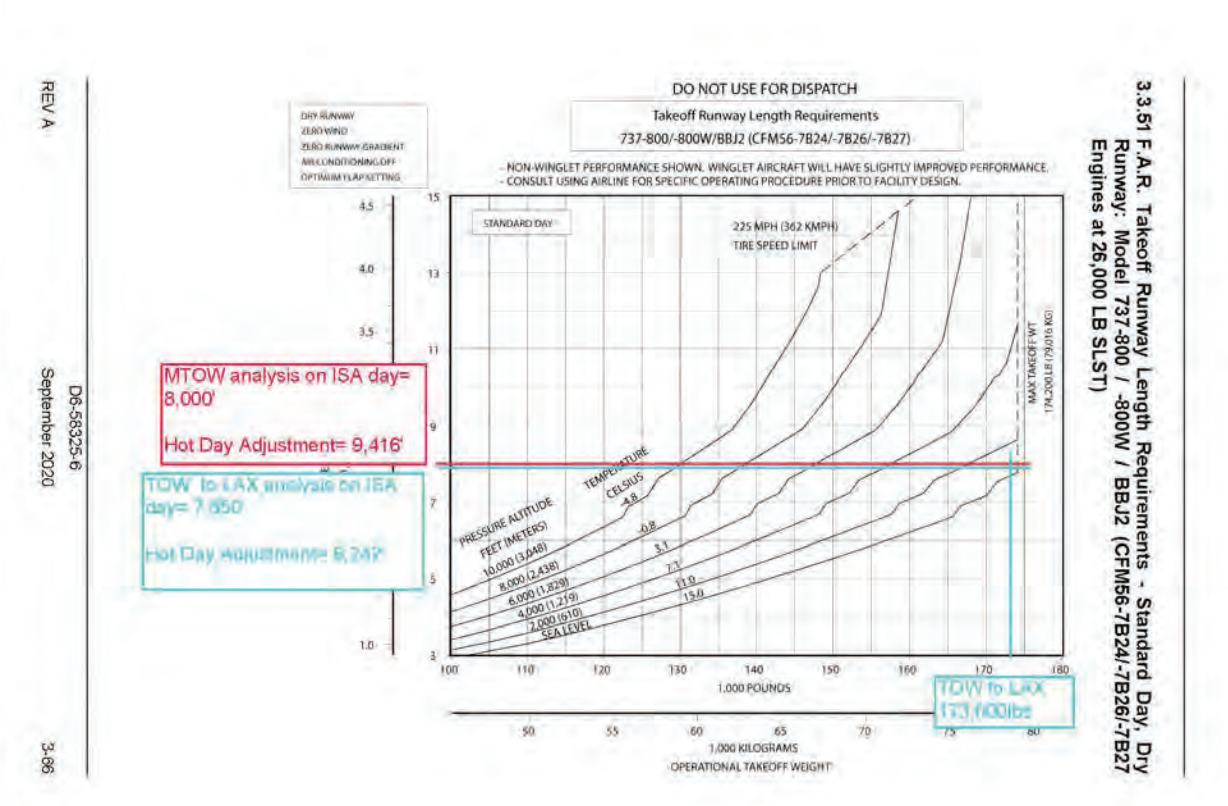
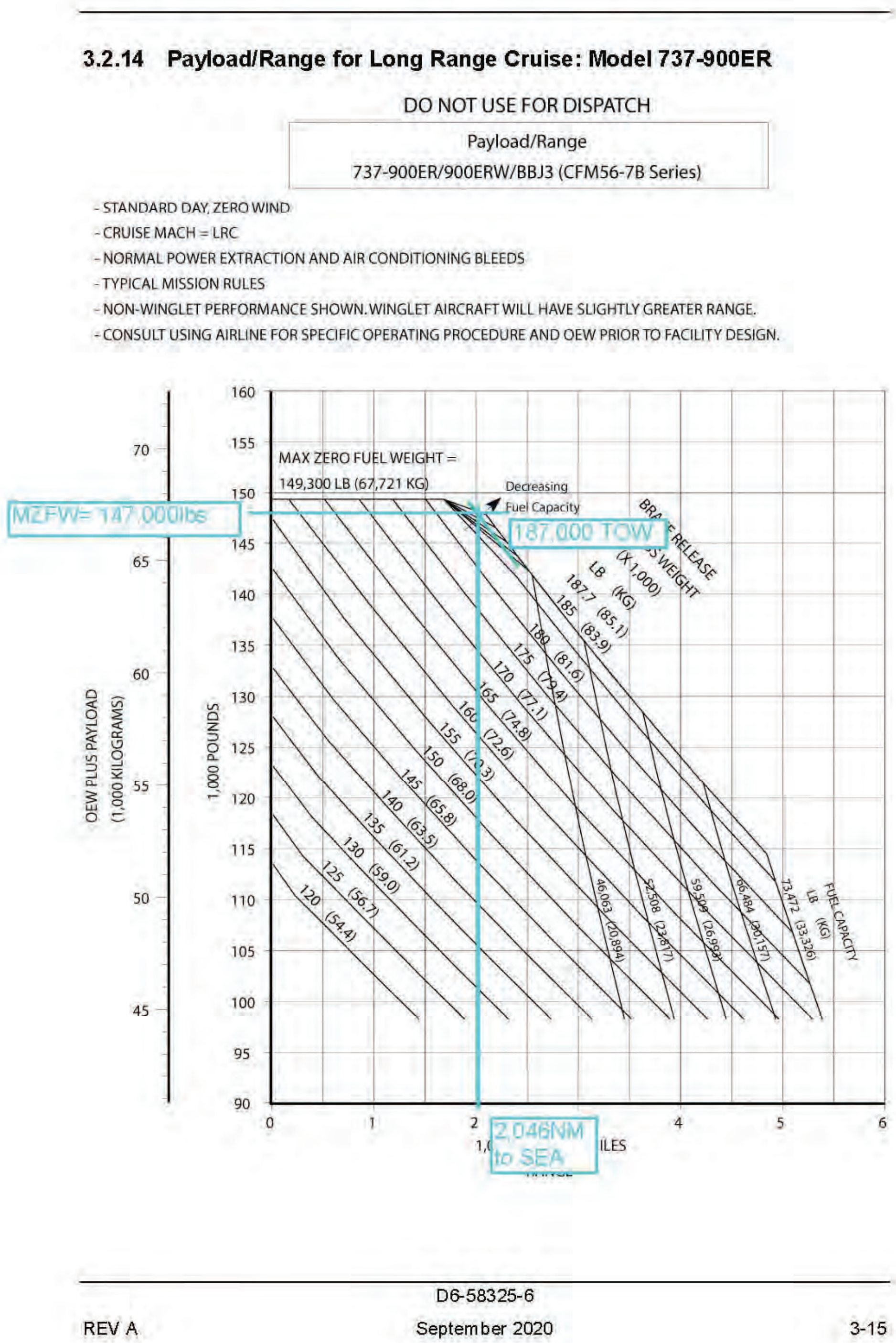
FIGURE 11 B737-800W TAKEOFF LENGTH CHART



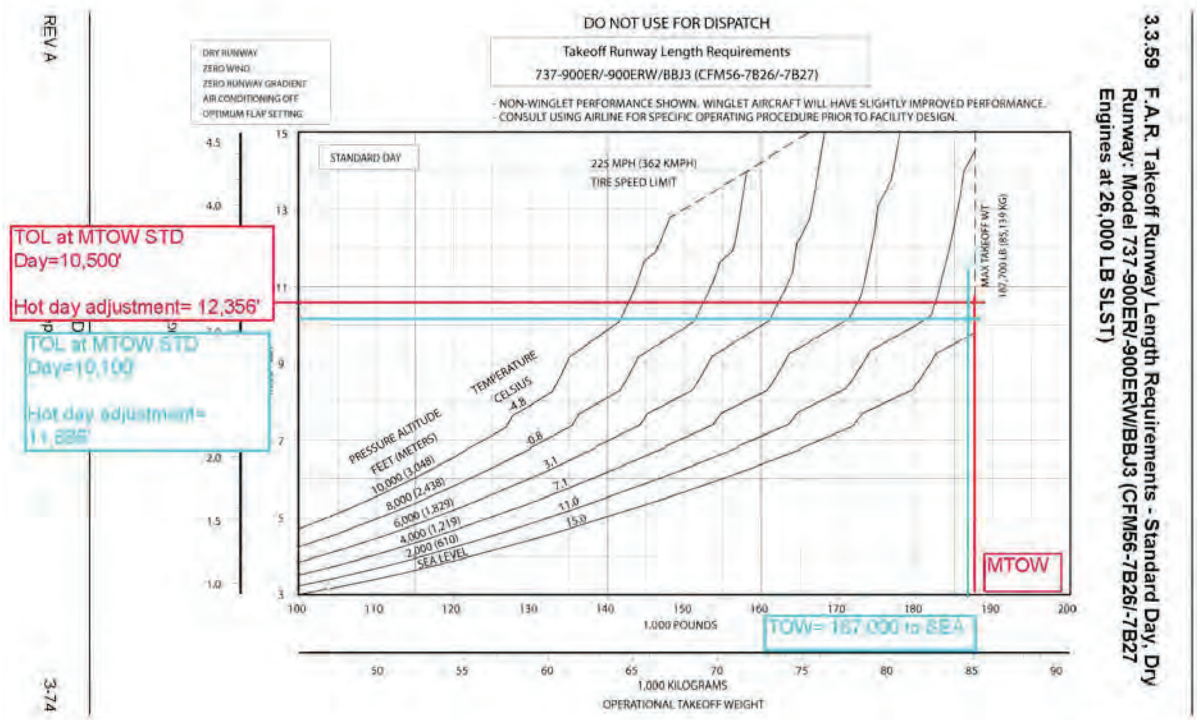
Source: Boeing 737 Airplane Characteristics for Airport Planning, September 2020. Landrum & Brown analysis, 2021.

FIGURE 12 B737-900ER PAYLOAD-RANGE CHART



Source: Boeing 737 Airplane Characteristics for Airport Planning, September 2020. Landrum & Brown analysis, 2021..

FIGURE 13 B737-900ER TAKEOFF LENGTH CHART



Source: Boeing 737 Airplane Characteristics for Airport Planning, September 2020. Landrum & Brown analysis, 2021.

Michael J. Landguth, A.A.E.
President & CEO

Raleigh-Durham Airport Authority

1000 Trade Drive • P.O. Box 80001 • RDU Airport, NC 27623
tel: (919) 840-7700 • fax: (919) 840-0715 • www.rdu.com

To: Wes Mittlesteadt, PE, Lead Civil Engineer, FAA Memphis ADO

From: Delia Chi, CM, Vice President of Planning and Sustainability

CC: Tommy L. Dupree, Manager, FAA Memphis ADO
Duane Johnson, Assistant Manager, FAA Memphis ADO
Aaron Braswell, Environmental Protection Specialist, FAA Memphis ADO
Jamal Stovall, GISP, Community Planner, FAA Memphis ADO

Date: March 9, 2022

Subject: RDU Proposed Runway 5L/23R Replacement Project

The following is provided in response to your request in an email dated January 28th, 2022 for additional information concerning the proposed runway length at RDU. The FAA requested the Airport Authority to: 1) work with Alaska Airlines to identify relevant obstacles to determine if mitigation was possible; 2) determine if the parameters in the airline performance engineering analysis align to FAA criteria in *FAA AC 150/5325-4B, Runway Length Requirements for Airport Design;* and 3) forward the Alaska Airlines performance data to FAA before incorporation in the Environmental Assessment (EA).

1) The Airport Authority requested Alaska Airlines conduct runway performance and obstacle analysis for Runway 5L/23R for the B737-900 aircraft. Alaska Airlines conducted the additional analysis based on the requested inputs provided by FAA in **Attachment 1** and the runway configurations as shown in **Attachment 2**. Alaska Airlines provided their output of the performance engineering as a direct calculation of payload offsets (number of seats) on the requested runway lengths (feet): 10,000, 10,500, 10,639, and 11,000, which is provided in **Attachment 3**. While the FAA requested obstacles limiting takeoff performance in the 40:1 or outside of the 40:1, the FAA agreed Alaska Airlines could perform the obstacle analysis based on the 62.5:1 One-Engine Inoperative (OEI) requirements and Obstacle Accountability Area (OAA), per *FAA AC 120-91A, Airport Obstacle Analysis*. The analysis resulted in the identification of several trees close-in to the departure end as existing and future obstacles. Most of the trees identified as obstacles are within the control of the Airport Authority and can be mitigated. The water tower identified as an obstacle for 5L departures, situated approximately 4,100 feet from the 23R end and within the OAA, remains an obstacle today and in the future. The Airport Authority will provide mitigation information in the EA as requested.

2) Alaska Airlines completed their analysis based on parameters aligning with *FAA AC 150/5325-4B, Runway Length Requirements for Airport Design*. The Airport Authority believes the parameters in the airline performance engineering analysis align to FAA's criteria in AC 150/5325-4B and provides the necessary justification for the proposed runway length.

3) The Airport Authority is providing the Alaska Airlines response in **Attachment 3** as requested by the FAA. The B737-900 aircraft performance analysis for flights departing for SEA indicates improved

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President & CEO

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payload offsets as the runway pavement length increases as shown in **Table 1**. The Airport Authority reviewed the payload offsets (number of seats) on the requested runway lengths and developed potential lost revenue by Alaska Airlines associated with the payload reductions. While not included in the calculations, limiting passengers also results in a financial impact to the Airport Authority. The financial impact of payload offset only grows through the forecast planning horizon.

Table 1 Alaska Airlines Runway 5L/23R Performance Analysis Summary

Runway Placement	**Existing**	**Replacement**	**Replacement**	**Replacement**	**Replacement**
Pavement Length (ft)	**10,000**	**10,000**	**10,500**	**10,639**	**11,000**
5L Takeoff					
Payload Offset (lbs)	6,600	5,600	3,300	3,300	3,300
Payload Offset (seats)	32	27	16	16	16
Annual Revenue Impact in 2028 ($)	1.99 million	1.68 million	0.99 million	0.99 million	0.99 million
Annual Revenue Impact in 2033 ($)	2.25 million	1.90 million	1.13 million	1.13 million	1.13 million
Obstacles	Wake County EMS, Trees, Water Tower	Trees, Water Tower	Trees, Water Tower	Trees, Water Tower	Trees, Water Tower
23R Takeoffs					
Payload Offset (lbs)	3,600	4,100	2,400	2,100	1,200
Payload Offset (seats)	18	20	12	10	6
Annual Revenue Impact in 2028 ($)	1.54 million	1.71 million	1.03 million	0.86 million	0.51 million
Annual Revenue Impact in 2033 ($)	1.75 million	1.94 million	1.17 million	0.97 million	0.58 million
Obstacles	Trees	Trees	Trees	Trees	Trees

Note: Table 1 presents two 10,000-foot-long runway options that differ in runway placement, either in its existing location or in the replacement location 537 feet away, from centerline to centerline. The two options result in different obstruction impacts, and different payload offsets.
The annual revenue impact was calculated based on an average of $201.76 per flight per seat which reflects the average non-stop ticket price from RDU to SEA on Alaska Airlines from 2016 Q4 to 2021 Q3. Existing runway use was used to determine the frequency of flights under each scenario assuming the flight would only utilize RW 5L/23R.
Source: Alaska Airlines; United States Bureau of Transportation Statistics and Air Passenger Origin and Destination Survey Data (DB1B).

