Airlines across the world are returning their fleets to service. This article looks at the performance of eight Airbus and Boeing narrowbody types over 14 routes that have ESADs between 484nm and 2,730nm. The relative differences in fuel burn between the types are examined by Ian Britchford.

737 MAX 8 & 9 fuel burn and operating performance

The 737 MAX returned to revenue service in late 2020 with many airlines across the world. The 737 MAX 10's (737-10) flight test programme is well underway for entry into service in 2023. Its fuel burn and operating performance are analysed here, and considered against the A320 current engine option (ceo) and new engine option (neo) families, and the 737NG family.

Aircraft types

The A320 and 737 families have been hugely successful. The A320ceo and A321ceo have had more than 6,500 orders, while the 737-800 and 737-900ER have won more than 5,600.

The later generation aircraft are set to follow in their footsteps, having already achieved more than 6,000 orders for the A320neo, and more than 4,800 for the 737 MAX family.

The in-service fleet of the newer generation aircraft continues to grow at a similar rate, with Boeing having delivered over 400 MAXs, and Airbus a similar number for the neo family. This article will directly compare the fuel burn and operating performance of the more popular variants of this aircraft family.

The comparison will be for eight aircraft types: the A320ceo, A321ceo, A320neo, A321neo, 737-800, 737-900ER(W), 737 MAX-8 (737-8), and the 737 MAX-9 (737-9) *(see table, page 19)*.

Recent improvements in cabin design have taken advantage of lighter composite materials. These have led to smaller and slimmer galleys, increased passenger capacity with slimmer seats, and cabin reconfiguration to reposition toilets and services. In addition, with many airlines reducing their in-flight service offering, this has resulted in them requiring less galley space, thereby freeing up more floor area for seats. This makes it more challenging to compare the aircraft types on a fair or equal basis, since the number of seats will influence the payloads carried and the number of available seat-miles (ASM) generated per route. Having a higher number of seats and ASMs will give an aircraft an economic advantage in terms of fuel consumption and cost per seat or per ASM.

The aircraft are examined on the basis of being configured like those of the mainline US carriers like Alaska, American Airlines, Delta and United. These carriers operate with first, economy-plus and economy cabins. Economy-plus is also referred to as premium, main cabin extra or comfort plus, depending on the airline.

The first-class layout uses four-abreast seating, while both the economy-plus and economy seats are at six-abreast. The economy-plus seats typically offer two to three inches more legroom than the economy cabin, but some airlines can achieve five inches extra legroom.

Most mainline US carriers are using the

On a group of routes between 484nm and 2,575nmn, the 737-8 has an average 13% lower trip fuel burn compared to the 737-800. The 737-8 has a 0.8-3.0% higher trip fuel burn than the A320neo.

AIRCRAFT SPECIFICATIONS & WEIGHTS

Aircraft types	A320ceo	A321ceo	A320neo	A321neo	737-800	737-900ER	737-8	737-9
Engine	CFM56-5B4/P	CFM56-5B3	CFM LEAP-1A26	CFM LEAP-1A32	CFM56-7B26	CFM56-7B27B3	CFM LEAP-1B27	CFM LEAP-1B28B1
Engine bypass ratio	5.7:1	5.7:1	11.0:1	11.0:1	5.1:1	5.1:1	9.0:1	9.0:1
MRTX - lbs	172,842	207,630	175,047	214,730	174,900	188,400	182,700	195,200
MTOW - lbs	171,961	206,132	174,165	213,848	174,200	187,700	182,299	194,700
MLW - lbs	145,505	171,520	148,592	174,606	146,300	157,300	152,800	163,900
MLW - lbs	137,789	162,701	141,757	166,669	138,300	149,300	1465,400	156,500
OEW/DOW - lbs	96,500	105,800	97,700	109,800	91,300	98,500	98,500	105,000
Max payload - lbs	41,289	56,901	44,057	56,869	47,000	50,800	46,900	51,500
Fuel capacity - USG	6,303	6,353	6,303	6,353	6,875	7,390	6,820	6,820
Seat configuration	160	192	160	192	160	179	160	179
Passenger payload - lbs	36,960	44,352	39,270	45,276	36,960	41,349	39,732	44,121
Remaining cargo - lbs	4,329	12,549	4,787	11,593	10,040	9,451	7,168	7,379
Range with full passenger payload - nm	2,800 - 2,900	3,200	3,300 - 3,400	4,000	1,800 - 2,500	1,800 - 2,500	3,300 - 3,850	3,300 - 3,850
MTOW / seat - lbs	1,705	1,074	1,025	1,091	1,089	1,049	1,059	1,019
OWE/DOW/seat - lbs	603	551	575	560	571	550	573	550

