6. ECONOMIC VALUES RELATED TO AIRCRAFT PERFORMANCE FACTORS

6.1 INTRODUCTION

Certain types of investment programs or regulatory changes can affect aircraft performance. This can occur by changing the weight of the aircraft, which in turn changes the fuel burn as well as altering the time in certain phases of flight. This section covers two elements related to aircraft performance:

- The changes in fuel use caused by incremental changes in aircraft weight
- The proportion of time spent in various phases of flight on representative aircraft missions, which may also be influenced by changes in aircraft weight

Measures are developed for air carrier and general aviation aircraft. Data were not available on military aircraft performance. This section also contains data on the price of aviation fuel and sources for updated information on fuel prices.

The objective of this section is to provide values for use in economic analyses related to investment and regulatory decisions that alter the performance of aircraft. For example, increases in aircraft weight affect fuel burn. The issue of when mandated increases in aircraft weight affect the suitability of an aircraft for specific missions is not directly examined in this section. For example, aircraft are designed with a target mission in terms of payload and range in mind, and these are performed at an assumed maximum aircraft weight. If a regulation were to cause a large change in aircraft weight, then the aircraft may not be capable of performing some of the missions for which it was designed. In this section, the values presented assume that the incremental changes in aircraft weight do not occur at the limits of the payload-range envelope.

When regulatory actions occur during the aircraft design phase, aircraft weight increases will often cause an increase in installed power, fuel capacity, and so forth to maintain the target payload-range capability. Essentially, the increase in aircraft weight requires an increase in the amount of fuel used to fly the same mission. The increase in fuel used adds weight to the aircraft requiring additional fuel to be carried. The aircraft design would then be optimized for these new performance parameters. The re-optimization of an aircraft design is not considered in the values developed below. Re-optimization of a design may be the most appropriate type of analysis in some cases; however, it is not possible to capture this in a standard economic value.

6.2 APPROACH

The current analysis was performed in 2019 and is an update to the previously-published analysis that was performed in 2015. Tables 6-1 through 6-4 include the results of the 2019 analysis alongside the results of the 2015 analysis for the reader’s convenience. The aircraft analyzed in the 2015 analysis were not re-analyzed in 2019 because there were no changes to the underlying data that would affect results; however, a data error was discovered that affected the 2015 results for some aircraft and the error was corrected in this update.

The aircraft selected for analysis were based on review of FAA's Air Traffic Services Business Model (ATSBM) data regarding the types of aircraft operating in the National Airspace System (NAS), FlightGlobal air carrier fleet data[1], and the typical missions in terms of stage length at which they were operated from the ATSBM.[2] FAA selected the most frequently observed aircraft within each aircraft type/user group combination and determined the typical stage length(s) for the missions performed by this aircraft.

These form the basis for the mission lengths over which the increases in fuel burn (based on increases in aircraft weight) were calculated, as well as the lengths of mission for which flight segment times were developed. Research conducted for a prior economic values study (FAA-APO-98-8: Tables 7-16 and 7-18) showed that the incremental fuel burn per pound of additional weight was relatively constant over the range weight added. Weight penalties used in this report range from 100 to 500 pounds depending on aircraft type.

6.2.1. Air Carrier Aircraft

The air carrier aircraft analyzed in the 2019 analysis were the most common aircraft types operated by U.S. air carriers in 2019 based on fleet size data from FlightGlobal. In the 2015 analysis, air carrier aircraft operated by passenger/combination carriers were selected using FY 2013 ATSBM data. The aircraft were selected for each economic values category based on number of flights. The aircraft types having the greatest number of flights were chosen to represent all aircraft within a category. This 2019 update used fleet size data rather than number of flights because FY 2017 ATSBM data were the latest available at the time of analysis; the FY 2017 data did not adequately capture the changing nature of the air carrier fleet through 2019.

In some cases, aircraft manufacturer data necessary for calculating fuel burn were not available for the selected aircraft. In these cases, the next most common aircraft type for which data were available was chosen. In general, one to six aircraft types were selected to represent each aircraft category.

6.2.2. General Aviation Aircraft

General aviation aircraft selections were retained from the 2015 analysis, which was based on flight frequencies in FY 2013 ATSBM data. (The general aviation fleet and usage patterns change more slowly than those for air carrier aircraft.) Two new aircraft, the Cirrus SR22 and Pilatus PC-12, and an additional stage length for the Global Express, were added for the 2019 analysis based on FY 2018 ATSBM data. In some cases, aircraft manufacturer data necessary for calculating fuel burn were not available for the selected aircraft. In these cases, the next most common aircraft type for which data were available was chosen. In general, one aircraft type was selected to represent each aircraft category.