The Airport Authority is requesting the FAA review the analysis provided by Alaska Airlines and concur with their findings, as well as the Authority's justification for the proposed runway length. We look forward to working with the FAA in concluding the runway length issue so we can move forward with the EA. The EA is a critical component for the Airport Authority to complete and then to implement our Runway 5L/23R Replacement Project as we continue our existing Runway 5L/23R ongoing repair efforts, extensive monitoring, and more frequent cleaning which requires an unusually high number of runway closures.

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CITY OF DURHAM
Tammie Hall, **Treasurer**
Yesenia Polanco-Galdamez

Combined FAA Southern Region and Headquarters Comments
RDU Runway Length Analysis

1. A critical path issue is the 5L obstacles limiting takeoff performance. Recommend RDU work with Alaska Airlines to identify the relevant obstacles and assess if they can be mitigated (and include mitigation in the EA). Obstacles could be located in the 40:1 or outside of the 40:1. If the obstacles cannot be mitigated, it may be challenging to get to regular use (250 departures at that trip distance) of aircraft needing the longer runway which is an essential step towards justification.

2. In RDU's 12/17 email to Alaska Airlines, RDU asked the airline to evaluate B739 performance on the potential 10,639' runway vs the existing 10,000 runway. While a good start, it's not the entire analysis needed for justification. The FAA needs to be sure that the parameters in the airline performance engineering analysis align to our criteria in AC 150/5325-4B, since this links to justification and then purpose and need in the EA.

3. Strongly recommend RDU forward the Alaska Airlines performance data requested below before incorporation in the EA. FAA will quickly review and assess if any tweaks are needed before hours and time are spent on the runway justification document. If the airline has any questions, the ADO can put them in contact with our ARP expert.

Analysis requested:
Aircraft performance engineering calculations for balanced takeoff and landing distance, for the aircraft type and trip distances using the following parameters that align to AC 150/5325-4B.

Input Criteria
Aircraft Types: B739 as operated to Alaska Airlines to SEA.
Weight of A/C:
Takeoff: Assume 100% load factor of passengers and baggage; max as available/applicable within operating limits; typical fuel load for route with required reserves.
Landing at Max Landing Weight (MLW).
Runways:
05L and 23R separately, with existing obstacles, in the relocated location. Identify controlling obstacles. [Follow-on: Airport/consultant should then assess ability to remove (e.g., trees may be feasible, buildings less so, terrain not). If feasible to remove, then include obstacle mitigation in the EA. Also calculate takeoff performance with relevant obstacles removed.]
Runway condition:
Dry (RCC-6) for balanced field takeoff.
Wet (RCC-5) for landing. Include 60% factor as required by 14 CFR Part 121. (Note: RCC 4 and below with contaminated runways are not applicable for AIP funded projects but can be calculated as an additional value if of interest to the airport for development with local funding.)
Temperature: Mean-max temperature is 91F. Option to use 94F per National Climate Assessment projection at RDU.
Wind: Zero/Calm.
Airfield elevation: 435' feet MSL
Thrust: Full takeoff power, not reduced or derate power; normal procedure takeoff and flaps.

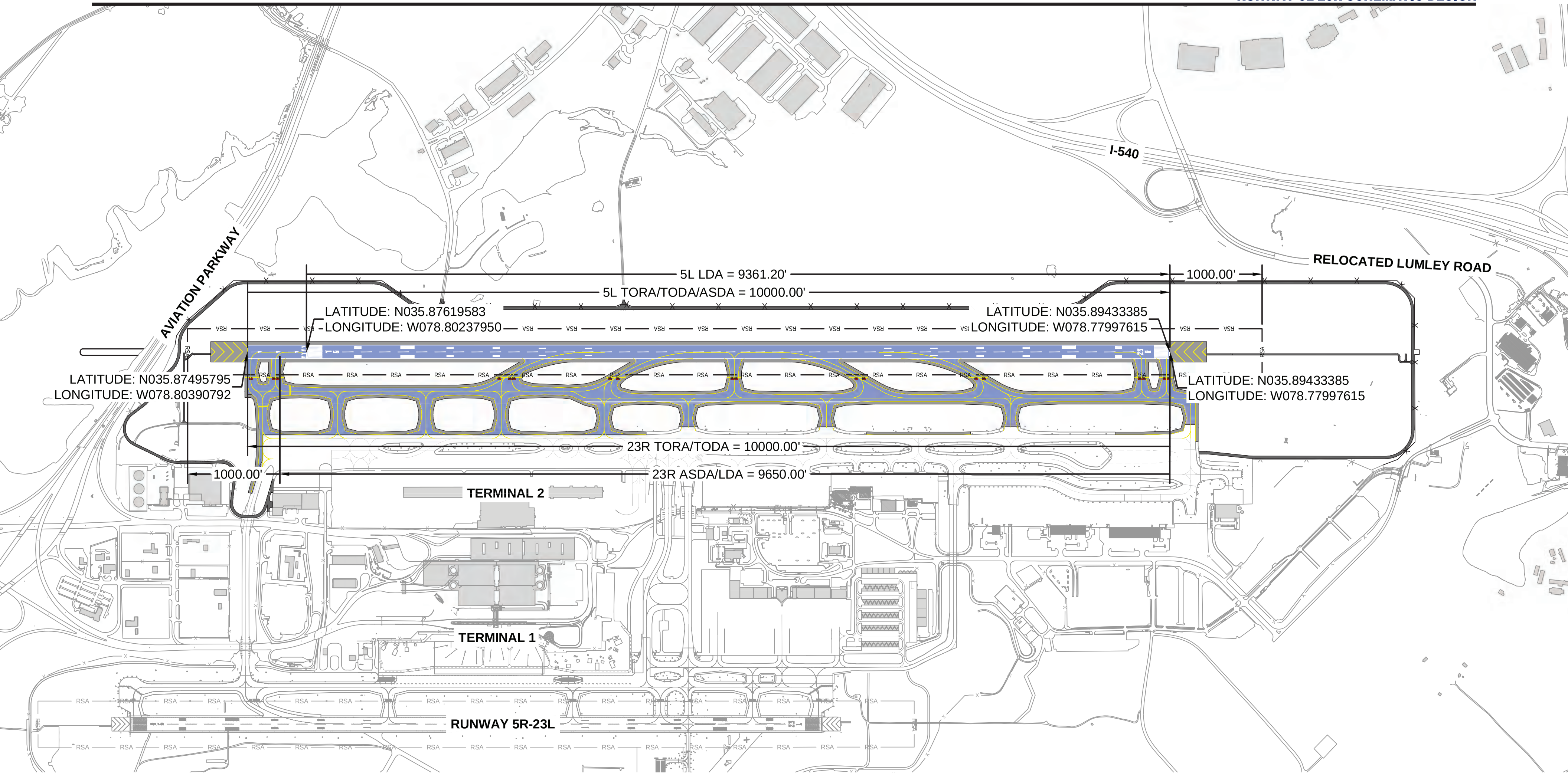
Outputs/Results:

Combined FAA Southern Region and Headquarters Comments
RDU Runway Length Analysis

Typically the output of the performance engineering analysis is available one of two ways:
1. Calculation of MRTW (Max Runway Takeoff Weight) on runway lengths of 10000, 10500, 10639, 11000. Indicate number of seats empty per runway increment. What we're looking to understand is the runway length at which payload offloads (reductions in seats filled or bags/cargo) begin, holding other parameters constant.
2. Or: Direct calculation of any payload offsets (seats/cargo) on these runway lengths: 10000, 10500, 10639, and 11000. For newer aircraft types, the aircraft manufacturers may restrict disclosure of precision data; the ~500 foot increments are intended to help mitigate this concern.

Attachment 2

RALEIGH-DURHAM INTERNATIONAL AIRPORT
RUNWAY 5L-23R SCHEMATIC DESIGN



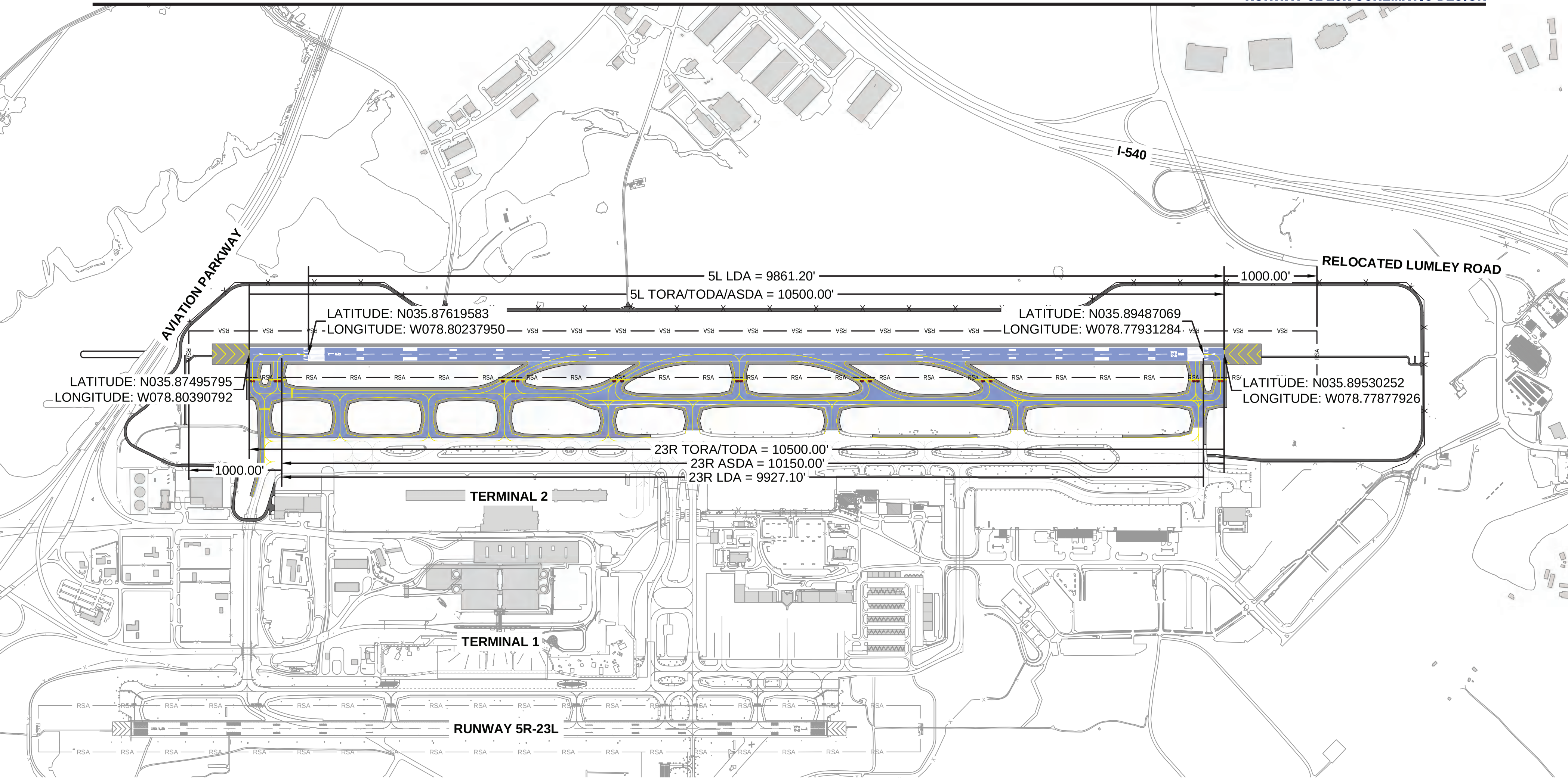
DATE: February 3, 2022
DRAWN BY: CDM
DATUM: NAD83 North Carolina State Planes, US Foot
SOURCE: RS&H, Inc.
Existing Survey provided by MA Engineering Consultants, Inc., 2018

500 0 500 1000
GRAPHIC SCALE
(IN FEET)

NORTH

RS&H

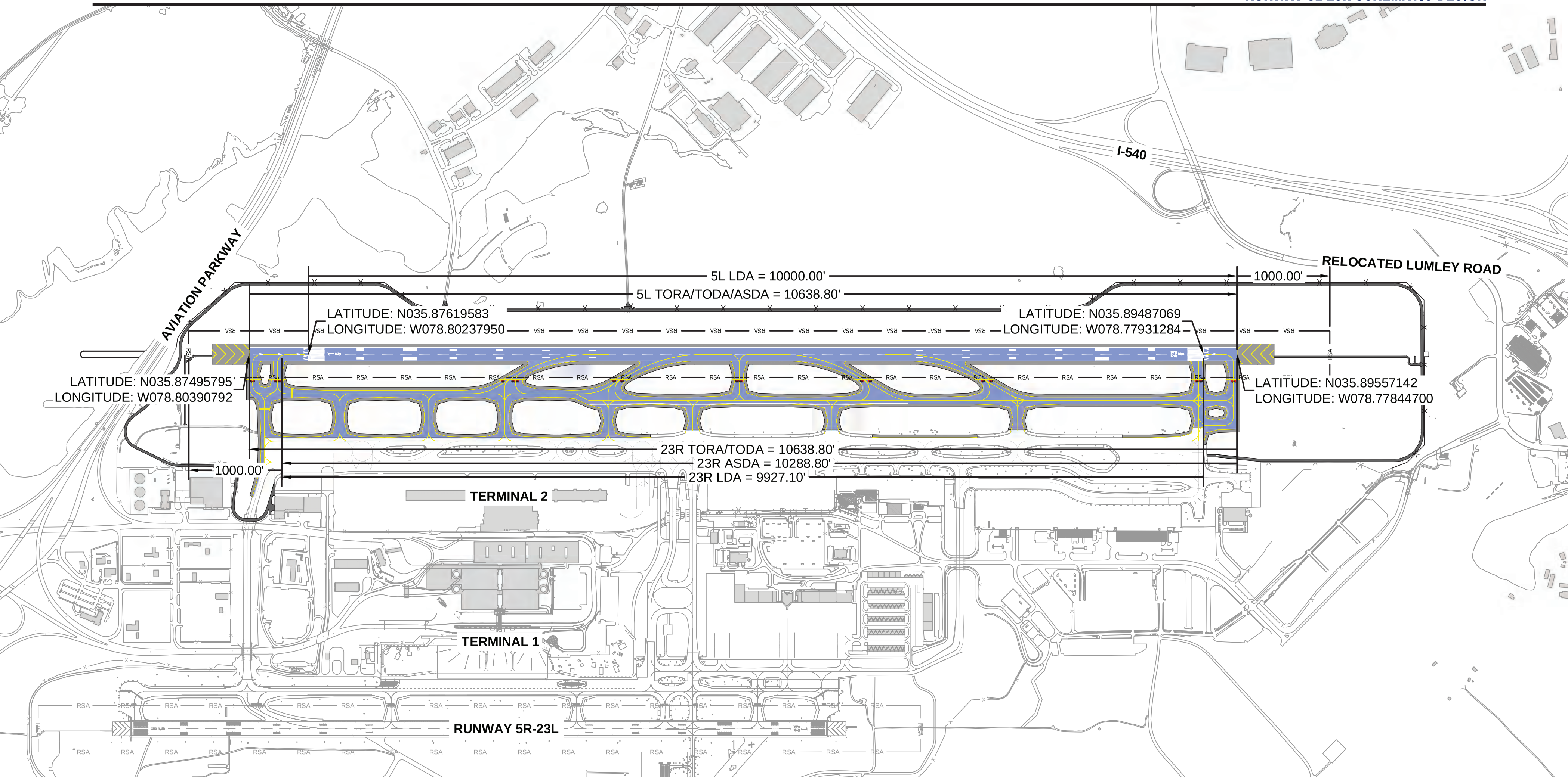
FIGURE 1
RUNWAY 5L-23R 10,000' LOCATIONS AND DECLARED DISTANCES



DATE: February 3, 2022
DRAWN BY: CDM
DATUM: NAD83 North Carolina State Planes, US Foot
SOURCE: RS&H, Inc.
Existing Survey provided by MA Engineering Consultants, Inc., 2018