introduction of the newer aircraft types to maximise their service offering. One carrier operating the 737 has increased its economy seating by 12 seats when comparing the 737-800 with the 737-8, even though the two have the same fuselage length. As stated, this makes a fair comparison more challenging. Therefore, for the purposes of this performance evaluation it has been assumed that the newer aircraft types will have the same passenger seat capacity as the older models they are replacing. For example, the A320neo will be evaluated with the same number of seats as the A320ceo; and the 737-9 will have the same cabin layout and seat count as the 737-900ER(W). This will allow a direct comparison of trip fuel burn and fuel burn per ASM for the four pairs of aircraft types that are of equal size. These are the 737-800 and 737-8, 737-900ER and 737-9, A320ceo and A320neo, and the A321ceo and A321neo. Any increase in seat numbers a newer type might have over an older aircraft would give the newer type a further advantage.

A320ceo & A320neo

The A320 family is offered with the choice of engine variant. The A320ceos are powered by either the CFM56-5 series or the IAE V2500. The CFM56-5B4/P has a bypass ratio of 5.7:1, and is rated at 27,000lbs of thrust compared to the International Aero Engines V2527-A5 rated at 24,800lbs with a bypass ratio of 4.8:1.

The A320 analysed here is powered by the CFM56-5B4/P with a maximum take-off weight (MTOW) of 171,961lbs, a maximum landing weight (MLW) of 145,505lbs, and a fuel capacity of 6,303 US gallons (USG) *(see table, this page)*. This weight variant is one of more than 20 different available options, and gives the A320ceo a range of 2,800-2,900nm with full passenger payload. This study uses a seat configuration of 16/18/126, giving a maximum passenger payload of 160.

The engine choice on the A320neo is between: the Pratt & Whitney PW1127G, with a thrust rating of 27,000lbs, an intake fan diameter of 81 inches, and a bypass ratio of 12.5:1; and the CFM LEAP-1A26 with a thrust rating of 26,000lbs, an intake fan diameter of 78 inches, and a bypass ratio of 11.0:1.

The wider intake fan diameters leading to higher bypass ratios provide better propulsive efficiency. It is the CFM LEAP-1A26-powered aircraft that is used in this comparison. The A320neo in this study uses one of the 11 certified weight variants.

It is analysed with an MTOW of 174,165lbs, an MLW of 148,592lbs, and a fuel capacity of 6,303USG *(see table, this page)*. Due to the additional structural requirements of the A320neo, it is 1,200lbs heavier than the A320ceo. With a maximum fuel capacity, the A320neo covers a 3,300-3,400nm range with a full passenger payload. The aircraft in this study has been configured with the same seat layout of 16/18/126 as the A320ceo, thereby giving it a seat capacity of 160 passengers.

A321ceo & A321neo

The A321ceo is equipped with either: the IAE V2533-A5 engine, rated at 33,000lbs of thrust with a fan diameter of 63.5 inches and a bypass ratio of 4.5:1; or the CFM56-5B with thrust ratings of 30,000lbs to 33,000lbs, a fan diameter of 68.3 inches and a bypass ratio of up to 5.5:1. The engine option used in this comparison is the CFM56-5B3/P.

The A321ceo has a maximum fuel capacity of 6,353USG, giving it a range of up to 3,200nm when equipped with sharklets. The three-class cabin configuration used in the study is 20/29/143, giving a maximum capacity of 192 seats. The weight configuration used in this analysis is one of the 12 certified weight variants for this aircraft. The weights used are an MTOW of 206,132lbs, an MLW of 171,500lbs, and an operating empty weight (OEW) of 105,800lbs *(see table, this page)*.

The A321neo is offered to airlines with the choice of the PW1133G rated at 33,000lbs, the same 81-inch fan diameter and bypass ratio of 12.5:1 as the A320neo; or the CFM LEAP-1A32, rated at 32,000lbs of thrust, a fan diameter of 78 inches and a bypass ratio of 11.0:1.

As with the rest of the Airbus aircraft, the engine option chosen for this study is the CFM LEAP-1A32 variant.

The improvements in engine design give the A321neo a range of up to 4,000nm with maximum passenger payload. The A321neo takes advantage of the ACF cabin enhancements that offer more seats. The seat configuration used in the analysis is 20/29/143, so a total of 192 seats.