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[1] Fleets data and market insights

[2] The ATSBM provides data on all flights operating under instrument flight rules (IFR) that were operated in the NAS.

6.2.3. Aircraft Performance Data

The data presented in this analysis were based on flight test results obtained at aircraft certification and represent the nominal level of performance at aircraft delivery. The performance manuals are produced by the aircraft manufacturer and represent the optimal performance achievable by the operator. Due to external and internal configuration changes, the aircraft's actual performance will vary as a factor of weight, operating conditions, etc. In addition, it can be expected that actual aircraft performance will degrade as the aircraft ages, further restricting its capabilities. For example, no factor has been applied to account for degradation in fuel efficiency over time.

6.2.3.1. General Assumptions

The analysis was performed in accordance with Approved Transport Category Operations, in particular Part 25, paragraph 25.121 and amendment 42. Regulatory performance is calculated with air conditioning bleeds off. Small aircraft performance is determined with reference to Part 23, Part 27, Part 29 or Part 135 requirements.

Climb, cruise, descent and holding fuel flows are calculated on the basis of an economic air conditioning mode. Takeoff performance is calculated for zero wind, dry, hard and level runway, and no obstacles. Holding and diversion fuel allowances were calculated for the respective aircraft weights at the beginning of the hold or diversion profile.

6.2.3.2. Aircraft Parameters

The Operating Empty Weight (OEW) is the weight of a typical aircraft as equipped for passenger operations. Included in the OEW is the manufacturer's empty weight plus standard and operational items. Standard items include: unusable fuel, seats, carpet, engine oil, emergency equipment, toilet fluids and chemicals, galley, buffet, etc. Operational items include crew, baggage, manuals, food, beverages, and life vests, among others.

The Maximum Zero Fuel Weight (MZFW) is the maximum allowable weight of the aircraft before fuel is added.

The Maximum Structural Payload is the difference between the MZFW and the OEW. For purposes of this analysis 70 percent of the maximum structural payload was assumed for the base case performance analysis. An additional calculation involving either a 100 or 500 pound payload increment was then performed. The difference in fuel burn against the base case was determined to be the incremental fuel burn for the weight increment.

The Maximum Landing Weight (MLW) is the certified maximum allowable weight of the aircraft at touchdown.

Mission Takeoff Weight is the total of OEW, passenger and/or cargo weight, mission fuel weight and reserve fuel weight. Takeoff weight may be limited by aircraft performance. Mission Takeoff Weight may be less than the Maximum Takeoff Weight (MTOW).

The combination of maximum payload and maximum fuel weight plus the OEW may exceed the MTOW. In such situations, the operator must balance (reduce) payload, reserves, and mission needs to achieve the requirements of the flight profile to reduce the overall weight to MTOW or below. This involves a tradeoff between the payload and fuel load carried, and generally affects the maximum range that can be achieved.

6.2.3.3. Flight Profile

A mission is conducted over a specified distance. The effects of wind were not included in the analysis. The mission distance is applied from takeoff point (origin airport) to landing point (destination airport). No distance credit is taken for the taxi-out, takeoff, approach and landing, and taxi-in, as these segments may not be in the same direction as the desired flight path.