FIGURE 2
RUNWAY 5L-23R 10,500' LOCATIONS AND DECLARED DISTANCES

RALEIGH-DURHAM INTERNATIONAL AIRPORT
RUNWAY 5L-23R SCHEMATIC DESIGN

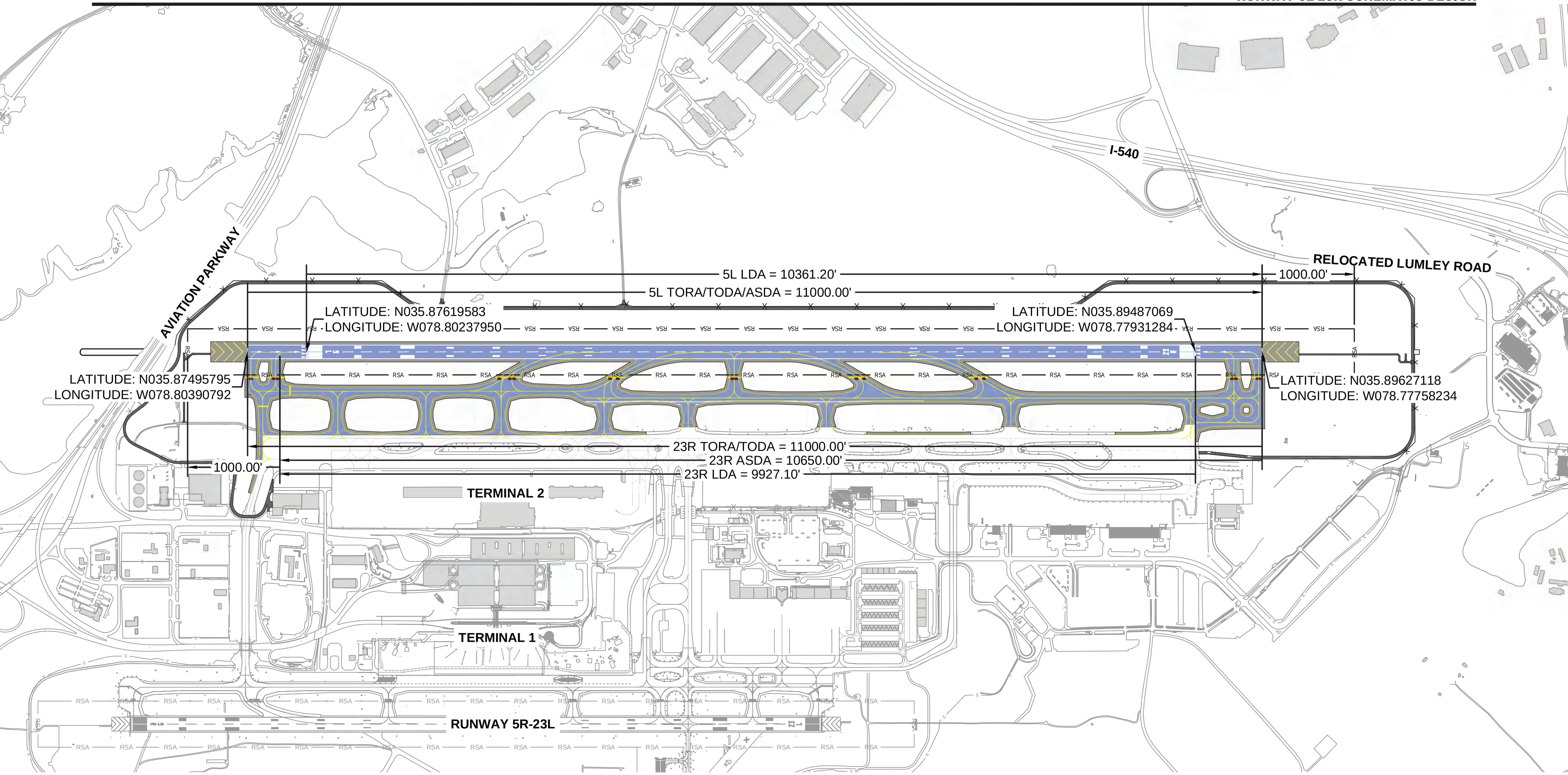


DATE: February 3, 2022
DRAWN BY: CDM
DATUM: NAD83 North Carolina State Planes, US Foot
SOURCE: RS&H, Inc.
Existing Survey provided by MA Engineering Consultants, Inc., 2018

RS&H

FIGURE 3
RUNWAY 5L-23R 10,639' LOCATIONS AND DECLARED DISTANCES

RALEIGH-DURHAM INTERNATIONAL AIRPORT
RUNWAY 5L-23R SCHEMATIC DESIGN



DATE: February 3, 2022
DRAWN BY: CDM
DATUM: NAD83 North Carolina State Planes, US Foot
SOURCE: RS&H, Inc.
Existing Survey provided by MA Engineering Consultants, Inc., 2018

RS&H

FIGURE 4
RUNWAY 5L-23R 11,000' LOCATIONS AND DECLARED DISTANCES

From: Charles Ostick
To: Chi, Delia; Lynae Craig
Cc: Sandifer, Bill; Perry, Kenneth; Chris Babb; Rob Adams; Walz, John; dale.stubbs@rsandh.com; Stair, Rachel
Subject: RE: RDU Runway 5L/23R Length Performance Analysis
Date: Thursday, February 24, 2022 5:13:11 PM
Attachments: image001.png
image002.png
FAA Request for Addtional RW Length Info_Alaska Ailines- RDU to SEA.docx
20220204_Alaska Airlines Requested Runway Length Data RDU RW 5L-23R_v1.pdf

CAUTION: This email attachment originated from a third party. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hello Delia and Team,

In accordance with the attached "FAA Request…" here are Outputs/Results, in the form of "2. Or: Direct calculation of any payload offsets (seats/cargo)", each calculated in accordance with the Input Criteria specified (including dry runway), for each of the 4 runway configuration in the attached "…Requested Runway Length…" document. Consideration of obstacles, as required by 14 CFR 121.189, is critical to making this analysis.

In summary, the option on Page 1 degrades capacity compared to the existing runway. Options on Pages 2, 3, or 4 improve capacity compared to the existing runway.

Taking off 23R:

> All options are limited by trees in the vicinity of Pleasant Grove Church Rd which are outside, to the right, of the AC 120-91A Obstacle Accountability Area (OAA) for the current runway. Options which start takeoff further from the trees relieve this limit, but no option eliminates it.

0. From the current runway, we are not limited by obstacles. We forecast payload offset of 3600 lb, or approximately 18 seats.
1. For the option on Page 1, with TORA/TODA = 10000 ft, we forecast payload offset of 4100 lb, or approximately 20 seats, which is worse than the existing runway.
2. For the option on Page 2, with TORA/TODA = 10500 ft, we forecast payload offset of 2400 lb, or approximately 12 seats, which is better than the existing runway.
3. For the option on Page 3, with TORA/TODA = 10638 ft, we forecast payload offset of 2100 lb, or approximately 10 seats.
4. For the option on Page 4, with TORA/TODA = 11000 ft, we forecast payload offset of 1200 lb, or approximately 6 seats.

Taking off from runway 5L:

> The OAAs for all 4 proposals avoid the obstacles that limit the current runway, either trees near the Wake County EMS Station or the water tower near Our Lady of La Vang North Carolina Catholic Church. All proposals give better takeoff weights than the current runway.

0. From the current runway, we are limited by obstacles. We forecast payload offset of 6600 lb, or approximately 32 seats.
1. For the option on Page 1, with TORA/TODA/ASDA = 10,000 ft., we are field limited by accelerate-go. We forecast payload offset of 5600 lb, or approximately 27 seats.
2. For the option on Page 2, with TORA/TODA/ASDA = 10,500 ft, the additional runway length relieves the field limit. We are instead limited by trees in the vicinity of Interstate 70, where Google Maps identifies Triangle Equipment Co. We forecast payload offset of 3300 lb, or approximately 16 seats.
3. For options on Pages 3 and 4, with TORA/TODA/ASDA > 10,500 ft, we remain limited by the obstacles identified for Page 2 and can show no additional benefit when taking off in this direction. We forecast payload offset of 3300 lb or approximately 16 seats.

I trust these Results will support you in making the most appropriate long term investment Raleigh-Durham International Airport.

Regards,
--charles

____

Charles Ostick / 206-979-0513
Flight Operations Engineer, Alaska Airlines / SEAOZ

Warning: Any safety-related, security-related and/or commercial information in this document is considered proprietary and is exempt from disclosure under federal law, including 49 U.S.C. 40115 and 40123, 14 CFR 193, 49 CFR 7.29 and 5 U.S.C. 552(b), and applicable state laws. This document is released with an expectation of confidential treatment.

From: Chi, Delia <Delia.Chi@rdu.com>
Sent: Saturday, February 19, 2022 8:13 PM
To: Charles Ostick <charles.ostick@alaskaair.com>; Lynae Craig <lynae.craig@AlaskaAir.com>
Cc: Sandifer, Bill <bill.sandifer@rdu.com>; Perry, Kenneth <kenneth.perry@rdu.com>; Chris Babb <chris.babb@landrumbrown.com>; Rob Adams <rob.adams@landrumbrown.com>; Walz, John <john.walz@rsandh.com>; dale.stubbs@rsandh.com; Stair, Rachel <rachel.stair@rdu.com>
Subject: RE: RDU Runway 5L/23R Length Performance Analysis

[EXTERNAL SENDER]

Hi Charles,

Thank you for the update. Have a great weekend and talk to you next week!

Cheers,

Delia Chi

From: Charles Ostick <charles.ostick@alaskaair.com>
Sent: Friday, February 18, 2022 5:11 PM
To: Chi, Delia <Delia.Chi@rdu.com>; Lynae Craig <lynae.craig@AlaskaAir.com>
Cc: Sandifer, Bill <bill.sandifer@rdu.com>; Perry, Kenneth <kenneth.perry@rdu.com>; Chris Babb <chris.babb@landrumbrown.com>; Rob Adams <rob.adams@landrumbrown.com>; Walz, John <john.walz@rsandh.com>; dale.stubbs@rsandh.com; Stair, Rachel <rachel.stair@rdu.com>
Subject: RE: RDU Runway 5L/23R Length Performance Analysis

Hello Delia,

I don't have any progress to report today, but I do still intend to deliver by the end of next week.
Thank you for checking in.

Regards,
--*charles*

____

Charles Ostick / 206-979-0513
Flight Operations Engineer, Alaska Airlines / SEAOZ

Warning: Any safety-related, security-related and/or commercial information in this document is considered proprietary and is exempt from disclosure under federal law, including 49 U.S.C. 40115 and 40123, 14 CFR 193, 49 CFR 7.29 and 5 U.S.C. 552(b), and applicable state laws. This document is released with an expectation of confidential treatment.

From: Chi, Delia <Delia.Chi@rdu.com>
Sent: Friday, February 18, 2022 12:31 PM
To: Charles Ostick <charles.ostick@alaskaair.com>; Lynae Craig <lynae.craig@AlaskaAir.com>
Cc: Sandifer, Bill <bill.sandifer@rdu.com>; Perry, Kenneth <kenneth.perry@rdu.com>; Chris Babb <chris.babb@landrumbrown.com>; Rob Adams <rob.adams@landrumbrown.com>; Walz, John <john.walz@rsandh.com>; dale.stubbs@rsandh.com; Stair, Rachel <rachel.stair@rdu.com>
Subject: RE: RDU Runway 5L/23R Length Performance Analysis

[EXTERNAL SENDER]

Hi Charles and Lynae,

I hope you are both doing well. I just wanted to check in with you on the Runway 5L/23R performance length analysis for the Runway 5L/23R Replacement Project EA. When we last met via Teams (February 2, 2022), I had said I would check in with you on February 18th. Please let us know if you have any preliminary information to share or an update on the analysis.

Thank you!

Cheers,

Delia Chi

From: Chi, Delia
Sent: Thursday, February 10, 2022 1:57 PM
To: 'Charles Ostick' <charles.ostick@alaskaair.com>; 'Lynae Craig' <lynae.craig@AlaskaAir.com>
Cc: Sandifer, Bill <bill.sandifer@rdu.com>; Perry, Kenneth <kenneth.perry@rdu.com>; Chris Babb <chris.babb@landrumbrown.com>; 'Rob Adams' <rob.adams@landrumbrown.com>; 'Walz, John' <john.walz@rsandh.com>; 'dale.stubbs@rsandh.com' <dale.stubbs@rsandh.com>; Stair, Rachel <rachel.stair@rdu.com>
Subject: RE: RDU Runway 5L/23R Length Performance Analysis

Hi Charles and Lynae:

We spoke to FAA regarding the two proposed modifications to their Runway 5L-23R length analysis. See their response below. They agreed with our request to analyze just the OEI surface. However, they disagreed with the modification to evaluate takeoff distance based on a wet runway condition, quoting the FAA Advisory Circular 150/5325-4B, Runway Length Requirements for Airport Design.