The aircraft weights used in this analysis are: an MTOW of 213,848lbs; an MLW of 174,606lb; and an OEW of 109,800lbs *(see table, page 19)*. Like the A320, the A321 neo is significantly heavier than the A321ceo. The increase in OEW of

AIRCRAFT PAYLOADS IN TWO COMPARISON SCENARIOS

Payload scenario one

Aircraft type	Passengers	Payload
737-800:	150	34,650lbs
737 MAX-8:	150	34,650lbs
A320ceo:	150	34,650lbs
A320neo:	150	34,650lbs
737-900ER(W):	170	39,270lbs
737 MAX-9:	170	39,270lbs
A321ceo:	170	39,270lbs
A321neo:	170	39,270lbs

Payload scenario two

Aircraft type	Passengers	Payload
737-800:	136	31,416lbs
737 MAX-8:	136	31,416lbs
A320ceo:	136	31,416lbs
A320neo:	136	31,416lbs
737-900ER(W):	152	35,112lbs
737 MAX-9:	152	35,112lbs
A321ceo:	163	37,653lbs
A321neo:	163	37,653lbs

more than 3% is more than offset by the increase in engine efficiency to offer customers better performance and lower fuel burn.

737-800 & 737-8

The 737NG family has a single engine offering: the 737NG with the CFM56-7B; and the 737 MAX family with the CFM LEAP-1B.

The 737-800 is the most popular variant of the four NG models, with nearly 5,000 aircraft delivered and making up 72% of the NG fleet in service. The CFM56-7B26 engine on the heavier weight variant offers 26,000lbs of thrust, with a fan diameter of 68 inches and a bypass ratio of 5.1:1. The typical range for this aircraft is 1,800-2,500nm with maximum passenger payload. The seat configuration used is 16/30/114, giving a seat count of 160, which is the same total as on the A320ceo and A320neo in this study.

The fourth generation 737-8 is equipped with the more fuel-efficient CFM LEAP-1B engine. The aircraft also features some minor aerodynamic improvements and airframe modifications. The engine variant used in this study is the CFM LEAP-1B27, with a thrust rating of 27,000lbs, a fan diameter of 69 inches and bypass ratio of 9.0:1.

The 'Sky' interior means the MAX series of aircraft benefits from increased seat capacity over the NG series. The three-class cabin configuration used in this study is 16/30/114, giving a maximum passenger capacity of 160 (the same as the 737-800) to allow a clearer performance and fuel burn comparison.

The aircraft weights used are at the HGW2 option with an MTOW of 182,200lbs, an MLW of 152,800lbs, and an OEW of 98,500lbs *(see table, page 19)*.

Similar to the A320 family, the 737 MAX series has a weight penalty because of its larger engines, but again the aircraft benefits from improved propulsive efficiency and so lower fuel burn.

737-900ER & 737-9

This comparison is made using the 737-900ER(W) rather than the 737-900, because the 737-900 is limited to the same seat capacity as the 737-800 due to the exit doors configuration. It therefore offers no additional benefit in this comparison. The 737-900ER(W) has an MTOW of 187,700lbs, an MLW of 157,300lbs and a seat capacity of 179. This is equivalent to 19 seats more than the -800, and 13 passengers fewer than the A321ceo *(see table, page 19)*.

The 737-9 uses the same CFM LEAP-1B engine as the 737-8. For the purposes of this study, the 737-9 is operated with the CFM LEAP-1B28B1 rated at 28,000lbs thrust. The weight variant used in this analysis has an MTOW of 194,700lbs, an MLW of 163,900lbs, and an OEW of 105,000lbs.

Like the A321neo, the 737-9 has a weight penalty in its OEW compared to its earlier counterpart. The weight increase in the 737-9 is nearly 7% higher than the 737-900ER(W). The cabin layout used for this analysis is 20/42/117, giving a total seat count of 179. This is the same configuration as the 737-900ER(W), but 13 seats fewer than the A321neo.

The specifications and weights of all the aircraft in this study are shown *(see table, page 19)*.

Evaluation route network

Since all eight aircraft types are in operation in the US, the performance and fuel burn evaluation compares the selected aircraft variants on 14 sectors departing from Boston (BOS) Logan International airport.

The sectors are chosen to ensure a westerly direction so that all operate against a headwind component, and give the fuel consumption for each type over stage lengths or tracked distances of between 420nm and 2,429nm *(see table, page 21)*.

It is recognised that on some of the sectors, particularly the shorter ones, mainline carriers may in fact opt to use a regional jet operated by one of their subsidiary airlines. The analysis, however, considers these routes to give a more comprehensive comparison of the aircraft types over a wide range of mission lengths around the world. The 14 routes are listed *(see table, page 21)*.