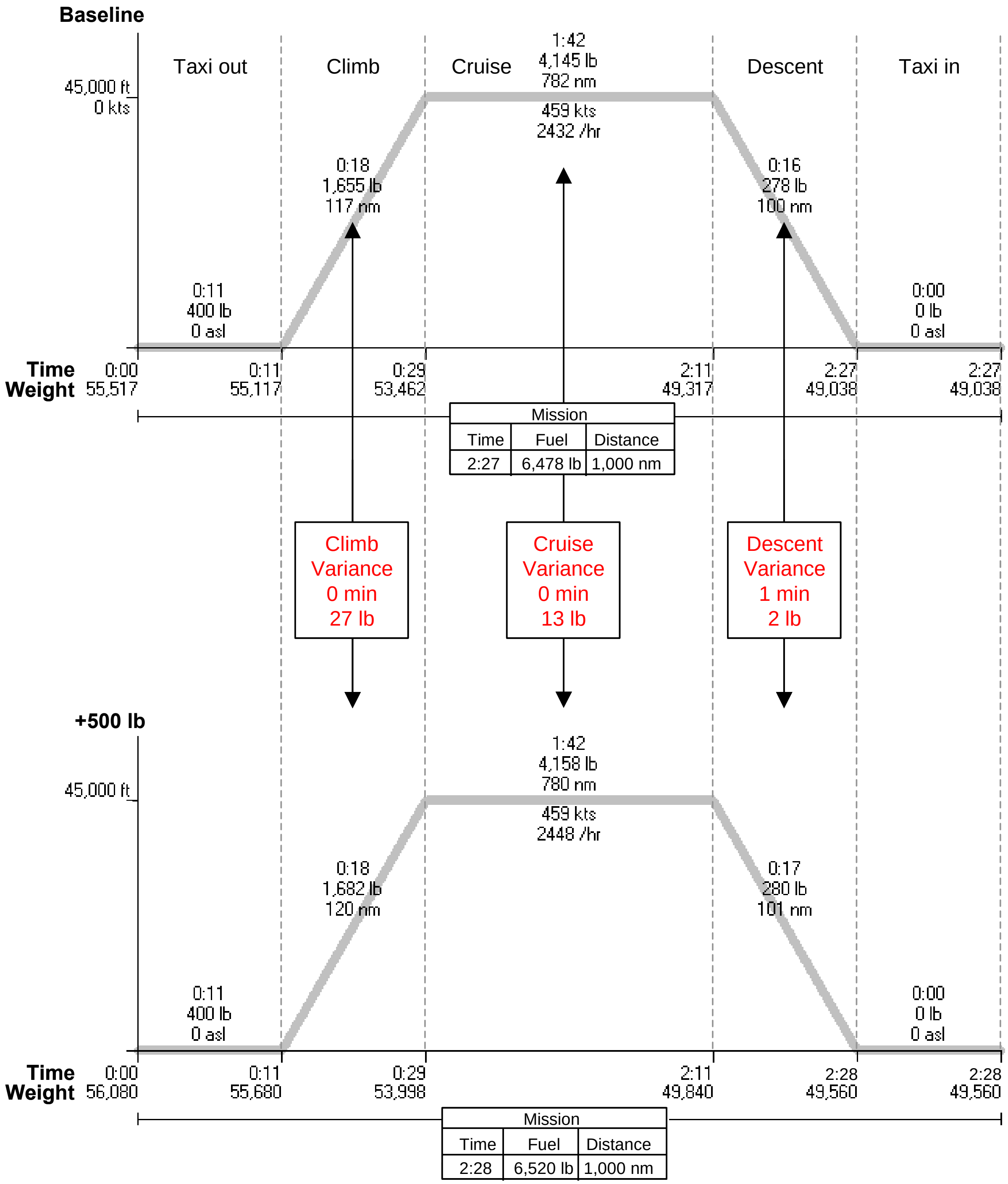
All of the factors shown above must be taken into account for proper mission planning. A computer model was used with given parameters to calculate the optimal result. For optimization purposes, the computer model iterates to achieve the best payload vs. time ratio. This is due to most costs being time based.

The current industry practice is to allow the aircraft to maintain straight and level flight (in the mission cruise portion) for a minimum of 30 percent of the mission distance. This is to allow for safe movement about the cabin and the servicing of passengers.

Figure 6-1 illustrates the development of performance changes related to a 500-pound weight penalty for a Gulfstream IV operating at a 1,000 nm stage length. The assumptions include an instrument standard (ISA) day, zero winds, level operation, 70 percent payload, Mach 0.8 cruise speed and National Business Aviation Association (NBAA) instrument flight rules (IFR) reserves. It shows the mission time, fuel burn and distance for each flight segment. The top part of the figure is the baseline mission and the bottom part is the same mission with a 500-pound weight penalty. The mission with the 500-pound weight penalty uses 42 more pounds of fuel, while the flight time for the mission is increased by one minute from 2 hours 27 minutes to 2 hours 28 minutes.

The performance models and manufacturer data also permit estimation of the time aircraft spend in various mission segments of a flight including taxi-out, takeoff, climb, cruise, descent, landing, and taxi-in. Not all mission segments are available for each aircraft analyzed, using manufacturer data.

Figure 6-1: Gulfstream IV Illustrative Performance Calculations
1,000nm Stage Length and 500 lb Weight Penalty*



Total variance for 500 lb weight increase = 1 min of additional flight time and 42 lb or 6.3 usg of additional fuel

* Range 1,000 nm, ISA, zero winds, sea level takeoff, 70% payload, cruise at Mach 0.80 and NBAA IFR reserves

6.3 AIR CARRIER AIRCRAFT

This section presents the analysis of weight penalties and mission segments for large commercial aircraft. It considers aircraft used in passenger or combination service as well as those used in all-cargo service.