Would you be able to conduct the analysis for takeoff lengths under a dry hot-day condition instead of a wet condition? If not, is there a particular reason for assessing it based on a wet condition?

Thank you both so much for your attention to this matter.

Cheers,

Delia Chi

From: Chi, Delia
Sent: Monday, February 7, 2022 12:01 PM
To: Charles Ostick <charles.ostick@alaskaair.com>; Lynae Craig <lynae.craig@AlaskaAir.com>
Cc: Sandifer, Bill <bill.sandifer@rdu.com>; Perry, Kenneth <kenneth.perry@rdu.com>; Chris Babb <chris.babb@landrumbrown.com>; Rob Adams <rob.adams@landrumbrown.com>; Walz, John <john.walz@rsandh.com>; dale.stubbs@rsandh.com; Stair, Rachel <rachel.stair@rdu.com>
Subject: RDU Runway 5L/23R Length Performance Analysis

Hi Charles and Lynae:

Attached are the requested documents for the Runway 5L/23R aircraft performance analysis. Please let me know if you need more information to get started with the analysis. I will follow-up with you on February 18th, but feel free to reach out if you would like to connect sooner. Also, we are still working with FAA to confirm our requested changes to their original performance analysis request. I will let you know what they say.

Thanks!

Cheers,

Delia Chi

Delia Chi, CM | Vice President of Planning and Sustainability | Delia.Chi@rdu.com | 919.840.7744
Raleigh-Durham Airport Authority | 1000 Trade Drive | RDU Airport, North Carolina 27623

U.S. Department
of Transportation
**Federal Aviation
Administration**

Memphis Airports District Office
2600 Thousand Oaks Blvd., Suite 2250
Memphis, TN 38118-2486

Phone: 901-322-8180

April 14, 2022

Ms. Delia Chi, CM
Vice President of Planning and Sustainability
Raleigh-Durham Airport Authority
1000 Trade Drive
PO Box 80001
RDU Airport, NC 27623

RE: Runway Replacement Program
Raleigh-Durham International Airport (RDU)

Dear Ms. Chi:

The Federal Aviation Administration (FAA) is in receipt of your memorandum dated March 9, 2022 providing additional information concerning the proposed length for Runway 5L/23R.

The FAA accepts the technical performance engineering analysis provided by Alaska Airlines as adequate justification meeting the requirements of Advisory Circular (AC) 150/5325-4B, *Runway Length Requirements for Airport Design*, for runway length of 10,639 feet when Runway 5L/23R is replaced with a new runway. The analysis shows that 10,639 feet is a balanced runway length providing substantive benefit to Alaska Airline's Boeing 737-900 aircraft operations in both directions on future Runway 5L/23R.

As you are aware, the current Airport Layout Plan (ALP) for RDU reflects a "Future-Phase 1" length of 10,000 feet for Runway 5L/23R. Therefore, an update to the ALP is required to reflect a "Future-Phase 1" length of 10,639 feet for Runway 5L/23R. The Memphis ADO requests that you provide an acceptable scope of work and schedule to complete this ALP update concurrently or prior to completion of the ongoing Environmental Assessment (EA) for the proposed Runway Replacement Program.

At this time, the FAA is unaware of any significant environmental impacts the additional 639 feet of runway may cause. Therefore, the FAA concurs with continuation of an EA as the appropriate level of analysis to meet the requirements of the National Environmental Policy Act (NEPA).

As with any EA, should significant environmental impacts appear likely upon completion of the EA, the FAA reserves the right to conduct an Environmental Impact Statement (EIS) to meet the requirements of NEPA.

Should you have any questions or concerns, please do not hesitate to call Wes Mittlesteadt at (901) 322-8191 or e-mail him at Wesley.Mittlesteadt@faa.gov.

Sincerely,

Tommy L. Dupree
Manager, Memphis Airports District Office

Cc: Mike Hines, Manager, Airports Planning and Environmental
Kent Duffy, Airports Planning and Environmental
Steve Hicks, Director of Airports Southern Region
Terry Washington, Regional Capacity Manager, Airports Southern Region
Jamal Stovall, Memphis Airports District Office
Wes Mittlesteadt, Memphis Airports District Office

TECHNICAL MEMORANDUM – LUMLEY ROAD TUNNEL ANALYSIS

Date: October 5, 2022

Produced By: Landrum & Brown, Airport Design Consultants, Inc.

STUDY OVERVIEW

The Raleigh-Durham Airport Authority (RDUAA) has proposed the relocation of a portion of Lumley Road out of the Runway Protection Zone (RPZ) as part of the Runway 5L/23R Replacement Project at the Raleigh-Durham International Airport (RDU). An Environmental Assessment (EA) is currently being conducted for this project. The purpose of this technical memorandum is to evaluate the potential of a tunnel for Lumley Road under the RPZ instead of relocating it at grade outside and around the RPZ. Per FAA safety standards for RPZs as defined in Advisory Circular (AC) 5300-13B *Airport Design*, Lumley Road cannot remain in its current condition with the implementation of the Runway 5L/23R Replacement Project.

This memorandum provides a preliminary evaluation of the technical and economic feasibility of the tunnel alternate. The analysis utilizes information from the 2017 CH2M report on *Lumley Road / Commerce Boulevard Relocation* and discussions with the U.S. Environmental Protection Agency (EPA) involved with the clean-up of the Ward Transformer Superfund Site.

As provided in this memo, the tunnel alternative as compared to relocation of Lumley Road is the most expensive option from both the initial construction and the annual operating and maintenance perspective. Factors that make tunneling a resource-intensive and long-range economic commitment include, but are not limited to, installation and maintenance of fire and life safety systems, drainage, and structural systems that require inspection and maintenance, adaptability to regional active transportation plans, and ongoing environmental impacts.

GENERAL REQUIREMENTS

The evaluation of the Lumley Road tunnel alternative considers:

- requirements to accommodate traffic demand (2017 CH2M report);
- design requirements, per the April 2022 North Carolina Department of Transportation *Roadway Design Manual* (2022 NCDOT Design Manual).

The study assumes that:

- the initial requirements and proposed at-grade alternatives in the 2017 CH2M report are still valid;
- all properties within the RPZ and road relocation area have or will be acquired by RDUAA;
- Runway 5L/23R will be relocated and its length increased to 10,639 feet as part of the Runway 5L/23R Replacement Project;
- the intersection of Lumley Road and Commerce Boulevard would be relocated; and

- detailed analyses would be investigated at a later design phase if the tunnel alternative were advanced past preliminary evaluation (verification of vertical sight distance, requirements for tunnel operations, pavement markings, etc.).

TRAFFIC CHARACTERISTICS

Design vehicles are used to determine the minimum design criteria for roadways. The design vehicle is assumed to be a WB-67, which is the industry standard for indicating the size of interstate semi-trailer (where the "Wheel-Base or WB" between the front tires and most rear tires is approximately 67-feet) and is consistent with the design vehicle used in the 2017 CH2M report. Traffic on Lumley Road is assumed to operate as a rural minor arterial with a design speed of 40 miles-per-hour (mph) and minimum curve radius of 535 feet.

LUMLEY ROAD DESIGN CHARACTERISTICS

The City of Raleigh has identified adding a separated bikeway to Lumley Road in their long-term bikeway plan (https://raleighnc.gov/transit-streets-and-sidewalks/bike-plan) (see **Figure 1**). If the design for the long-term bikeway is not included in the planning for the tunnel, once a tunnel is constructed adding a bikeway would not be feasible without total reconstruction of the tunnel. Therefore, this memo includes the potential for a tunnel with and without a potential bike lane.

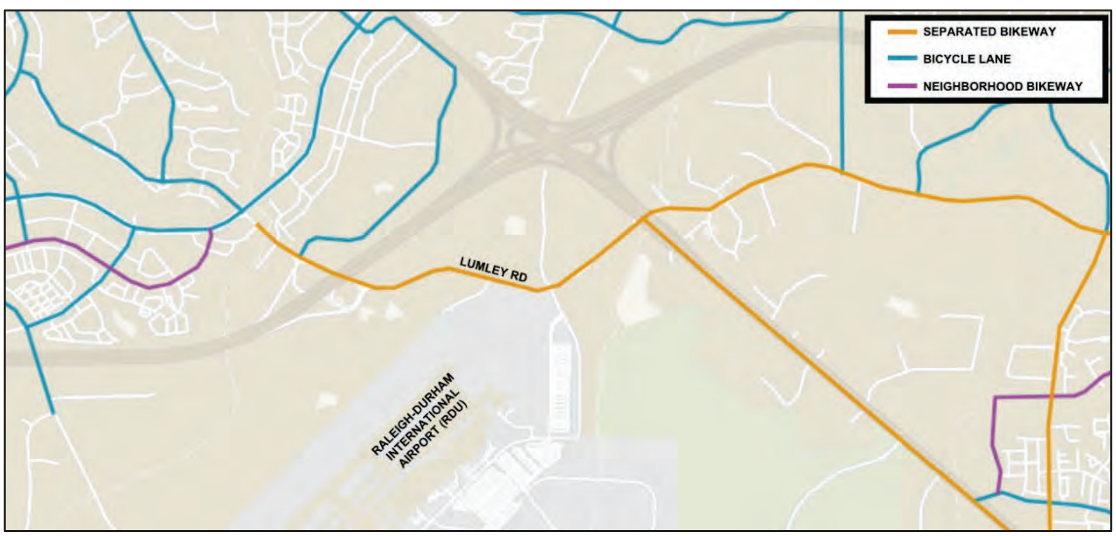


Figure 1: City of Raleigh Long Rand Bikeway Plan.

In order to accommodate a potential bike lane, the analysis assumes that horizontal clearance is provided for the full roadway cross section to include four lanes (two in each direction) plus sidewalk for maintenance and emergency egress, and a bike lane to accommodate Raleigh's long-term plan. The dimensions and details are shown in **Figure 2**.

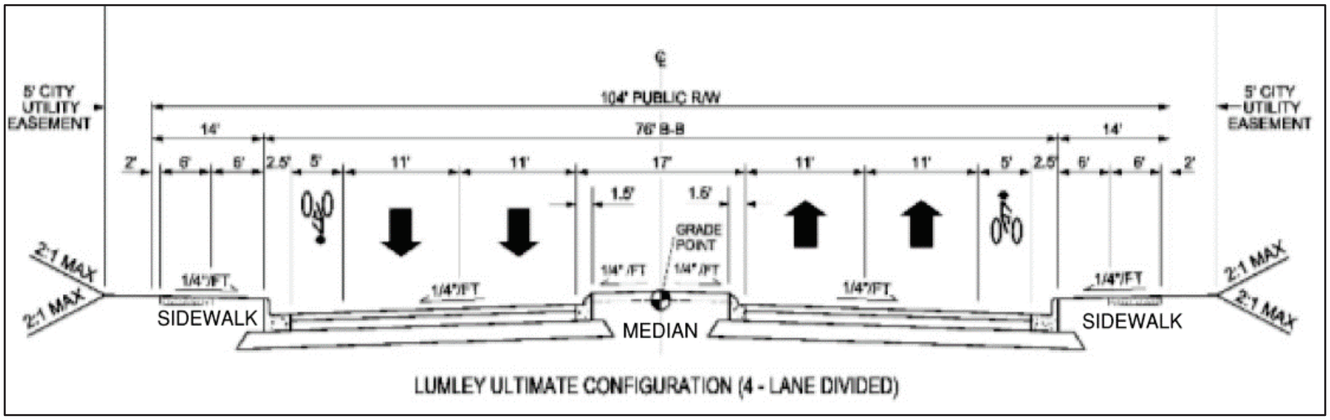


Figure 2: Typical Section for Proposed Lumley Road with bike lanes. Source: CH2M, 2017.

In order to reduce the potential width of the tunnel alternative, both the bike lanes and sidewalks could potentially be removed thus reducing the overall width. Alternate alignments of these two features could be more easily resolved and provided at grade around the RPZ. **Figure 3** shows an alternate minimum width of the tunnel. The NCDOT Design Manual requires a minimum 1.5-foot clear zone regardless of whether bicycle and pedestrian facilities are included. The total cross section without bike lanes and sidewalks would need to be a minimum of 60 feet. This includes a five-foot easement on each side of the road for city utilities.

ROAD & TUNNEL REQUIREMENTS

Relocation of Commerce Blvd. and Intersection

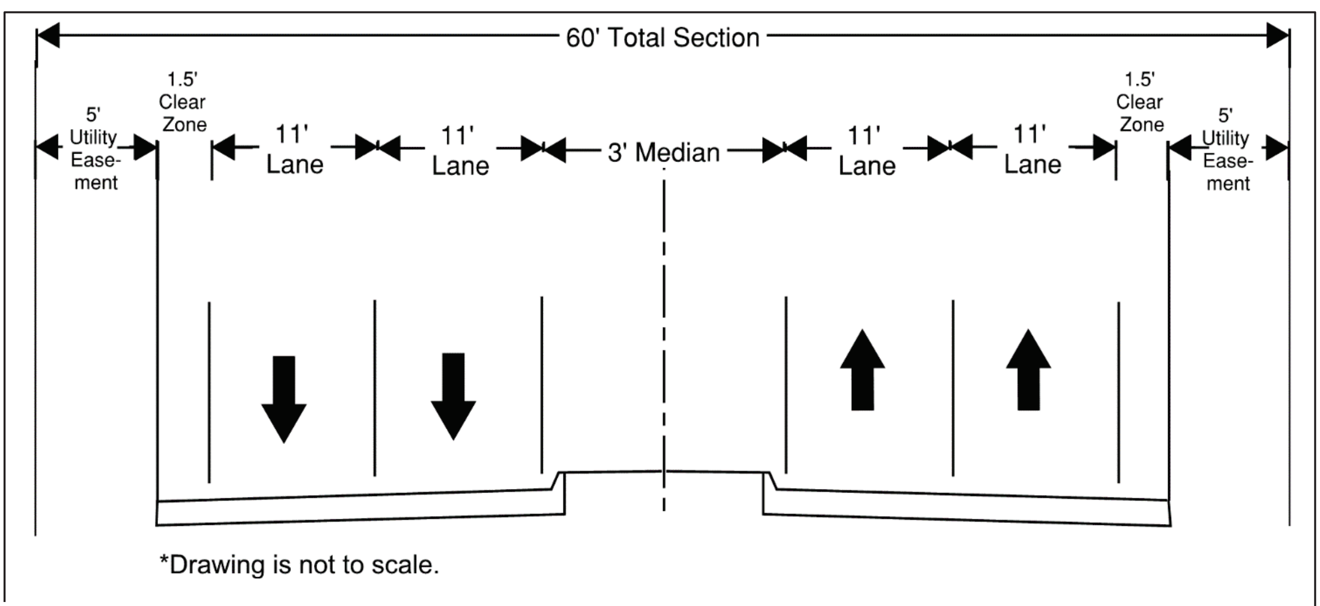


Figure 1: Typical section for Lumley Road tunnel without bike lanes

The Lumley-Commerce intersection would have to be relocated to remove it from the RPZ. Commerce Blvd. Depending on the longitudinal grade, the length of Lumley Road shown in **Figure 4**, or a portion thereof, would be required to transition from the existing elevation down approximately 30 feet to the elevation of the tunnel pavement. Therefore, with the tunnel alternative, the intersection would also have to be relocated.