The equivalent still air distance (ESAD) travelled for the aircraft on each route is 484nm for the shortest BOS-YYZ (Toronto Pearson) sector, to 2,730nm for the BOS-LAX (Los Angeles) route. This compares to a tracked distance of 2,349nm because of strong headwind.

All the mission lengths are within the stated maximum still air passenger range of all eight aircraft types. Therefore to study the fuel burn and operating performance of these aircraft, two different payload scenarios have been run.

The first is payload scenario 1, which assumes that an equal number of passengers are carried on each of the four similar-sized and directly competing aircraft types; and with no additional cargo payload carried. This scenario is run with 150 passengers on the A320ceo, A320neo, 737-800 and 737-8; and 170 passengers on the A321ceo, A321neo, 737-900ER(W) and 737-9.

The second comparison is payload scenario 2, which is based on an 85% passenger load factor based on each type's seat capacity, with no additional cargo. This is chosen to represent a typical airline operation. In this scenario, the calculated passenger numbers are 136 for the A320ceo, A320neo, 737-800 & 737-8; 163 for the A321ceo & A321neo; and 152 for the 737-900ER(W) and 737-9.

Although there have recently been discussions in the industry to potentially increase the passenger weight assumptions used in flight planning, the scenarios use a standard passenger weight of 231lbs that includes checked and carry-on luggage. It is assumed that no additional cargo is taken on these flights. The payload weights for the two scenarios are detailed *(see table, this page)*.

The main operational factors evaluated are taxi fuel burn, flight fuel burn, the tracked distance, ESAD, and the difference in ASMs between the eight aircraft types. PPS flight planning software is used to calculate the fuel burns and times.

ROUTE CHARACTERISTICS FOR ANALYSIS OF AIRCRAFT PERFORMANCE

Route	BOS-YYZ	BOS-DTW	BOS-CVG	BOS-ORD	BOS-ATL	BOS-STL	BOS-MIA	BOS-DFW	BOS-DEN	BOS-PHX	BOS-SEA	BOS-YVR	BOS-LAX	BOS-SFO
Flight time - mins	74-82	98-107	120-128	136-145	140-148	160-169	178-187	221-237	252-264	326-339	344-358	339-353	373-388	350-365
Taxi out time - mins	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Taxi in time - mins	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Block time - mins	104-112	128-137	150-158	166-175	170-178	190-199	208-217	251-267	282-294	356-369	374-388	369-383	403-418	380-396
Tracked distance - nm	420	576	720	831	854	974	1,161	1,392	1,581	2,060	2,205	2,220	2,349	2,429
Wind component - kts	-58	-61	-60	-58	-54	-61	-37	-62	-58	-59	-55	-47	-62	-53
ESAD - nm	484	667	830	955	976	1,130	1,272	1,622	1,823	2,376	2,516	2,481	2,730	2,575
Alternate airport & distance - nm	YHM/58	TOL/57	DAY/57	MKE/84	BHM/141	BLV/53	FLL/47	DAL/36	COS/104	TUS/101	YXX/104	YXX/64	ONT/73	OAK/35

Operating Assumptions

The main operating parameters are:

- The flight rules
- The assumptions on flight track and flight levels
- The cruise speed and flight profile
- The wind component and temperature
- The reserve fuel policy
- The taxi-in and taxi-out times and the associated taxi fuel burns
- The time spent in potential holding patterns or delays

The evaluation uses US domestic flight rules relating to the cruise altitudes and flight levels. All the flights are in a westerly direction, so they will use even flight levels with 2,000 feet separation.

The flight tracks and cruise altitudes have been optimised by the PPS flight planning solution to achieve the lowest total cost for fuel burn, time-related costs, and all navigation and air traffic control (ATC) charges.

US airspace can be congested near the major airports, which could lead to the aircraft having to operate at the non-optimum cruise altitude. To allow a fair comparison of the performance of the eight aircraft types, however, it was decided to assume that the optimum flight level could be achieved. In addition to keeping the comparison focused on the fuel burn performance, it was also assumed there would be no additional holding required, or any airborne or ground delays.

To enable a comparison of the different aircraft types, all the flights were evaluated using long-range cruise (LRC) performance. It is recognised that most aircraft operators fly their aircraft based on a cost index, which is a more cost-efficient method of operation that balances the cost of fuel against time-related costs.

The cost index used is heavily dependent on the operator's internal financial cost structure and their fuel prices, and can vary by the aircraft type and even the individual aircraft registration if it is financed differently. Since no two aircraft operators plan and fly using the same cost index, and the method that each operator uses to determine a type's speed based on the cost index set is different, it makes a flight-for-flight comparison between different aircraft types impossible when using a cost index. For this reason, a fixed speed of LRC can be applied to all the aircraft variants. The PPS flight planning software was allowed to optimise the flight profile based on the cruise speed setting. There was no additional performance deterioration factor added to any of the aircraft types.