6.3.1. Incremental Fuel Burn

As noted above, incremental fuel burn related to an increase in aircraft weight was calculated for selected aircraft types and selected stage lengths. The aircraft types selected present a sampling of the most common aircraft in use within each economic values category. Mission lengths were based on typical mission lengths for each aircraft type, as observed in FY 2013 and FY 2018 ATSBM data; the aircraft analyzed in 2019 used the same stage lengths as were used for other aircraft in the same aircraft category in the 2015 analysis for ease of comparison. For most aircraft models, multiple mission lengths were analyzed. A weight penalty of 500 pounds was used for most larger narrow-body and wide-body jet aircraft, while a weight penalty of 200 pounds was used for most smaller narrow-body, regional jet and turboprop aircraft. In a few cases, these weight penalties did not produce reliable results so a different weight penalty was used.

Table 6-1 presents the results for all large commercial aircraft (including both passenger and all-cargo aircraft). The table presents the aircraft type, passenger or cargo configuration, the stage lengths analyzed, the weight penalty and the incremental fuel burn in pounds per flight. In addition, the incremental fuel burn per pound of weight added is calculated in U.S. gallons per flight.[3] Also shown is the total flight time for the specific mission analyzed. The incremental fuel burn in gallons per hour per pound of weight added is calculated by dividing the incremental fuel burn per flight per pound of weight added by the flight time.

As noted above, prior research has shown that the incremental fuel per pound of weight added is relatively constant for the weight increases considered in this section. Therefore, the additional fuel consumption per year can be estimated by the amount of weight added times the incremental fuel burn times the annual utilization in flight hours. For example, assume that a regulation imposes a 100-pound weight penalty on a B737-700W that operates over a 500 nm average stage length for 3,000 hours per year. The annual cost at $2.16 per gallon for the additional fuel consumed because of the increase in aircraft weight is $1,944 (3,000 hours x $2.16 per gallon x 0.003 incremental gallons per flight hour per pound of weight added x 100 pound weight penalty).

[3] Fuel weight in pounds is converted to U.S. gallons by using 6.7 lbs. per gallon.

Table 6-1: Large Commercial Aircraft – Incremental Fuel Burn

				1	2	3	4	5	6
Aircraft Category	**Service Type**	**Aircraft Type**	**FAR Part**	**Stage Length (nautical miles)**	**Weight Penalty (pounds)**	**Incremental Fuel Burn per Flight (pounds)**	**Incremental Fuel Burn per Flight per Pound of Weight Added (gallons)**	**Flight Time (hours)**	**Incremental Fuel Burn per Flight Hour per Pound of Weight Added (gallons)**
Wide-body more than 300 seats	Passenger	B747-400	25	5,000	500	199	0.059	11.2	0.005
		B777-300	25	2,000	500	68	0.020	4.7	0.004
				5,000	500	210	0.063	10.3	0.006
		A350-900	25	2,000	500	57	0.017	4.6	0.004
				5,000	500	191	0.057	10.3	0.006
Wide-body 300 seats and below	Passenger/ All-Cargo	B767-300	25	2,200	500	85	0.025	5.3	0.005
				5,000	500	203	0.061	11.3	0.005
	Passenger	B777-200	25	2,200	500	58	0.017	4.7	0.004
				5,000	500	176	0.052	10.1	0.005
		B787-8	25	2,000	500	48	0.014	4.7	0.003
				5,000	500	175	0.052	10.3	0.005
		B787-9	25	2,000	500	53	0.016	4.2	0.004
				5,000	500	186	0.056	10.2	0.005
Four-engine wide-body	All-Cargo	B747-8	25	5,000	500	246	0.073	10.3	0.007
Three-engine wide-body	All-Cargo	MD-11F	25	1,500	500	60	0.018	3.3	0.005
				4,000	500	159	0.047	8.8	0.005
Two-engine wide-body	All-Cargo	A300F	25	700	500	26	0.008	1.7	0.005
				1,500	500	57	0.017	3.6	0.005
Narrow-body more than 160 seats	Passenger / All-Cargo	B757-200	25	1,000	500	37	0.011	2.7	0.004
				2,000	500	80	0.024	4.8	0.005
	Passenger	A321	25	500	500	10	0.003	1.5	0.002
				2,000	500	22	0.006	4.8	0.001
		A320neo	25	1,000	500	13	0.004	2.3	0.002
				2,000	500	31	0.009	4.5	0.002
		B737-800W	25	1,000	500	41	0.012	2.7	0.005
				2,000	500	89	0.027	4.9	0.005
		B737 MAX 8	25	1,000	500	36	0.011	2.3	0.005
				2,000	500	79	0.023	4.5	0.005
		B737-900	25	1,000	500	9	0.003	2.3	0.002
				2,000	500	20	0.006	4.4	0.002
Narrow-body 160 seats and below	Passenger/ All-Cargo	B737-300	25	500	200	10	0.007	1.6	0.005
				1,000	200	21	0.016	2.7	0.006
	Passenger	A320	25	500	200	7	0.005	1.5	0.003
				1,000	200	14	0.010	2.6	0.004
		A319	25	500	200	7	0.005	1.5	0.003
				1,000	200	13	0.010	2.6	0.004
		B717-200	25	500	500	24	0.007	1.6	0.005
		B737-700W	25	500	200	7	0.005	1.5	0.003
				1,000	200	17	0.013	2.6	0.005
		A220-300	25	500	200	11	0.008	1.3	0.006
				1,000	200	22	0.016	2.4	0.007
RJ more than	Passenger	CRJ700	25	250	200	5	0.004	0.9	0.004