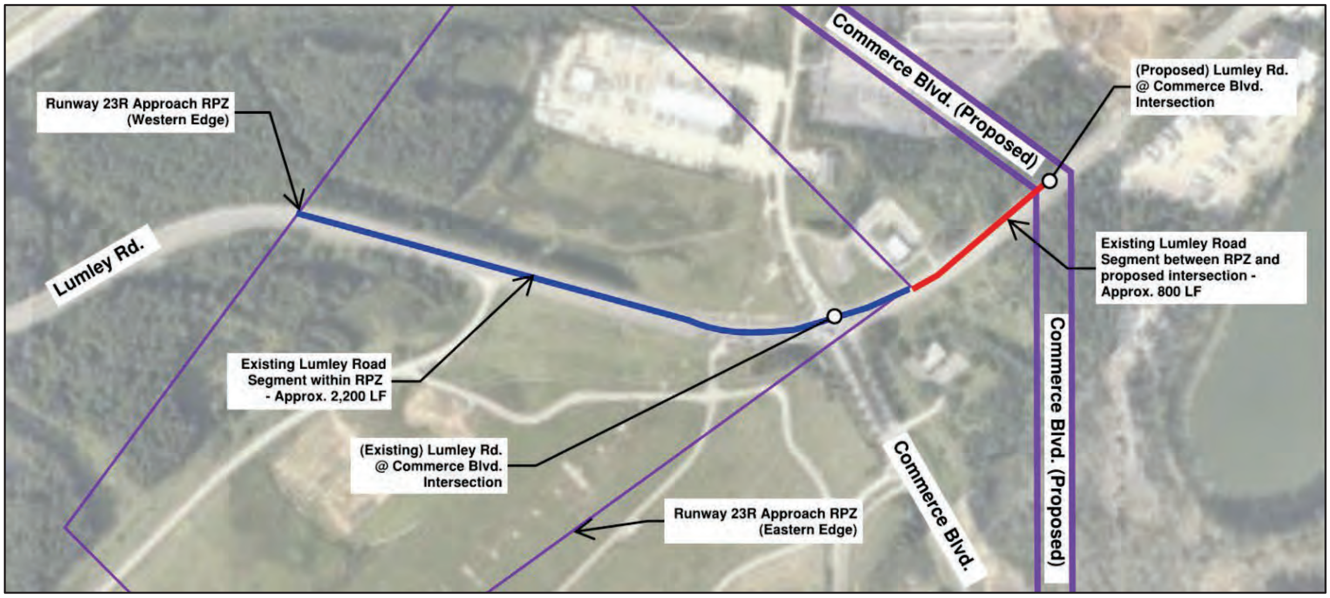


Figure 2: Approximate length of Lumley Road within RPZ and prior to proposed intersection

Roadway Depth Below Surface Elevation

The 2022 NCDOT Roadway Design Manual suggests a desirable clearance of 17 feet and 6 inches (17'-6") for highway bridges crossing arterials that have not yet been designed. The minimum height clearance is recommended because of the known presence of trucks.

For conceptual planning, assume an additional five (5) feet of vertical clearance is required for overhead signage and lighting within the tunnel, which adds up to a total clearance of 22'-6" between road surface and tunnel ceiling. Eastbound signage is imperative considering the short distance available between the tunnel and the proposed Lumley-Commerce intersection. The roof deck of the tunnel is assumed to be three (3) feet thick. Four (4) feet of ground cover is assumed between the finished ground elevation and the exterior of the tunnel structure to provide separation between natural weather elements and clearance for future utility development between the tunnel and the ground surface.

Roadway Depth Below Surface Elevation

Vertical clearance within tunnel	17.5 feet
Signage and lighting clearance	5.0 feet
Exterior wall thickness	3.0 feet
Ground cover	4.0 feet
TOTAL ROADWAY DEPTH BELOW SURFACE	29.5 feet

**Conservative values assumed for conceptual planning purposes. Actual depth below surface can change during design.*

Maximum Grade and Transition Distance

The elevation of the existing ground is approximately 400 feet mean sea level (msl) at the eastern tunnel portal and approximately 385 feet msl at the proposed Lumley-Commerce intersection (see **Figure 5).** Assuming that that tunnel is constantly 29.5 feet below existing grade, then the roadway elevation at the eastern portal is approximately 370.5 feet msl. To meet the existing grade at the proposed intersection, the roadway climbs 14.5 feet over 800 linear feet. The resulting longitudinal grade (roadway profile) is 1.81%, which satisfies maximum grade requirements per the 2022 NCDOT Roadway Design Manual. The maximum longitudinal grade for this situation is 6.0%. Therefore, during design, the ramp length down into the tunnel area could be reduced. On the western side of the tunnel, the transition to the tunnel elevation would not require a major transition grade because the existing elevation is already at the tunnel roadway elevation. Driver safety elements such as sight distance are essential to design on the western portal, but the design should be simpler than the eastern portion because the nearest decision points are far from the western tunnel portal.

Figure 5: Existing elevations. Source, https://topobuilder.nationalmap.gov/, 2022

Horizontal Alignment, Sight Distance, and Special Driver Characteristics for Tunnel Environment

Vertical alignment and sight distance requirements are key determiners on the feasibility of this tunnel alternative. The tunnel's horizontal alignment is assumed to follow the existing alignment of Lumley Road. The enclosed tunnel portion of Lumley Road will begin and end at the edges of the relocated Runway 23R Approach RPZ, which is a total tunnel length of approximately 2,200 feet (see Figure 4).

There are approximately 800 feet between the edge of Runway 23R Approach RPZ and the proposed intersection of Lumley Road and Commerce Boulevard (see the red line segment in Figure 4). At 40 mph (58.67 ft/sec), a driver would reach the proposed intersection in approximately 13.6 seconds, assuming there are no queues on the eastbound approach. Within this distance, drivers must be prepared to perceive a red signal, vehicle queue, and other hazards between the tunnel and the Lumley-Commerce intersection, and then come to a complete stop. While average perception-reaction times range between 0.6-1.5 seconds, some drivers can take up to 3.5 seconds to react to upcoming hazards (2022 NCDOT Roadway Design manual, Section 3.2.4). Assuming a 3.5-second reaction time and travel at 58.67 ft/sec, the available stopping distance is approximately 595 feet. The minimum stopping sight distance for 40 mph rural arterials is 305 feet (2022 NCDOT Roadway Design manual, Table 3-1). Based on the 800-foot length, the space available for stopping sight distance will satisfy NCDOT's design requirements.

Tunnels produce an unusual environment for drivers, especially when considering the transition from an enclosed setting (inside of the tunnel) to an open setting (exiting the tunnel). Perception of two-way traffic in an enclosed space can also produce dizzying effects on drivers, which can be mitigated by dividing the road with a wall so that drivers do not see opposing traffic. Advance-warning signs, preferably ones integrated with the intersection signal controller, may be required within the tunnel given the complex driving environment and the presence of heavy vehicles on Lumley Rd. The environment would be made more complex if pedestrians and bicycles are added to the vehicle mix. If the City of Raleigh pursues pedestrian and bicycle routes within the tunnel, the confined nature of the tunnel poses a safety issue as potential escape routes in case of an out-of-control vehicle are limited. Further analysis of the intersection and advance-warning signs needs to be performed during design.

Tunnel Construction

Tunnels can be constructed via mining methods (using a tunnel boring machine) or through cut-and-cover methods. Geotechnical data was not obtained or reviewed to determine the best method to construct Lumley Road below grade. The tunnel is only constrained vertically by the elevation of the existing ground; the tunnel can be shallow and would likely be constructed via cut-and-cover methods. While at-grade alternatives require utilities, roadway materials, and any temporary construction materials, a tunnel requires considerable earthwork to be exported from the site and concrete and other materials to be imported. The construction process for a tunnel is considerably more robust than at-grade roadways.

From a maintenance of traffic (MOT) perspective the tunnel alternative will have a bigger impact on the daily typical operation and use of the Lumley Road. In the at-grade alternatives where Lumley Road is relocated, the existing roadway is anticipated to still be available to maintain traffic operations during most of the construction activities. To construct the tunnel in the same/similar alignment, a road closure of Lumley and or detour would be required. An alternate tunnel alignment or temporary roadway to maintain traffic could be required which may impact the Ward Transformer site anyway. This would be an added expense to constructing this alignment that is not calculated at this time.

TUNNEL ALTERNATIVE EVALUATION

This section evaluates the tunnel alternative using criteria including intersection operation, safety, engineering feasibility, right-of-way impact, environmental sensitivity, construction cost, local connectivity, and access.

Intersection Operation – With the tunnel alternative, the Lumley-Commerce intersection would still need to be relocated. The relocated Lumley-Commerce intersection would likely be a signalized T-intersection or roundabout. Further engineering design is required to ensure that appropriate distances are available for vehicle queuing and visibility requirements.

Safety – Stopping reaction time between the tunnel and the proposed Lumley-Commerce intersection may require advance warning signs. Driver comfort can decrease when tunnels are encountered. Tunnels require systems for ventilation, firefighting and fire protection, emergency egress, drainage, electrical, and lighting.

Engineering Feasibility – Tunneling is expected to be feasible from an engineering perspective. However, horizontal distance available between the eastern tunnel portal and the Lumley-Commerce intersection is limited and constrained by the extents of the Runway 23R Approach RPZ. Sight distance and stopping distance between the eastern portal and the proposed intersection will need to be further reviewed.

The alignment of the tunnel and construction techniques would impact the existing Lumley Road traffic, adjacent roadways, and businesses. Though the businesses are expected to be able to continue to operate, access to the businesses and Wake County EMS station would change.

Mt Herman Road would have to be realigned so that it could connect with Lumley Road before the start of the tunnel and out of the RPZ. For example access to the businesses will need to be changed from Mt Herman Road to the proposed Lumley Road (see **Figure 6**).

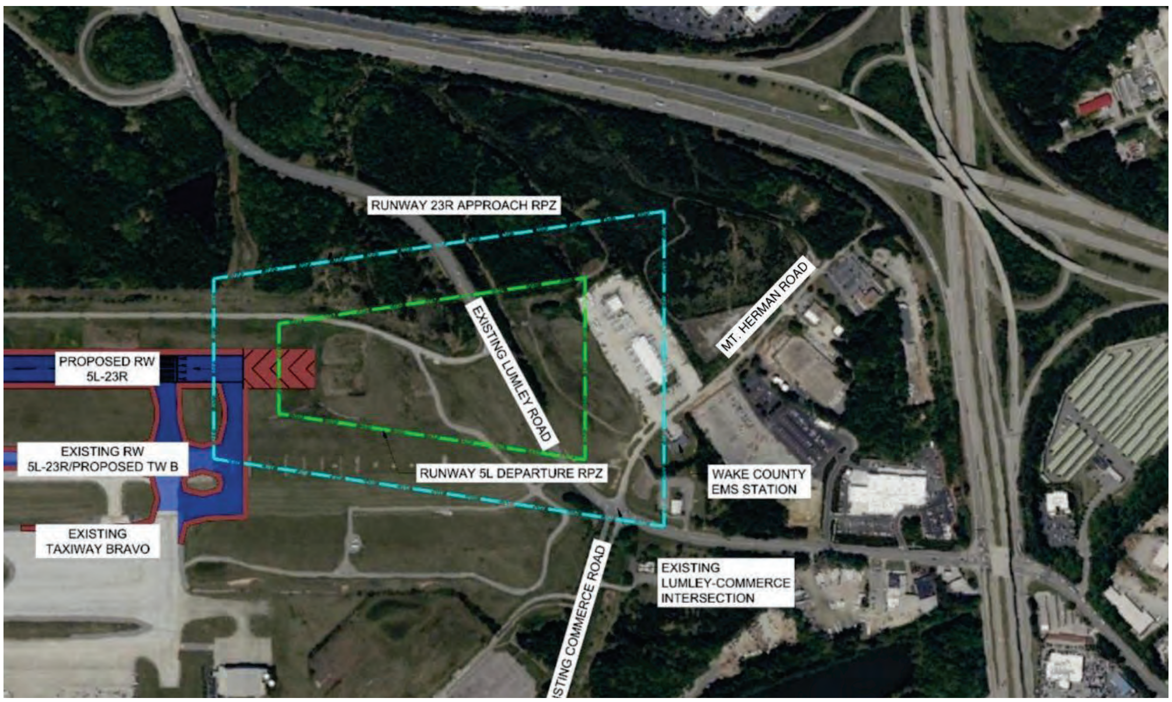


Figure 6: Proposed RPZ and nearby businesses

Environmental Sensitivity – Tunneling results in great earth disturbance. The tunnel alternative avoids crossing environmentally sensitive areas and avoids other site impacts. However, further study is required to determine whether the soil beneath Lumley Road is contaminated and would preclude tunneling without remediation.

In addition, information about geotechnical conditions and water resources would still need to be assessed in the design of the tunnel. In recent projects, the Airport has experienced a need to de-water sites during construction. For a tunnel project, de-watering would be necessary during construction and throughout the tunnel's indefinite lifespan.

Construction/Operating & Maintenance Cost – The estimated construction cost for the tunnel alternative with bike and pedestrian facilities is roughly $72.7 Million. This equates to a total Planning Level Program Estimate of $101.8M. The estimated construction cost for the tunnel alternative without bike and pedestrian facilities is roughly $53.4 Million. This equates to a total Planning Level Program Estimate of $74.8M. The difference in cost for the two tunnel alternatives is driven by the smaller cross section required for the alternative without bike and pedestrian facilities. Reducing the width of the tunnel reduces the value of roadway and structural concrete materials required for the alternatives. Both are substantially higher than the Planning Level Program Estimates of the previous at-grade alternatives, which range from $24.5-31.3 Million. The Program Estimates include an additive 15% for Construction Engineering & Inspection and an additional 25% contingency as for each planning-level estimate. A 25% contingency is an industry average and may be subject to change. Initial cost estimates for the Lumley Road Tunnel alternative (with and without the bike lane) is provided in **Attachment 1**.