All the flights were in a westerly direction, with an initial heading ranging from 208 degrees on the BOS-MIA (Miami) sector, to 299 degrees on the BOS-YVR (Vancouver) route. The westerly direction lead to a headwind component for all flights. The average headwind component is stated *(see table, this page)*. The wind speed was based on an 85% average for the month of June, and the temperature was set at ISA.

A US domestic reserve policy was applied to all flights. The reserve policy was planned with fuel to reach a defined alternate and 45 minutes continued cruise. The alternate airports were selected based on distance from the destination airport and their operational use by mainline carriers. The same alternate airport was planned for each aircraft type. The alternates used and their distance from the destination airport are listed *(see table, this page)*. The cruise speed to the alternate was LRC; the same as the primary sector.

It was assumed that all flights would have a 20-minute taxi-out time departing BOS, and take 10 minutes to taxi in at all the destination airports. It is understood that in real airline operations the taxi-out and taxi-in times would vary by flight. The aim was remove this variability from the analysis, thereby allowing a fair comparison of both block- and flight-fuel burns.

Although it is most fuel-efficient to perform a reduced engine taxi, where operationally safe to do so, in the evaluation both taxi-out and taxi-in were performed with both engines operating to reduce the variability caused by differences in engine cool-down times.

A fuel density of 6.55lbs per USG was used for conversion to volume. All the flight and block time, wind components, distances, and alternate airports are shown *(see table, this page)*.

Relative fuel burn

The block- and flight- (take-off to landing) fuel burns for seven of the 14 evaluation routes are listed *(see tables, pages 23 & 24)* in absolute terms in USG, and in fuel burn per ASM.

The first table is the payload scenario 1, where equal passenger payloads have been carried on the similar-sized aircraft. These results will allow a better comparison of the fuel burn performance.

The data in the second table is payload scenario 2, which uses an 85% passenger load factor to provide a better evaluation of each aircraft's ASMs. This is because it will take into account the additional capacity and potentially improved economics of the aircraft types with more seat capacity.

The A320ceo, A321ceo and 737-900ER(W) are the only aircraft in the evaluation that are payload-limited on the longer routes. In payload scenario 1 the A320ceo is limited to 127 passengers on BOS-LAX due to the strong headwind component, while the 737-900ER(W) has its payload reduced to 165 passengers from the planned payload of 170.

The A321ceo is limited from its planned 170 passengers as follows: 145 on BOS-PHX (Phoenix); 133 on BOS-YVR; 108 on BOS-SEA (Seattle); 123 on BOS-SFO (San Francisco); and 70 on BOS-LAX. The aircraft is limited by its fuel tank capacity, so that payload is reduced to make the range. The payload reduction is significant enough that operating the aircraft is not viable, so these sectors have not been used for the A321ceo against the other seven aircraft types.

In addition to lower fuel burn compared to its equal-sized 737NG counterparts and A320ceo family competitors, the 737 MAX also has superior operating performance.

Relative fuel consumption

The spot fuel price for the US aviation industry is 210 US cents per USG for Jet A-1, which is 5% higher than the same period in 2020. Fuel remains one of the largest operating costs for any aircraft operator, so controlling this cost is a challenge for all airlines. The relative high cost of aviation fuel increases the operating cost and performance differences between the aircraft types.

The longer sectors produce lower fuel burn and cost per seat and per ASM than shorter routes. This is because as the portion of the flight in the cruise phase, which has the lowest fuel burn rate per hour, increases, the average fuel burn per hour and per mile reduces .

Under payload scenario 1, where the same number of passengers is carried on the equivalent aircraft types, the lowest fuel cost per ASM for a route is on the A320neo at 2.30 cents per ASM *(see table, page 23)*. In comparison, the fuel cost per ASM for the 737-8 with the same payload on the same sector is almost the same as 2.31 cents per ASM.

The lowest fuel cost per ASM in the analysis is for the A320neo on BOS-SFO, with an ESAD of 2,576nm in payload scenario 2, where all types carry an 85% passenger payload. The A320neo's ASM performance on this sector is 2.19 cents per ASM. In contrast, the 737-8's performance is 2.54 cents per ASM for the same payload and route, and 16% higher than the A320neo.

Relative operational cost

The three main operational costs for flight relate to fuel burn, overflight and airport charges, while the time-dependent costs relate to the aircraft, crew and maintenance.