Aircraft Category	Service Type	Aircraft Type	FAR Part	1 Stage Length (nautical miles)	2 Weight Penalty (pounds)	3 Incremental Fuel Burn per Flight (pounds)	4 Incremental Fuel Burn per Flight per Pound of Weight Added (gallons)	5 Flight Time (hours)	6 Incremental Fuel Burn per Flight Hour per Pound of Weight Added (gallons)
60 seats				500	200	9	0.007	1.5	0.004
		CRJ900	25	250	200	5	0.004	0.9	0.004
				500	200	8	0.006	1.5	0.004
		E175	25	250	200	4	0.003	1.0	0.003
				500	200	11	0.008	1.5	0.005
		E175 E2	25	250	200	4	0.003	1.0	0.003
				500	200	10	0.008	1.5	0.005
		A220-100	25	500	200	9	0.007	1.3	0.005
				1,000	200	18	0.013	2.4	0.006
RJ 60 seats and below	Passenger	CRJ200	25	250	200	5	0.004	0.9	0.004
				500	200	13	0.010	1.5	0.006
		ERJ 145	25	250	200	3	0.002	0.9	0.002
				500	200	12	0.009	1.5	0.006
Turboprop more than 60 seats	Passenger	Dash 8-400	25	200	500	6	0.002	1.0	0.002
				500	500	16	0.005	2.0	0.002
	All-Cargo	ATR 72-200*	25	200	200	9	0.003	1.3	0.002
				500	200	19	0.006	2.3	0.002
		ATR 72-600	25	200	500	5	0.001	0.9	0.002
				500	500	15	0.004	2.1	0.002
Turboprop 20-60 seats	Passenger	Dash 8-100	25	200	200	2	0.001	1.1	0.001
				500	200	5	0.004	2.2	0.002
		SF340	25	200	200	1	0.001	1.1	0.001
				500	200	2	0.001	2.2	0.001
	All-Cargo	ATR 42-300	25	200	200	2	0.001	1.1	0.001
				500	200	4	0.003	2.3	0.001
Turboprop under 20 seats (Part 23)	Passenger	Beech 1900	23	200	200	4	0.003	1.2	0.002
				500	200	19	0.014	2.6	0.005
	All-Cargo	Beech 65a90	23	150	200	2	0.001	1.0	0.001
		Cessna 208	23	150	100	1	0.001	1.0	0.001

Source: GRA analysis of aircraft manufacturer data

Col 1: Typical stage length(s) for aircraft type based on analysis of FY13 FAA Air Traffic Services Business Model (ATSBM) data; 2019 analysis used similar stage lengths for ease of comparison
Col 2: Generally, weight penalty of 500 pounds was used for larger narrow-body and wide-body jet aircraft and weight penalty of 200 pounds was used for smaller narrow-body, regional jet and turboprop aircraft; in some cases, an alternate weight penalty was used due to data limitations
Col 3: The incremental fuel (in pounds) that would be burned based on manufacturer data and Columns 1 and 2
Col 4: Column 3 divided by Column 2 divided by 6.7 (conversion factor of jet fuel in pounds to gallons)
Col 5: Manufacturer data based on Column 1
Col 6: Column 4 divided by Column 5; an error affected the calculation of Column 6 for some aircraft in the published version of the 2015 analysis - the error was corrected during the 2019 analysis
* Mislabeled as ATR 72-300 in 2015 analysis

6.3.2. Flight Profiles

Flight profiles for large commercial aircraft are presented in Table 6-2. These are based on simple averages of the data from the specific aircraft that were used for calculating the incremental fuel burn shown in Table 6-1 above.[4] Since flight profiles were not available for some aircraft used in Table 6-1, and some aircraft with flight profile data were not used in Table 6-1 due to data limitations, the specific aircraft types used in Table 6-2 are shown in the table. Not all mission segments could be calculated for each aircraft and some have been aggregated.