The Operating & Maintenance (O&M) of the tunnel is not included in the estimates. The O&M is expected to be significantly higher than the similar efforts for the at-grade roadway on a monthly and yearly basis. Some of the operating costs would include electrical service for the lighting, ventilation, and drainage pumping systems. From the maintenance perspective, regular structural and fire & life safety systems inspections would be required.

Local Connectivity and Access –The relocation alternative would result in far less impacts to people traveling Lumley Road because a large portion of the road could be constructed while existing Lumley is still in use. During construction of a tunnel, Lumley Road would be shut down or rerouted on a constrained roadway for the entirety of construction, resulting in disruption of local traffic pattern.

LUMLEY ROAD RELOCATION ALTERNATIVE

The relocation of Lumley Road would result in the roadway crossing the contaminated Ward Transformer Superfund Site (see **Figure 7**), which has undergone remediation including installing a cap barrier for the soil. This site is currently undergoing a Remedial Investigation/Feasibility Study overseen by the EPA. The roadway relocation would involve excavation of dirt below ground

Figure 7: Ward Transformer Superfund Site, north of RDU and Lumley Rd. Source: US EPA, 2022.

surface in this area to create the subbase for the roadway. It is anticipated that contaminated soil and fill material may be encountered during demolition and construction activities. Any contaminated soil would be properly disposed of and/or remediated pursuant to applicable regulations. The relocated roadway's asphalt is an EPA-approved engineering control for preventing exposure to contamination on a property. The FAA has coordinated with the EPA. In a meeting on June 28, 2022, the EPA stated that it is acceptable to go below the existing cap and to change the shape of the soil pile in the potential road relocation area. The soil in this area is not highly contaminated and the anticipated impacts due to the road relocation would be minor. An initial cost estimate for the Lumley Road Relocation alternative is provided in **Attachment 1**.

SUMMARY AND RECOMMENDATION

This technical memorandum provides a preliminary evaluation of potentially providing a tunnel solution for Lumley Road instead of relocation outside and around the RPZ. Based on this preliminary evaluation and FAA's coordination with EPA, the tunneling alternative would result in unnecessary disruption of traffic patterns, undue complexity from a constructability perspective, and significantly higher initial and on-going yearly costs compared to the at-grade Lumley Road relocation alternative. Therefore, for these reasons the tunneling of Lumley Road alternative is not recommended to be carried forward for detailed analysis in the EA.

Attachment 1
Estimated Construction and Program Cost

RDU EA - Lumley Road Relocation - Tunneling Alternative (with Ped/Bike)
Raleigh-Durham International Airport
Preliminary Cost Estimate - September 2022

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL	ASSUMPTIONS / CALCULATIONS NOTES
1	Lumley Road	SY	31,667	$ 200.00	$ 6,333,333	Assumes 2,500 LF of roadway, 114' cross section
2	Commerce Relocation	LS	1	$ 1,500,000.00	$ 1,500,000	Based on previous planning study.
3	Curb and Gutter	LF	10,000	$ 45.00	$ 450,000	Assumes four curbs, two for each direction of flow.
4	New Traffic Signal	LS	1	$ 150,000.00	$ 150,000	Based on previous planning study.
5	Thermoplastic Marking	Mile	0.47	$ 100,000.00	$ 47,348	From NCDOT estimating standards.
6	MOT	LS	1.00	$ 500,000.00	$ 500,000	
7	**Lumley Road Relocation Subtotal**				**$ 8,480,682**	
8	Clearing and Grubbing	AC	8.61	$ 25,000.00	$ 215,220	Assumes 2,500 LF of roadway, with 150 total width of disturbance.
9	Unrestricted Excavation and Hauling on site to location required for Runway fill	CY	510,000.00	$ 9.00	$ 4,590,000	Assumes no double handling of excavated material. Laying back of side walls and/or Sheeting and Shoring is included in the unit price.
10	Erosion & Sediment Control	AC	8.61	$ 75,000.00	$ 645,661	Assumes area is equal to the clearing and grubbing limits.
11	Stormwater Managemet	LS	1	20%	$ 1,696,136	Assumes 20% of Lumley Road construction cost.
12	Drainage Improvements	LS	1	$ 1,200,000.00	$ 1,200,000	Based on previous planning study.
13	Utility Relocation	LS	1	25%	$ 2,120,170	Assumes 25% of Lumley Road construction cost.
14	Structural Concrete for Tunnel	TON	84,000	$ 450.00	$ 37,800,000	Based on tunnel being 2,500 feet long and 114 feet wide. Ceiling structure is 3 feet thick. Walls are 2,500 feet long, 35 feet high, and 1.5 feet wide.
15	Special Systems (includes mechanical systems, electrical system, and security/safety systems for ventilation life safety, fire supression, CCTV, etc.)	LF	2,500	$ 5,000.00	$ 12,500,000	Updated to 2,500 ft tunnel from 2,200 ft.
	Subtotal A =				**$ 69,247,870**	
			Mobilization	5%	$ 3,462,300	
	Subtotal B = Construction Cost				**$ 72,710,170**	
			CEI	15%	$ 10,906,500	
			Planning Level Contingency	25%	$ 18,177,500	
	Subtotal C = Program Cost Estimate				**$ 101,794,170**	

Attachment 2
Estimated Construction and Program Cost

RDU EA - Lumley Road Relocation - Tunneling Alternative (without Ped/Bike)
Raleigh-Durham International Airport
Preliminary Cost Estimate - September 2022

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL	ASSUMPTIONS / CALCULATIONS NOTES
1	Lumley Road	SY	16,667	$ 200.00	$ 3,333,333	Assumes 2,500 LF of roadway, 60' cross section
2	Commerce Relocation	LS	1	$ 1,500,000.00	$ 1,500,000	Based on previous planning study.
3	Curb and Gutter	LF	10,000	$ 45.00	$ 450,000	Assumes four curbs, two for each direction of flow.
4	New Traffic Signal	LS	1	$ 150,000.00	$ 150,000	Based on previous planning study.
5	Thermoplastic Marking	Mile	0.47	$ 100,000.00	$ 47,348	From NCDOT estimating standards.
6	MOT	LS	1.00	$ 500,000.00	$ 500,000	
7	**Lumley Road Relocation Subtotal**				**$ 5,480,682**	
8	Clearing and Grubbing	AC	5.74	$ 25,000.00	$ 143,480	Assumes 2,500 LF of roadway, with 100 FT total width of disturbance.
9	Unrestricted Excavation and Hauling on site to location required for Runway fill	CY	510,000.00	$ 9.00	$ 4,590,000	Assumes no double handling of excavated material. Laying back of side walls and/or Sheeting and Shoring is included in the unit price.
10	Erosion & Sediment Control	AC	5.74	$ 75,000.00	$ 430,441	Assumes area is equal to the clearing and grubbing limits.
11	Stormwater Managemet	LS	1	20%	$ 1,096,136	Assumes 20% of Lumley Road construction cost.
12	Drainage Improvements	LS	1	$ 1,200,000.00	$ 1,200,000	Based on previous planning study.
13	Utility Relocation	LS	1	25%	$ 1,370,170	Assumes 25% of Lumley Road construction cost.
14	Structural Concrete for Tunnel	TON	53,500	$ 450.00	$ 24,075,000	Based on tunnel being 2,500 feet long and 60 feet wide. Ceiling structure is 3 feet thick. Walls are 2,500 feet long, 35 feet high, and 1.5 feet wide.
15	Special Systems (includes mechanical systems, electrical system, and security/safety systems for ventilation life safety, fire supression, CCTV, etc.)	LF	2,500	$ 5,000.00	$ 12,500,000	2500
	Subtotal A =				**$ 50,885,910**	
			Mobilization	5%	$ 2,544,200	
	Subtotal B = Construction Cost				**$ 53,430,110**	
			CEI	15%	$ 8,014,500	
			Planning Level Contingency	25%	$ 13,357,500	
	Subtotal C = Program Cost Estimate				**$ 74,802,110**	

ENGINEER'S PRELIMINARY ESTIMATE OF PROBABLE CONSTRUCTION COSTS
LUMLEY ROAD RELOCATION
RALEIGH-DURHAM (RDU) AIRPORT
June 2, 2022

Item No.	Spec. Section	Description	Quantity	Unit	Unit Price	Extended Total
1	800	Mobilization	1	LS	$ 1,385,000.00	$ 1,385,000.00
3	200	Clearing and Grubbing	10	AC	$ 15,000.00	$ 150,000.00
4	225	Unclassified Excavation	124,193	CY	$ 20.00	$ 2,483,869.88
5		Treated Material Excavation (0-10ppm) & Embankment for Utility Corridor	5,600	CY	$ 214.00	$ 1,198,400.00
6		Utility Corridor Fresh Material Embankment (0 ppm)	5,600	CY	$ 98.00	$ 548,800.00
7		Treated Material Excavation (0-10 ppm) & Embankment for Lumley Corridor	17,500	CY	$ 214.00	$ 3,745,000.00
8	250	Removal of Existing Asphalt Pavement	29,236	SY	$ 12.00	$ 350,834.67
9	305	Drainage Pipes	1	LS	$ 600,000.00	$ 600,000.00
10	305	Drainage Structures	30	EA	$ 10,000.00	$ 300,000.00
11	520	Aggregate Base Course 12"	44,612	SY	$ 20.00	$ 892,243.33
12	610	Asphalt Concrete Intermediate Course	14,125	TON	$ 150.00	$ 2,118,684.36
13	610	Asphalt Surface Course	7,062	TON	$ 160.00	$ 1,129,964.99
14	846	Curb and Gutter	13,511	LF	$ 25.00	$ 337,775.00
15	862	Steel Beam Guardrail	7,900	LF	$ 15.00	$ 118,500.00
16	1110	Traffic Control	1	LS	$ 50,000.00	$ 50,000.00
17	1205	Thermo Pavement Markings	34,200	LF	$ 3.00	$ 102,600.00
18		Ductile Iron Force Main, 30"	11,500	LF	$ 800.00	$ 9,200,000.00
19		Ductile Iron Water Main, 16"	4,000	LF	$ 400.00	$ 1,600,000.00
20		30" Forcemain Removal and Disposal	11,500	LF	$ 150.00	$ 1,725,000.00
21		16" Waterline Removal and Disposal	4,000	LS	$ 75.00	$ 300,000.00
22		Utility Trench Select Backfill	2,750	CY	$ 72.00	$ 198,000.00
23		Utility Restoration	1	LS	$ 250,000.00	$ 250,000.00
24		Traffic Signal	1	LS	$ 300,000.00	$ 300,000.00
25		Contingencey (20%)	1	LS	$ 5,800,000.00	$ 5,800,000.00
					Total:	$ 34,884,672.22

Subject:	**Off-Site Borrow Analysis** Runway 5L-23R Replacement Program EA Support
RDUAA No.:	080879
RS&H No.:	203-2760-000
Date:	October 21, 2022

C.1 SCHEMATIC COST ESTIMATE BORROW ASSUMPTIONS

During the Runway 5L-23R schematic design program, RS&H produced an "Alternative Borrow Pit Location Cost Analysis (Off-Airport Property)" memorandum that evaluated the impacts to the program cost and schedule for obtaining the required fill material from off-site sources in lieu of utilizing on-site material. In addition to a comparison between off-site and on-site fill sourcing, the memorandum compared costs and scheduling impacts for a conveyor system over Brier Creek Reservoir versus traditional truck hauling from borrow pit sites (see Attachment 1).

To obtain all 5 million (M) cubic yards (CY) of material from on-sites sources, potential Waters of the U.S. (WOTUS) and potential Neuse River Watershed riparian buffers (NRB) would be impacted. The Environmental Assessment (EA) evaluated alternatives for both avoiding and minimizing impacts to potential WOTUS and NRB. However, the Authority has requested RS&H and the Construction Manager at Risk (CMR) to reevaluate the use of off-site borrow sources with current market assumptions and construction costs.

For preliminary estimates, the CMR has assumed a production rate of 16,000 CY per day from on-site borrow areas by utilizing double shifts and two conveyors. If the on-site borrow areas are not used exclusively, the remaining fill material will be obtained from local quarries via traditional truck hauling. Two alternatives to exclusively sourcing material from on-site were considered, and there would be no impacts to potential WOTUS or NRB in either of these scenarios.

Alternative 1A (Alt 1A):

1. 2.5 M CY of fill would be obtained from borrow sites 1A/1B.
2. 2.5 M CY of fill would be obtained from off-site borrow sources.

Alternative 1B (Alt 1B):

1. 3.1 M CY of fill would be obtained from borrow sites 1A/1B (assumes removal of existing farm pond).
2. 1.9 M CY of fill would be obtained from off-site borrow sources.

Alternative 2 (Alt 2):

3. 5 M CY of fill material would be obtained from off-site borrow sources.

Table 1 Borrow Material Source Alternatives Comparison

Borrow Material Source	+Quantity (CY)	*Cost/CY	***Total	Total Duration (days)
On-Site Material with Conveyance System	5,000,000	$7.76	$38,800,000	470
Alt 1A				
On-Site	2,500,000	$7.76	$19,400,000	245
Martin Marietta - Raleigh	1,750,000	$16.59	$29,032,500	788
Wake Stone - Knightdale	750,000	$38.35	$28,762,500	848
		Total	$77,195,000	**1,093
Alt 1B				
On-Site	3,100,000	$7.76	$24,056,000	308
Martin Marietta - Raleigh	1,750,000	$16.59	$29,032,500	788
Wake Stone - Knightdale	150,000	$38.35	$5,752,500	170
		Total	$77,195,000	**788
Alt 2				
Martin Marietta - Raleigh	1,750,000	$16.59	$29,032,500	788
Martin Marietta - Garner	1,250,000	$44.25	$55,312,500	1654
Wake Stone - Knightdale	1,000,000	$38.35	$38,350,000	1130
West Brothers - Durham	500,000	$36.91	$18,455,000	532
Gorilla Materials - Durham	500,000	$56.14	$28,070,000	822
		Total	$169,220,000	**2,740

*Represents costs delivered to the site. Placement and compaction costs are not included. +Approximation. **Assumes up to two quarries running simultaneously. ***Assumes 2022 construction dollars

Table 2 Off Site Borrow Alternative Schedule Impacts

Borrow Material Source	Total Duration (Days)	*Increase in Duration (Days)	*Increase in Duration (Months)	*Increase in Duration (Years)
On-Site Material	470	-	-	-
Alt 1A	1093	623	21	1.7
Alt 1B	788	318	11	0.9
Alt 2	2,740	2,270	75	6.2

*Increase in duration in comparison with obtaining all material from on-site.