The overflight and airport charges are typically based on the aircraft's certified MTOW. The charges are split by weight category. It is assumed that the aircraft in this evaluation are all in the same weight category. All the aircraft would therefore be charged the same in operation for this route structure so these charges would not affect the comparison of ASM versus cost.

All the aircraft were evaluated using LRC speed. Due to the aircraft types and the defined LRC speed, this has resulted in differences in the flight times. The flight times on the sectors varied by up to 15 minutes between aircraft types or 3.7% on the longest sector BOS-SFO. In real operations, the block times would be impacted by external factors such as weather, traffic and ATC constraints, all of which could reduce this difference. The cost index calculated by the airline to the scheduled times planned by the carrier may also impact the actual flight time.

Therefore this evaluation will focus on the relative fuel costs between the aircraft types, but it is worth noting that in operation the overflight and airport charges combined with the time-related costs could almost double the per ASM cost compared to fuel. This would make the relative operational cost difference between the aircraft types even greater.

A320ceo versus A320neo

The A320neo offers a significant improvement in fuel burn compared with the A320ceo, despite the neo's 1,200lbs higher OEW. The CFM56-5B4/P is rated at 27,000lbs thrust compared to the 26,000lbs thrust on the A320neo powered by the CFM LEAP-1A26.

The A320neo has an average fuel burn improvement of 17.7% compared to the A320ceo over the 14 routes. The improvement ranges from 17.4% to 18.3% on the sectors where an equivalent payload is carried.

The A320ceo is payload-limited to 127 passengers on BOS-LAX, whereas the A320neo has no reduction in passenger payload on any sector in this evaluation.

The fuel cost per ASM improves with range for both the A320ceo and A320neo. The A320neo has a 0.55-0.69 cents per ASM benefit over the A320ceo for the same 85% passenger payload of 136.

Improvements introduced to the A320neo's aircraft interior design and configuration to increase passenger seat capacity would further increase the A320neo's cost per ASM advantage.

A321ceo versus A321neo

The fuel tank capacity means the A321ceo is passenger payload-restricted on the five longest sectors from BOS to PHX, SEA, SFO, YVR and LAX. These sectors have therefore been removed from the comparison to allow a better review of the comparative performance.

In this comparison, the A321neo shows an even greater fuel burn performance improvement over the A321ceo, in contrast to the A320neo over the A320ceo.

On the sectors where the A321ceo and A321neo carry the same passenger payload, the A321neo has an 18.9% average improvement in trip fuel burn. Using the evaluation payloads of 170 passengers and 163 passengers on the payload 1 and payload 2 scenarios, the A321neo has no payload limitation on any sector. As a result of its lower fuel burn, the A321neo offers a better fuel cost per ASM of 0.55 to 0.88 cents per ASM compared to the A320ceo.

In the same trend as on the A320 family, Airbus has reduced the thrust rating on the CFM LEAP-1A32 to 32,000lbs, down from the 33,000lbs that is used on the CFM56-5B3/P, despite the A320neo's 7,000lbs higher MTOW.

737-800 versus 737-8

The fuel burn improvement on the 737-8 powered by the CFM LEAP-1B27 compared to the CFM56-7B-powered 737-