Table 6-2: Large Commercial Aircraft – Breakdown of Flight Profiles

Aircraft Category	Aircraft Types Included in this Table	Average Flight Profiles (minutes)					
		Taxi Out and Takeoff	Climb	Cruise	Descent and Landing	Taxi In	Total
Wide-body more than 300 seats	No Detailed Flight Path Data Available						
Wide-body 300 seats and below	A330; B777-200	12	17	419	23	5	476
Four-engine wide-body	No Detailed Flight Path Data Available						
Three-engine wide-body	No Detailed Flight Path Data Available						
Two-engine wide-body	No Detailed Flight Path Data Available						
Narrow-body more than 160 seats	A321; B737-800W	12	18	152	20	5	207
Narrow-body 160 seats and below	A319; A320; B737-300; B737-700W	12	19	69	19	5	125
RJ more than 60 seats	CRJ700; CRJ900; E175; E175 E2; E190	12	20	27	16	5	80
RJ 60 seats and below	CRJ200	12	23	19	16	5	74
Turboprop more than 60 seats	ATR 72-200; Dash 8-400	11	21	46	17	5	100
Turboprop 20 - 60 seats	ATR 42-300; Dash 8-100; EMB-120; SF340	11	18	50	13	5	97
Turboprop under 20 seats (Part 25)	No Detailed Flight Path Data Available						
Turboprop under 20 seats (Part 23)	Beech 1900; Beech 65a90; Cessna 208	6	18	46	14	5	89
Piston engine (Part 25)	No Data Calculated for this Aircraft Category						
Piston engine (Part 23)	No Data Calculated for this Aircraft Category						

Source: GRA analysis of aircraft manufacturer data

6.4 GENERAL AVIATION

Table 6-3 contains the results of the performance analysis of weight penalties for selected general aviation and air taxi aircraft. The underlying performance data does not differentiate between air taxi and other general aviation aircraft. The same mission analysis rules as above were used except that a weight penalty of 100 pounds was applied to all aircraft. In addition, rotorcraft performance is considered in this section. As can be seen, most aircraft were evaluated over one proposed mission length, except for the Global Express business jet which was

[4] Weighted averages were not calculated because there was not a good representation of the aircraft within each group. Thus, the category averages should be viewed as approximations of the amount of flight time in each flight segment of a typical aircraft mission.

evaluated at two mission lengths. The table shows the amount of the weight penalty, the incremental fuel burn per flight in pounds, and the incremental fuel burn per flight per pound of added weight in gallons. The flight time for the assumed mission and the incremental fuel burn per pound of weight added per flight hour are also shown in this table.

Table 6-3: General Aviation and Air Taxi Aircraft – Incremental Fuel Burn

			1	2	3	4	5	6
Aircraft Category	**Aircraft Type**	**FAR Part**	**Stage Length (nautical miles)**	**Weight Penalty (pounds)**	**Incremental Fuel Burn per Flight (pounds)**	**Incremental Fuel Burn per Flight per Pound of Weight Added (gallons)**	**Flight Time (hours)**	**Incremental Fuel Burn per Flight Hour per Pound of Weight Added (gallons)**
Piston engine airplanes, one-engine	Cessna 172	23	150	100	0.725	0.001	1.4	0.001
	Cirrus SR22*	23	250	100	0.000	0.000	1.5	0.000
Piston engine airplanes, multi-engine	Piper PA-30	23	250	100	0.648	0.001	1.7	0.001
	Beech Baron	23	250	100	0.769	0.001	1.4	0.001
Turboprop airplanes, one-engine	TBM700	23	300	100	1.307	0.002	1.2	0.002
	Cessna 208	23	150	100	0.499	0.001	1.0	0.001
	Pilatus PC-12*	23	270	100	3.090	0.005	1.3	0.004
Turboprop airplanes, multi-engine	Beech King Air B200	23	300	100	0.826	0.001	1.0	0.001
Turbojet/turbofan airplanes	Phenom 100	23	400	100	2.040	0.003	1.3	0.002
	Cessna 560	25	400	100	4.553	0.007	1.2	0.006
	Global Express*	25	900	100	4.000	0.006	1.9	0.003
		25	1,450	100	4.000	0.006	3.1	0.002
Rotorcraft piston	R44	27	100	100	1.411	0.002	1.7	0.001
Rotorcraft turbine, one-engine	Bell 206	27	100	100	2.792	0.004	0.9	0.005
	Bell UH-1	29	100	100	1.500	0.002	1.0	0.002
Rotorcraft turbine, multi-engine	EC145/BK117	29	100	100	1.031	0.002	0.8	0.002