The CMR utilized the following assumptions to establish the durations for Alt 1 and Alt 2. Only two borrow sources can be utilized at any given time due to limited access points to the project site, and current market labor and equipment shortages will affect labor shift duration and frequency of truck deliveries possible per day. Based on conversations with site contractors and quarries, only thirty (30) trucks could operate at any one source site due to personnel and equipment shortages. With just two (2) project site entrances, only two (2) borrow sources could be utilized at any given time for a maximum of sixty (60) trucks (30 per borrow site) in operation. However, this assumes these trucks will be available, which is unlikely based on the current shortages. Advanced coordination would be required to commit this volume of equipment and personnel.

Additionally, the operation could still be restricted by Department of Transportation (DOT) hour limitations for shift work and brokerage companies advising on truck orders.

Appropriate geotechnical investigations of potential borrow sources would be required prior to any borrow site location approval.

Considering the current trucking market and lack of available borrow material near the airport, obtaining off-site material will adversely impact the program's implementation and schedule significantly.

C.2 OFF-SITE BORROW SOURCE ENVIRONMENTAL IMPACTS

Obtaining and using off-site borrow material quantities referenced in options Alt 1 and Alt 2 would create the following additional environmental impacts, which would not meet the Least Environmentally Damaging Practicable Alternative (LEDPA) requirements and would create logistical complications during construction:

1. Off-site borrow material stockpiling would create erosion and sediment control issues.
   - A substantial amount of fill would need to be stockpiled at any one time to minimize construction delays would propagate issues into other phases of construction.
   - The erosion and sediment engineering controls necessary to prevent significant soil runoff from the stockpile would require substantial engineering and the possible construction of detention or retention basins.

2. Trucks to the site could present noise level and air quality degradation, traffic congestion, and stormwater permit compliance issues.
   - The frequency and number of trucks transiting the site could rapidly overwhelm track-out sediment control devices. The implementation of these best management practices (BMPs) would require substantial, if not impracticable, labor effort with an increased risk of potential discharges increased between cleanouts.
   - Facilities, equipment, BMPs, and substantial labor would be necessary to wash off the numerous, dirt-covered trucks before exiting the site.

3. The project would require a significant increase in staff and labor effort to meet the compliance requirements of the construction stormwater permits and SWPPP to complete routine inspections and repair damaged or failing BMPs.
   - In addition to track-out devices, other standard BMP controls for the stockpile site, truck staging areas, and exits must be inspected weekly by staff that may not be available based on current labor market limitations.
   - Routine repairs would require substantial, and likely unpracticable, maintenance and labor effort, assuming these BMPs could be effective under the Alt 1 and Alt 2 conditions, which is doubtful.

4. The off-site alternatives would require clearing and preparation of a large area to accommodate the soil stockpiling area.
   - This would increase the overall impact footprint as related to the LEDPA alternatives comparison.
   - The action could result in the temporary or permanent loss of forested area and wildlife habitats.

C.3 SUMMARY

Considering the current shortage of labor and equipment, the use of material from off-site sources would increase the program duration by an additional 0.9 – 6.2 years. Increasing the runway construction duration creates and unacceptable level of risk for the airport as continuing to utilize the existing deteriorating runway creates an aircraft/passenger safety hazard from increased foreign object debris (FOD) potential. The significant increase in the project duration, as well as the additional adverse environmental impacts, makes obtaining off-site material impracticable.

ATTACHMENT 1

ALTERNATIVE BORROW PIT LOCATION COST ANALYSIS (OFF-AIRPORT PROPERTY) JANUARY 8, 2020 MEMORANDUM

TECHNICAL MEMORANDUM

Subject:	**Alternative Borrow Pit Location Cost Analysis (Off-Airport Property)** Runway 5L-23R Replacement Program Program Validation and Schematic Design Development Services
RDUAA No.:	080879
RS&H No.:	203-2760-000
Date:	January 8, 2020

C.1 SCHEMATIC COST ESTIMATE BORROW ASSUMPTIONS

The schematic design cost estimate for the Runway 5L/23R and Taxiway B Replacement program (12/2019) compared the costs of a conveyor system with that of traditional truck hauling as means of transportation for approximately 5 million cubic yards of borrow material needed for the proposed program. Assumed in these costs were the use of Airport-owned borrow sites located adjacent to Brier Creek Reservoir as the source of material. The truck hauling route from borrow sites to project site is approximately 2 miles. The following construction estimates were established for excavation, transportation, and placement of material from the on-site borrow areas and incorporated into the schematic design cost estimate:

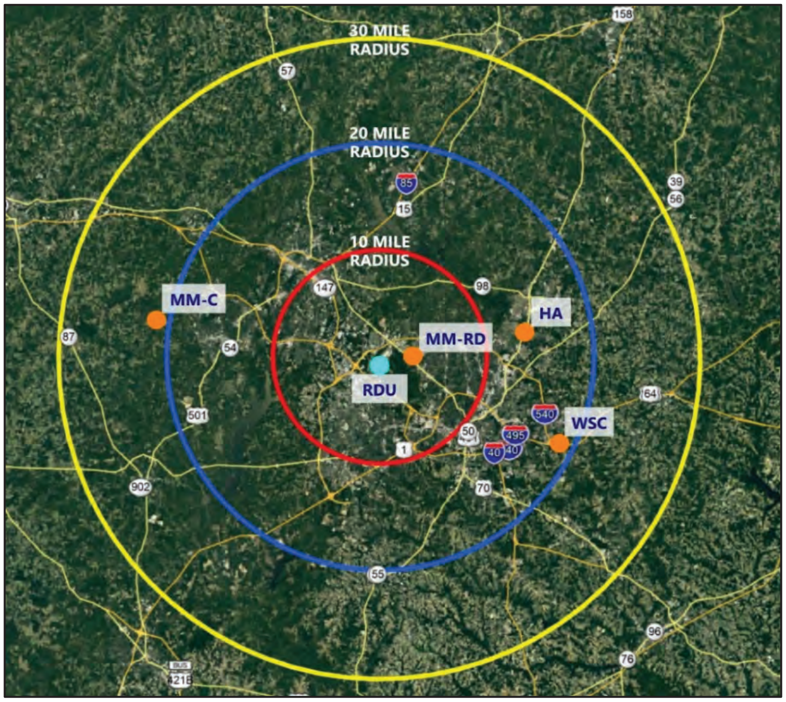
Borrow Material Transportation Method	Quantity (CY)	Unit Cost ($/CY)	Total	Total Duration (days)
Conveyance System	4,776,000	$6.00	$28,656,000	199
Traditional Truck Hauling	4,776,000	$8.00	$38,208,000	238

C.2 ALTERNATIVE SOURCES OF BORROW MATERIAL

If the Airport elects or is unable to make use of the on-site borrow areas, the necessary fill material will need to be obtained from local quarries via traditional truck hauling. The RS&H Team identified quarries within 10, 20, and 30-mile radii to determine how varying hauling distances could affect construction prices of the borrow material. The following quarry locations were investigated as potential sources of borrow material:

- Martin Marietta - Raleigh-Durham Quarry (MM-RD): 2-mile haul route
- Hanson Aggregates – Wake Forest (HA): 18-mile haul route
- Wake Stone Corporation – Knightdale (WSC): 22-mile haul route
- Martin Marietta – Carrboro (MM-C): 26-mile haul route

See the figure below for approximate quarry locations relative to RDU.



An initial cost analysis was performed for each quarry in which a production rate of 24,000 CY of borrow material per day, which matches the estimated rate of the proposed conveyor system, was held constant for an even comparison. As the distance from RDU increases more than a few miles, this assumed production rate becomes unrealistic as the number of trucks necessary to meet this rate becomes impractical.

Additional analysis was conducted in which 60 total trucks were assumed and held constant over each quarry option, which results in decreased daily production rates as the hauling distance from RDU increases. The following estimates were developed for the procurement, transportation, and placement of borrow material from the surrounding quarries and compared with the on-site borrow methods for reference:

Borrow Source	Haul Route Distance (miles)	Number of Trucks	Production Rate (CY/day)	Unit Cost ($/CY)	Total	Total Duration (days)	Difference from Base (price/duration)	
On-site Conveyor (Base)	N/A	N/A	24,000	$6.00	$28,656,000	199	N/A	N/A
On-site Trucking	2	25	20,000	$8.00	$38,208,000	238	+$9,552,000	+39
MM-RD	2	40	24,000	$13.65	$65,192,000	230[1]	+$36,536,000	+31
HA	18	160[2]	24,000	$31.00	$148,056,000	230[1]	+$119,400,000	+31
WSC	22	229[2]	24,000	$38.71	$184,879,000	230[1]	+$165,223,000	+31
MM-C	26	320[2]	24,000	$48.88	$232,962,000	230[1]	+$204,306,000	+31
HA	18	60	7,200	$43.54	$207,947,000	765[1]	+$179,291,000	+566
WSC	22	60	6,300	$48.95	$233,785,000	874[1]	+$205,129,000	+675
MM-C	26	60	4,500	$66.32	$316,744,000	1225[1]	+$288,088,000	+1026

1. 15% Efficiency Loss assumed is due to availability/reliability of off-site trucking.
2. Number of trucks considered impractical.

See Attachment 1 for a detailed breakdown of costs.

C.3 SUMMARY

As the haul distance from RDU increases, the total price of borrow material is anticipated to increase drastically. Assuming a reasonable amount of trucks in use, the increased distance and hauling time results in significantly lower daily production rates and a longer construction schedule to move all borrow material. The proportional increase in labor hours and equipment rental time for the duration of the hauling operation increases the overall price significantly.

ATTACHMENT 1

BORROW MATERIAL ANALYSES

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		Revision	
Original Date	7-Nov-19	Revision Date	
Assumed Bid Opening Date		CI Project No.	4111.18
Project Manager	DJH	Checked by	CSG

Earthwork Unit Cost - Traditional Hauling

Schematic Design Estimate

Unclassified to Embankment =	944,000	cy
Fill Required	5,720,000	cy
TOTAL Borrow	4,776,000	CY

Haul Distance is about 2 miles with Road Trucks.

Should make 4 trips per hour
10 hour day gives 40 trips per truck

Total Number of trucks =	40	ea.				
Total Days Production =	1600	Truck loads	15	CY/Load	24000	199
				Say		200
				Add 15% for Loss of Efficiency		230

Material from Quarry Nearby

Description	Number	Hours (reg)	Hours (OT)	Hourly Rate (Reg)	Hourly Rate (OT)	Total
Labor						
Foreman	2	1840	460	$ 50.00	$ 75.00	$ 253,000.00
Operators	13	1840	460	$ 19.00	$ 28.50	$ 624,910.00
Laborers	4	1840	460	$ 15.00	$ 22.50	$ 151,800.00
Truck Drivers	40	1840	460	$ 16.00	$ 24.00	$ 1,619,200.00
						$ 2,648,910.00
					40% Burden	$ 1,059,564.00
					Total Labor Cost	$ 3,708,474.00
Equipment						
Pick-up	2	2300		$ 15.00		$ 69,000.00
D9 Dozer	6	2300		$ 375.00		$ 5,175,000.00
Grader	1	2300		$ 300.00		$ 690,000.00
Tractor with Bog Disc	2	2300		$ 225.00		$ 1,035,000.00
Large Excavators	2	2300		$ 500.00		$ 2,300,000.00
Water Truck	2	2300		$ 175.00		$ 805,000.00
CAT 825 Compactors	2	2300		$ 225.00		$ 1,035,000.00
Tandem Dump Trucks	40	2300		$ 150.00		$ 13,800,000.00

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		Revision	
Original Date	7-Nov-19	Revision Date	
Assumed Bid Opening Date		CI Project No.	4111.18
Project Manager	DJH	Checked by	CSG

Earthwork Unit Cost - Traditional Hauling

Schematic Design Estimate

	$	24,909,000.00
20% Parts & Fuel	$	4,981,800.00
Total Equipment Cost	$	29,890,800.00
Total Borrow Hauling & Placement Cost	$	33,599,274.00
Total Material Cost ($5/cy per Martin Marietta Quarry)	$	23,880,000.00
Total Cost	$	57,479,274.00
Cost/CY	$	12.04
8% OH	$	0.96
	$	13.00
5% Profit	$	0.65
Total Cost for Quarry Source Fill & Placement	$	13.65

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		Revision	
Original Date	19-Dec-19	Revision Date	
Assumed Bid Opening Date		CI Project No.	4111.18
Project Manager	DJH	Checked by	CSG

Earthwork Unit Cost - Quarry Purchase (10mi Distance)

Schematic Design Estimate

Unclassified to Embankment =	944,000	cy
Fill Required	5,720,000	cy
TOTAL Borrow	4,776,000	CY

Quarry Location: 10501 Capital Blvd, Wake Forest, NC 27587
Haul Distance is about 18 miles with Road Trucks.

Should make 1 trip per 1.25 hours
10 hour day gives 8 trips per truck

Total Number of trucks = 160 ea. *This quantity of trucks is unrealistic.

Total Days Production =	1600	Truck loads	15	CY/Load	24000	199
				Say		200
				Add 15% for Loss of Efficiency		230

Material from Quarry Nearby

Description	Number	Hours (reg)	Hours (OT)	Hourly Rate (Reg)	Hourly Rate (OT)	Total
Labor						
Foreman	4	1840	460	$ 50.00	$ 75.00	$ 506,000.00
Operators	34	1840	460	$ 19.00	$ 28.50	$ 1,634,380.00
Laborers	4	1840	460	$ 15.00	$ 22.50	$ 151,800.00
Truck Drivers	160	1840	460	$ 16.00	$ 24.00	$ 6,476,800.00
						$ 8,768,980.00
					40% Burden	$ 3,507,592.00
					Total Labor Cost	$ 12,276,572.00
Equipment						
Pick-up	4	2300		$ 15.00		$ 138,000.00
D9 Dozer	6	2300		$ 375.00		$ 5,175,000.00
Grader	2	2300		$ 300.00		$ 1,380,000.00
Tractor with Bog Disc	4	2300		$ 225.00		$ 2,070,000.00
Large Excavators	6	2300		$ 500.00		$ 6,900,000.00
Water Truck	4	2300		$ 175.00		$ 1,610,000.00
CAT 825 Compactors	12	2300		$ 225.00		$ 6,210,000.00
Tandem Dump Trucks	160	2300		$ 150.00		$ 55,200,000.00

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		Revision	
Original Date	19-Dec-19	Revision Date	
Assumed Bid Opening Date		CI Project No.	4111.18
Project Manager	DJH	Checked by	CSG

Earthwork Unit Cost - Quarry Purchase (10mi Distance)

Schematic Design Estimate

	$	78,683,000.00
20% Parts & Fuel	$	15,736,600.00
Total Equipment Cost	$	94,419,600.00
Total Borrow Hauling & Placement Cost	$	106,696,172.00
Total Material Cost ($5/cy per Martin Marietta Quarry)	$	23,880,000.00
Total Cost	$	130,576,172.00
Cost/CY	$	27.34
8% OH	$	2.19
	$	29.53
5% Profit	$	1.48
Total Cost for Quarry Source Fill & Placement	$	31.00

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		**Revision**	
Original Date	7-Nov-19	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4111.18
Project Manager	DJH	**Checked by**	CSG

Earthwork Unit Cost - Quarry Purchase (20mi Distance)

Schematic Design Estimate

Unclassified to Embankment =	944,000 cy
Fill Required	5,720,000 cy
TOTAL Borrow	4,776,000 CY

Quarry Location: 6632 Knightdale Blvd, Knightdale, NC 27545
Haul Distance is about 22 miles with Road Trucks.