BLOCK FUEL PERFORMANCE OF A320CEO, A320NEO, A321CEO, A321NEO, 737-800, 737-900ER, 737-8 & 737-9 - PAYLOAD SCENARIO 1

City-pair	Aircraft variant	Engine variant	Seats	Payload carried - lbs	ESAD - nm	ASMs	Block time - mins	Block fuel - USG	Fuel burn/ ASM
BOS-YYZ	A320ceo	CFM56-5B4/P	150	34,650	483	72,450	104	1,138	0.0157
	A320neo	CFM LEAP-1A26	150	34,650	483	72,450	104	937	0.0129
	737-800W	CFM56-7B26	150	34,650	483	72,450	112	1,162	0.0160
	737-8	CFM LEAP-1B27	150	34,650	482	72,300	111	989	0.0137
	A321ceo	CFM56-5B3/P	170	39,270	483	82,110	105	1,288	0.0157
	A321neo	CFM LEAP-1A32	170	39,270	483	82,110	104	1,060	0.0129
	737-900ER	CFM56-7B27B3	170	39,270	487	82,790	112	1,275	0.0154
	737-9	CFM LEAP-1B27B1	170	39,270	486	82,620	112	1.111	0.0134
BOS-CVG	A320ceo	CFM56-5B4/P	150	34,650	831	124,650	150	1,761	0.0141
	A320neo	CFM LEAP-1A26	150	34,650	831	124,650	150	1,454	0.0117
	737-800W	CFM56-7B26	150	34,650	831	124,650	158	1,751	0.0140
	737-8	CFM LEAP-1B27	150	34,650	832	124,800	156	1,500	0.0120
	A321ceo	CFM56-5B3/P	170	39,270	831	141,270	151	1,995	0.0141
	A321neo	CFM LEAP-1A32	170	39,270	831	141,270	150	1,619	0.0115
	737-900ER	CFM56-7B27B3	170	39,270	831	141,270	157	1,913	0.0135
	737-9	CFM LEAP-1B27B1	170	39,270	831	141,270	158	1,683	0.0119
BOS-ATL	A320ceo	CFM56-5B4/P	150	34,650	977	146,550	170	2,054	0.0140
	A320neo	CFM LEAP-1A26	150	34,650	977	146,550	170	1,690	0.0115
	737-800W	CFM56-7B26	150	34,650	977	146,550	177	2,013	0.0137
	737-8	CFM LEAP-1B27	150	34,650	977	146,550	176	1,740	0.0119
	A321ceo	CFM56-5B3/P	170	39,270	977	166,090	170	2,313	0.0139
	A321neo	CFM LEAP-1A32	170	39,270	977	166,090	170	1,876	0.0113
	737-900ER	CFM56-7B27B3	170	39,270	977	166,090	176	2,207	0.0133
	737-9	CFM LEAP-1B27B1	170	39,270	977	166,090	178	1,945	0.0117
BOS-MIA	A320ceo	CFM56-5B4/P	150	34,650	1,272	190,800	208	2,564	0.0134
	A320neo	CFM LEAP-1A26	150	34,650	1,272	190,800	208	2,115	0.0111
	737-800W	CFM56-7B26	150	34,650	1,272	190,800	215	2,498	0.0131
	737-8	CFM LEAP-1B27	150	34,650	1,272	190,800	213	2,154	0.0113
	A321ceo	CFM56-5B3/P	170	39,270	1,272	216,240	208	2,899	0.0134
	A321neo	CFM LEAP-1A32	170	39,270	1,272	216,240	208	2,347	0.0109
	737-900ER	CFM56-7B27B3	170	39,270	1,272	216,240	214	2,748	0.0127
	737-9	CFM LEAP-1B27B1	170	39,270	1,272	216,240	217	2,431	0.0112
BOS-DEN	A320ceo	CFM56-5B4/P	150	34,650	1,824	273,600	282	3,693	0.0135
	A320neo	CFM LEAP-1A26	150	34,650	1,825	273,750	283	3,021	0.0110
	737-800W	CFM56-7B26	150	34,650	1,824	273,600	289	3,535	0.0129
	737 MAX-8	CFM LEAP-1B27	150	34,650	1,824	273,600	288	3,069	0.0112
	A321ceo	CFM56-5B3/P	170	39,270	1,824	310,080	283	4,158	0.0134
	A321neo	CFM LEAP-1A32	170	39,270	1,824	310,080	282	3,341	0.0108
	737-900ER	CFM56-7B27B3	170	39,270	1,824	310,080	288	3,916	0.0126
	737 MAX-9	CFM LEAP-1B27B1	170	39,270	1,824	310,080	294	3,465	0.0112
BOS-SEA	A320ceo	CFM56-5B4/P	150	34,650	2,517	377,550	374	5,126	0.0136
	A320neo	CFM LEAP-1A26	150	34,650	2,517	377,550	376	4,182	0.0111
	737-800W	CFM56-7B26	150	34,650	2,517	377,550	381	4,863	0.0129
	737-8	CFM LEAP-1B27	150	34,650	2,517	377,550	379	4,218	0.0112
	A321ceo	CFM56-5B3/P	108	25,160	2,516	271,728	375	5,279	0.0194
	A321neo	CFM LEAP-1A32	170	39,270	2,517	427,890	375	4,615	0.0108
	737-900ER	CFM56-7B27B3	170	39,270	2,518	428,060	379	5,395	0.0126
	737-9	CFM LEAP-1B27B1	170	39,270	2,517	427,890	388	4,773	0.0112
BOS-LAX	A320ceo	CFM56-5B4/P	127	29,359	2,729	346,583	403	5,376	0.0155
	A320neo	CFM LEAP-1A26	150	34,650	2,731	409,650	405	4,541	0.0111
	737-800W	CFM56-7B26	150	34,650	2,731	409,650	410	5,277	0.0129
	737-8	CFM LEAP-1B27	150	34,650	2,732	409,800	408	4,578	0.0112
	A321ceo	CFM56-5B3/P	70	16,170	2,730	191,100	405	5,394	0.0282
	A321neo	CFM LEAP-1A32	170	39,270	2,732	464,440	404	5,012	0.0108
	737-900ER	CFM56-7B27B3	165	38,168	2,732	450,780	407	5,843	0.0130
	737-9	CFM LEAP-1B27B1	170	39,270	2,731	464,270	418	5,183	0.0112