Source: GRA analysis of aircraft manufacturer data
*Indicates a new model (or model with a new stage length) in the 2019 edition of this report
Col 1: Typical stage length(s) for aircraft type based on analysis of FAA Air Traffic Services Business Model (ATSBM) data
Col 2: A weight penalty of 100 pounds was used for general aviation aircraft
Col 3: The incremental fuel (in pounds) that would be burned based on manufacturer data and Columns 1 and 2
Col 4: Column 3 divided by Column 2 divided by 6.7 (conversion factor of jet fuel in pounds to gallons)
Col 5: Manufacturer data based on Column 1
Col 6: Column 4 divided by Column 5

Table 6-4 summarizes performance data for the general aviation and air taxi aircraft. Performance profiles allow consideration of the proportion of mission length spent in each part of the flight profile. This permits calculation of costs by amount of time in each part of the flight using the cost data per flight hour from Section 4.

Table 6-4: General Aviation and Air Taxi Aircraft – Breakdown of Flight Profiles

Aircraft Category	Aircraft Type	Stage Length (nautical miles)	Fuel Type	Average Flight Profiles (minutes)					
				Taxi Out and Takeoff	Climb	Cruise	Descent and Landing	Taxi In	Total
Piston engine airplanes, one-engine	Cessna 172	150	Avgas	1	9	70	6	NC	87
	Cirrus SR22*	250	Avgas	NC	5	88	NC	NC	93
Piston engine airplanes, multi-engine	Piper PA-30	250	Avgas	1	9	85	7	NC	102
	Beech Baron	250	Avgas	1	8	58	16	NC	83
Turboprop airplanes, one-engine	TBM700	300	Jet A	1	14	40	15	NC	70
	Cessna 208	150	Jet A	1	11	32	15	NC	59
	Pilatus PC-12*	270	Jet A	NC	10	57	8	NC	75
Turboprop airplanes, multi-engine	Beech King Air B200	300	Jet A	1	7	43	10	NC	61
Turbojet/turbofan airplanes	Phenom 100	400	Jet A	1	9	63	6	NC	79
	Cessna 560	400	Jet A	1	8	48	16	NC	72
	Global Express*	900	Jet A	11	10	93	13	5	132
		1,450	Jet A	11	10	160	13	5	199
Rotorcraft piston	R44	100	Avgas	NC	NC	100	NC	NC	100
Rotorcraft turbine, one-engine	Bell 206	100	Jet A	NC	NC	53	NC	NC	53
	Bell UH-1	100	Jet A	NC	NC	60	NC	NC	60
Rotorcraft turbine, multi-engine	EC145/BK117	100	Jet A	NC	NC	46	NC	NC	46

Source: GRA analysis of aircraft manufacturer data

*Indicates a new model (or model with a new stage length) in the 2019 edition of this report

NC = Not Calculated

6.5 FUEL COSTS

In order to apply the incremental fuel burn data to an economic analysis, fuel price information is required. Data have been developed for both air carrier (Jet-A) and general aviation fuel (Jet-A and Avgas). Piston engine aircraft consume Avgas while all other aircraft consume Jet-A. All military aircraft use Jet-A.

Table 6-5 presents fuel consumption (Jet-A) reported by carriers filing Form 41, Schedule P-1.2(a). In addition to fuel consumption, carriers report fuel cost, from which an average cost per gallon was calculated. To enable comparison of average fuel cost over time, values are presented in both nominal and real (2018) dollars. Readers should be cautioned that large air carriers generally buy fuel in significant quantities and therefore pay substantially less than other users. In addition, some carriers purchase hedge contracts to insulate themselves from rapid increases in fuel prices. Smaller carriers may pay more than the average price of fuel for Form 41 carriers.

Table 6-5: Fuel Cost and Consumption—System-wide Operations U.S. Majors, Nationals and Large Regionals — All Services

Year	Fuel Consumption (gallons, millions)	Average Cost per Gallon (nominal)	Average Cost per Gallon ($2018)
1990	16,150	$0.78	$1.50
1991	15,248	$0.69	$1.28
1992	15,677	$0.64	$1.14
1993	16,072	$0.61	$1.05
1994	16,826	$0.56	$0.95
1995	17,318	$0.56	$0.92
1996	17,844	$0.67	$1.07
1997	18,619	$0.64	$1.01
1998	18,219	$0.51	$0.79
1999	19,767	$0.53	$0.80
2000	20,373	$0.81	$1.18
2001	19,204	$0.78	$1.11
2002	18,001	$0.72	$1.00
2003	18,300	$0.85	$1.15
2004	19,683	$1.16	$1.54
2005	19,950	$1.66	$2.14
2006	19,712	$1.97	$2.45
2007	19,886	$2.11	$2.55
2008	18,872	$3.07	$3.58
2009	17,061	$1.90	$2.22
2010	17,298	$2.27	$2.62
2011	17,558	$3.05	$3.40
2012	16,946	$3.15	$3.45
2013	16,824	$3.01	$3.24
2014	16,807	$2.86	$3.04
2015	17,349	$1.86	$1.97
2016	17,668	$1.46	$1.52
2017	18,029	$1.70	$1.74
2018	18,731	$2.16	$2.16