Should make 1 trip per 1.5 hours
10 hour day gives 7 trips per truck

Total Number of trucks =	229 ea.	*This quantity of trucks is unrealistic.			
Total Days Production =	1600 Truck loads	15 CY/Load		24000	199
			Say		200
			Add 15% for Loss of Efficiency		230

<u>Material from Quarry Nearby</u>

Description	Number	Hours (reg)	Hours (OT)	Hourly Rate (Reg)	Hourly Rate (OT)	Total
<u>Labor</u>						
Foreman	4	1840	460	$ 50.00	$ 75.00	$ 506,000.00
Operators	34	1840	460	$ 19.00	$ 28.50	$ 1,634,380.00
Laborers	4	1840	460	$ 15.00	$ 22.50	$ 151,800.00
Truck Drivers	229	1840	460	$ 16.00	$ 24.00	$ 9,269,920.00
						$ 11,562,100.00
					40% Burden	$ 4,624,840.00
					Total Labor Cost	$ 16,186,940.00
<u>Equipment</u>						
Pick-up	4	2300		$ 15.00		$ 138,000.00
D9 Dozer	6	2300		$ 375.00		$ 5,175,000.00
Grader	2	2300		$ 300.00		$ 1,380,000.00
Tractor with Bog Disc	4	2300		$ 225.00		$ 2,070,000.00
Large Excavators	6	2300		$ 500.00		$ 6,900,000.00
Water Truck	4	2300		$ 175.00		$ 1,610,000.00
CAT 825 Compactors	12	2300		$ 225.00		$ 6,210,000.00
Tandem Dump Trucks	229	2300		$ 150.00		$ 79,005,000.00

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		**Revision**	
Original Date	7-Nov-19	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4111.18
Project Manager	DJH	**Checked by**	CSG

Earthwork Unit Cost - Quarry Purchase (20mi Distance)

Schematic Design Estimate

	$ 102,488,000.00
20% Parts & Fuel	$ 20,497,600.00
Total Equipment Cost	$ 122,985,600.00
Total Borrow Hauling & Placement Cost	$ 139,172,540.00
Total Material Cost ($5/cy per Martin Marietta Quarry)	$ 23,880,000.00
Total Cost	$ 163,052,540.00
Cost/CY	$ 34.14
8% OH	$ 2.73
	$ 36.87
5% Profit	$ 1.84
Total Cost for Quarry Source Fill & Placement	$ 38.71

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		Revision	
Original Date	7-Nov-19	Revision Date	
Assumed Bid Opening Date		CI Project No.	4111.18
Project Manager	DJH	Checked by	CSG

Earthwork Unit Cost - Quarry Purchase (30mi Distance)

Schematic Design Estimate

Unclassified to Embankment =	944,000	cy
Fill Required	5,720,000	cy
TOTAL Borrow	4,776,000	CY

Quarry Location: 1807 NC-54, Carrboro, NC 27510
Haul Distance is about 26 miles with Road Trucks.

Should make 1 trip per 2 hours
10 hour day gives 5 trips per truck

Total Number of trucks =	320	ea.	*This quantity of trucks is unrealistic.			
Total Days Production =	1600	Truck loads	15	CY/Load	24000	199
					Say	200
					Add 15% for Loss of Efficiency	230

Material from Quarry Nearby

Description	Number	Hours (reg)	Hours (OT)	Hourly Rate (Reg)	Hourly Rate (OT)	Total
Labor						
Foreman	4	1840	460	$ 50.00	$ 75.00	$ 506,000.00
Operators	34	1840	460	$ 19.00	$ 28.50	$ 1,634,380.00
Laborers	4	1840	460	$ 15.00	$ 22.50	$ 151,800.00
Truck Drivers	320	1840	460	$ 16.00	$ 24.00	$ 12,953,600.00
						$ 15,245,780.00
					40% Burden	$ 6,098,312.00
					Total Labor Cost	$ 21,344,092.00
Equipment						
Pick-up	4	2300		$ 15.00		$ 138,000.00
D9 Dozer	6	2300		$ 375.00		$ 5,175,000.00
Grader	2	2300		$ 300.00		$ 1,380,000.00
Tractor with Bog Disc	4	2300		$ 225.00		$ 2,070,000.00
Large Excavators	6	2300		$ 500.00		$ 6,900,000.00
Water Truck	4	2300		$ 175.00		$ 1,610,000.00
CAT 825 Compactors	12	2300		$ 225.00		$ 6,210,000.00
Tandem Dump Trucks	320	2300		$ 150.00		$ 110,400,000.00

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		**Revision**	
Original Date	7-Nov-19	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4111.18
Project Manager	DJH	**Checked by**	CSG

Earthwork Unit Cost - Quarry Purchase (30mi Distance)

Schematic Design Estimate

	$ 133,883,000.00
20% Parts & Fuel	$ 26,776,600.00
Total Equipment Cost	$ 160,659,600.00
Total Borrow Hauling & Placement Cost	$ 182,003,692.00
Total Material Cost ($5/cy per Martin Marietta Quarry)	$ 23,880,000.00
Total Cost	$ 205,883,692.00
Cost/CY	$ 43.11
8% OH	$ 3.45
	$ 46.56
5% Profit	$ 2.33
Total Cost for Quarry Source Fill & Placement	$ 48.88

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		Revision	
Original Date	19-Dec-19	Revision Date	
Assumed Bid Opening Date		CI Project No.	4111.18
Project Manager	DJH	Checked by	CSG

Earthwork Unit Cost - Quarry Purchase (10mi Distance)

Schematic Design Estimate

Unclassified to Embankment =	944,000	cy
Fill Required	5,720,000	cy
TOTAL Borrow	4,776,000	CY

Quarry Location: 10501 Capital Blvd, Wake Forest, NC 27587
Haul Distance is about 18 miles with Road Trucks.

Should make 1 trip per 1.25 hours
10 hour day gives 8 trips per truck

Total Number of trucks =	60	ea.				
Total Days Production =	480	Truck loads	15	CY/Load	7200	663.3333333
				Say		665
				Add 15% for Loss of Efficiency		764.75

Material from Quarry Nearby

Description	Number	Hours (reg)	Hours (OT)	Hourly Rate (Reg)	Hourly Rate (OT)	Total
Labor						
Foreman	2	6118	1529.5	$ 50.00	$ 75.00	$ 841,225.00
Operators	21	6118	1529.5	$ 19.00	$ 28.50	$ 3,356,487.75
Laborers	4	6118	1529.5	$ 15.00	$ 22.50	$ 504,735.00
Truck Drivers	60	6118	1529.5	$ 16.00	$ 24.00	$ 8,075,760.00
						$ 12,778,207.75
					40% Burden	$ 5,111,283.10
					Total Labor Cost	$ 17,889,490.85
Equipment						
Pick-up	2	7647.5		$ 15.00		$ 229,425.00
D9 Dozer	4	7647.5		$ 375.00		$ 11,471,250.00
Grader	1	7647.5		$ 300.00		$ 2,294,250.00
Tractor with Bog Disc	2	7647.5		$ 225.00		$ 3,441,375.00
Large Excavators	4	7647.5		$ 500.00		$ 15,295,000.00
Water Truck	2	7647.5		$ 175.00		$ 2,676,625.00
CAT 825 Compactors	8	7647.5		$ 225.00		$ 13,765,500.00
Tandem Dump Trucks	60	7647.5		$ 150.00		$ 68,827,500.00

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		**Revision**	
Original Date	19-Dec-19	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4111.18
Project Manager	DJH	**Checked by**	CSG

Earthwork Unit Cost - Quarry Purchase (10mi Distance)

Schematic Design Estimate

	$ 118,000,925.00
20% Parts & Fuel	$ 23,600,185.00
Total Equipment Cost	$ 141,601,110.00
Total Borrow Hauling & Placement Cost	$ 159,490,600.85
Total Material Cost ($5/cy per Martin Marietta Quarry)	$ 23,880,000.00
Total Cost	$ 183,370,600.85
Cost/CY	$ 38.39
8% OH	$ 3.07
	$ 41.47
5% Profit	$ 2.07
Total Cost for Quarry Source Fill & Placement	$ 43.54

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		**Revision**	
Original Date	7-Nov-19	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4111.18
Project Manager	DJH	**Checked by**	CSG

Earthwork Unit Cost - Quarry Purchase (20mi Distance)

Schematic Design Estimate

Unclassified to Embankment =	944,000	cy
Fill Required	5,720,000	cy
TOTAL Borrow	4,776,000	CY

Quarry Location: 6632 Knightdale Blvd, Knightdale, NC 27545
Haul Distance is about 22 miles with Road Trucks.

Should make 1 trip per 1.5 hours
10 hour day gives 7 trips per truck

Total Number of trucks =	60	ea.				
Total Days Production =	420	Truck loads	15	CY/Load	6300	758.0952381
				Say		760
				Add 15% for Loss of Efficiency		874

Material from Quarry Nearby

Description	Number	Hours (reg)	Hours (OT)	Hourly Rate (Reg)	Hourly Rate (OT)	Total
Labor						
Foreman	2	6992	1748	$ 50.00	$ 75.00	$ 961,400.00
Operators	21	6992	1748	$ 19.00	$ 28.50	$ 3,835,986.00
Laborers	4	6992	1748	$ 15.00	$ 22.50	$ 576,840.00
Truck Drivers	60	6992	1748	$ 16.00	$ 24.00	$ 9,229,440.00
						$ 14,603,666.00
					40% Burden	$ 5,841,466.40
					Total Labor Cost	$ 20,445,132.40
Equipment						
Pick-up	2	8740		$ 15.00		$ 262,200.00
D9 Dozer	4	8740		$ 375.00		$ 13,110,000.00
Grader	1	8740		$ 300.00		$ 2,622,000.00
Tractor with Bog Disc	2	8740		$ 225.00		$ 3,933,000.00
Large Excavators	4	8740		$ 500.00		$ 17,480,000.00
Water Truck	2	8740		$ 175.00		$ 3,059,000.00
CAT 825 Compactors	8	8740		$ 225.00		$ 15,732,000.00
Tandem Dump Trucks	60	8740		$ 150.00		$ 78,660,000.00

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		Revision	
Original Date	7-Nov-19	Revision Date	
Assumed Bid Opening Date		CI Project No.	4111.18
Project Manager	DJH	Checked by	CSG

Earthwork Unit Cost - Quarry Purchase (20mi Distance)

Schematic Design Estimate

	$ 134,858,200.00
20% Parts & Fuel	$ 26,971,640.00
Total Equipment Cost	$ 161,829,840.00
Total Borrow Hauling & Placement Cost	$ 182,274,972.40
Total Material Cost ($5/cy per Martin Marietta Quarry)	$ 23,880,000.00
Total Cost	$ 206,154,972.40
Cost/CY	$ 43.16
8% OH	$ 3.45
	$ 46.62
5% Profit	$ 2.33
Total Cost for Quarry Source Fill & Placement	$ 48.95

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		**Revision**	
Original Date	7-Nov-19	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4111.18
Project Manager	DJH	**Checked by**	CSG

Earthwork Unit Cost - Quarry Purchase (30mi Distance)

Schematic Design Estimate

Unclassified to Embankment =	944,000	cy
Fill Required	5,720,000	cy
TOTAL Borrow	4,776,000	CY

Quarry Location: 1807 NC-54, Carrboro, NC 27510
Haul Distance is about 26 miles with Road Trucks.

Should make 1 trip per 2 hours
10 hour day gives 5 trips per truck

Total Number of trucks = 60 ea.

Total Days Production =	300 Truck loads	15 CY/Load		4500	1061.333333
			Say		1065
			Add 15% for Loss of Efficiency		1224.75

<u>Material from Quarry Nearby</u>

Description	Number	Hours (reg)	Hours (OT)	Hourly Rate (Reg)	Hourly Rate (OT)	Total
<u>Labor</u>						
Foreman	2	9798	2449.5	$ 50.00	$ 75.00	$ 1,347,225.00
Operators	21	9798	2449.5	$ 19.00	$ 28.50	$ 5,375,427.75
Laborers	4	9798	2449.5	$ 15.00	$ 22.50	$ 808,335.00
Truck Drivers	60	9798	2449.5	$ 16.00	$ 24.00	$ 12,933,360.00
						$ 20,464,347.75
					40% Burden	$ 8,185,739.10
					Total Labor Cost	$ 28,650,086.85
<u>Equipment</u>						
Pick-up	2	12247.5		$ 15.00		$ 367,425.00
D9 Dozer	4	12247.5		$ 375.00		$ 18,371,250.00
Grader	1	12247.5		$ 300.00		$ 3,674,250.00
Tractor with Bog Disc	2	12247.5		$ 225.00		$ 5,511,375.00
Large Excavators	4	12247.5		$ 500.00		$ 24,495,000.00
Water Truck	2	12247.5		$ 175.00		$ 4,286,625.00
CAT 825 Compactors	8	12247.5		$ 225.00		$ 22,045,500.00
Tandem Dump Trucks	60	12247.5		$ 150.00		$ 110,227,500.00

Project Title	Runway 5L/23R Replacement		
Location	Raleigh-Durham International Airport		
Submittal Stage	Schematic Design Estimate		
Client Project No.		**Revision**	
Original Date	7-Nov-19	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4111.18
Project Manager	DJH	**Checked by**	CSG

Earthwork Unit Cost - Quarry Purchase (30mi Distance)

Schematic Design Estimate

	$ 188,978,925.00
20% Parts & Fuel	$ 37,795,785.00
Total Equipment Cost	$ 226,774,710.00
Total Borrow Hauling & Placement Cost	$ 255,424,796.85
Total Material Cost ($5/cy per Martin Marietta Quarry)	$ 23,880,000.00
Total Cost	$ 279,304,796.85
Cost/CY	$ 58.48
8% OH	$ 4.68
	$ 63.16
5% Profit	$ 3.16
Total Cost for Quarry Source Fill & Placement	$ 66.32