Source: Form 41, Schedule P-1.2(a)
Note: Adjusted for inflation to 2018 dollars using Bureau of Labor Statistics, Consumer Price Index - All Urban Consumers

Table 6-6 reports general aviation fuel prices for Jet-A and Avgas. These data are for December 2018. While the prices in Table 6-5 are pretax and represent advance bulk purchases by commercial carriers, those in Table 6-6 include tax and represent retail purchases at general aviation airports, which account for the large differences in fuel prices. Also, for general aviation, aviation gasoline costs more per gallon than jet fuel, with prices averaging about $6.00 per gallon for Avgas vs. roughly $5.60 per gallon for Jet-A fuel for turbine engines.

Table 6-6: General Aviation Jet-A and Avgas Per Gallon Fuel Prices ($2018)

Region	Jet-A High Price	Jet-A Low Price	Jet-A Average Price	Avgas High Price	Avgas Low Price	Avgas Average Price
Eastern	$8.78	$4.35	$6.29	$8.48	$4.70	$6.51
New England	$7.51	$3.77	$5.22	$7.45	$4.50	$5.91
Great Lakes	$7.34	$3.90	$5.57	$8.59	$4.89	$6.07
Central	$7.70	$3.27	$5.00	$7.69	$4.39	$5.47
Southern	$8.28	$4.20	$6.04	$8.24	$4.25	$6.15
Southwest	$6.84	$3.16	$5.26	$7.17	$3.91	$5.50
NW Mountain	$7.79	$3.55	$5.35	$8.46	$4.65	$5.92
Western Pacific	$8.34	$4.10	$5.99	$8.52	$5.00	$6.30
Nationwide	**$7.95**	**$3.79**	**$5.59**	**$8.08**	**$4.54**	**$5.98**

The table above shows results of a fuel price survey of U. S. fuel suppliers performed in December 2018. Prices include taxes and fees.
Source: *Business & Commercial Aviation*, January 2019.

Table 6-7 shows the average rate of fuel consumption (gallons per hour) and the estimated annual fuel use in millions of gallons for the general aviation fleet in 2017.

Table 6-7: 2017 General Aviation Total Fuel Consumed and Average Fuel Consumption Rate by Aircraft Type (Includes Air Taxi Aircraft; Excludes Commuter Aircraft)

Aircraft Category	Certification	Jet Fuel: Turbine		Aviation Gasoline: 100 Low Lead		Automotive Gasoline		Total Fuel Use	
		Average Rate (GPH)	Estimated Fuel Use (Millions of Gallons)	Average Rate (GPH)	Estimated Fuel Use (Millions of Gallons)	Average Rate (GPH)	Estimated Fuel Use (Millions of Gallons)	Average Rate (GPH)	Estimated Fuel Use (Millions of Gallons)
Piston engine airplanes	Part 23	N/R	N/R	13.0	171.0	7.6	2.2	13.2	179.2
Turboprop airplanes	Part 23/25	75.9	197.2	50.0	1.3	N/R	N/R	75.6	198.5
Turbojet/turbofan airplanes	Part 23/25	296.1	1,203.8	11.0	a	-	-	296.1	1,203.8
Rotorcraft piston	Part 27/ Part 29	N/R	N/R	12.8	9.9	N/R	N/R	12.8	10.0
Rotorcraft turbine	Part 27/ Part 29	54.7	138.8	19.9	a	-	-	54.7	138.9
Other		N/R	N/R	N/R	N/R	3.7	a	12.9	1.6
Experimental		43.6	2.8	10.8	9.4	4.9	1.2	11.3	13.6
Light Sport		N/R	N/R	6.5	0.8	4.7	0.4	5.8	1.2
All Aircraft		**164.0**	**1,548.7**	**12.9**	**192.4**	**6.1**	**3.9**	**69.6**	**1,746.8**

Sources: FAA's General Aviation and Part 135 Activity Survey CY 2017.
a = < 0.05
N/R = Values not reported
Total fuel use includes consumption of jet fuel: piston and other fuel, but estimates for use of these fuel types are not reported separately.
Experimental aircraft includes experimental light-sport and light-sport aircraft for which airworthiness certificates are not final. Prior to 2012, estimates for these aircraft were included with light-sport.
Totals may not add due to rounding