BLOCK FUEL PERFORMANCE OF A320CEO, A320NEO, A321CEO, A321NEO, 737-800, 737-900ER, 737-8 & 737-9 - PAYLOAD SCENARIO 2

City-pair	Aircraft variant	Engine variant	Seats	Payload carried - lbs	ESAD - nm	ASMs	Block time - mins	Block fuel - USG	Fuel burn/ ASM
BOS-YYZ	A320ceo	CFM56-5B4/P	136	31,416	482	65,552	105	1,202	0.0183
	A320neo	CFM LEAP-1A26	136	31,416	483	65,688	104	989	0.0151
	737-800W	CFM56-7B26	136	31,416	483	65,688	112	1,202	0.0183
	737-8	CFM LEAP-1B27	136	31,416	486	66,096	114	1,058	0.0160
	737-900ER	CFM56-7B27B3	152	35,112	486	73,872	113	1,311	0.0177
	737-9	CFM LEAP-1B27B1	152	35,112	485	73,720	112	1,144	0.0155
	A321ceo	CFM56-5B3/P	163	37,416	483	78,729	105	1,351	0.0171
	A321neo	CFM LEAP-1A32	163	37,653	483	78,729	104	1,114	0.0142
BOS-CVG	A320ceo	CFM56-5B4/P	136	31,416	831	113,016	151	1,813	0.0160
	A320neo	CFM LEAP-1A26	136	31,416	831	113,016	151	1,498	0.0133
	737-800W	CFM56-7B26	136	31,416	831	113,016	158	1,782	0.0158
	737-8	CFM LEAP-1B27	136	31,416	832	113,152	157	1,547	0.0137
	737-900ER	CFM56-7B27B3	152	35,112	832	126,464	158	1,938	0.0153
	737-9	CFM LEAP-1B27B1	152	35,112	831	126,312	158	1,707	0.0135
	A321ceo	CFM56-5B3/P	163	37,653	831	135,453	151	2,040	0.0151
	A321neo	CFM LEAP-1A32	163	37,653	831	135,453	150	1,668	0.0123
BOS-ATL	A320ceo	CFM56-5B4/P	136	31,416	977	132,872	170	2,094	0.0158
	A320neo	CFM LEAP-1A26	136	31,416	977	132,872	170	1,729	0.0130
	737-800W	CFM56-7B26	136	31,416	977	132,872	177	2,042	0.0154
	737-8	CFM LEAP-1B27	136	31,416	977	132,872	176	1,773	0.0133
	737-900ER	CFM56-7B27B3	152	35,112	977	148,504	176	2,218	0.0149
	737-9	CFM LEAP-1B27B1	152	35,112	977	148,504	178	1,960	0.0132
	A321ceo	CFM56-5B3/P	163	37,653	977	159,251	170	2,365	0.0149
	A321neo	CFM LEAP-1A32	163	37,653	977	159,251	170	1,920	0.0121
BOS-MIA	A320ceo	CFM56-5B4/P	136	31,416	1,272	172,992	208	2,601	0.0150
	A320neo	CFM LEAP-1A26	136	31,416	1,272	172,992	209	2,149	0.0124
	737-800W	CFM56-7B26	136	31,416	1,272	172,992	216	2,524	0.0146
	737-8	CFM LEAP-1B27	136	31,416	1,272	172,992	214	2,189	0.0127
	737-900ER	CFM56-7B27B3	152	35,112	1,272	193,344	214	2,745	0.0142
	737-9	CFM LEAP-1B27B1	152	35,112	1,272	193,344	217	2,437	0.0126
	A321ceo	CFM56-5B3/P	163	37,653	1,272	207,336	209	2,933	0.0141
	A321neo	CFM LEAP-1A32	163	37,653	1,272	207,336	208	2,388	0.0115
BOS-DEN	A320ceo	CFM56-5B4/P	136	31,416	1,824	248,064	283	3,691	0.0149
	A320neo	CFM LEAP-1A26	136	31,416	1,824	248,200	283	3,031	0.0122
	737-800W	CFM56-7B26	136	31,416	1,825	248,200	290	3,535	0.0142
	737-8	CFM LEAP-1B27	136	31,416	1,825	248,200	289	3,078	0.0124
	737-900ER	CFM56-7B27B3	152	35,112	1,824	277,248	288	3,882	0.0140
	737-9	CFM LEAP-1B27B1	152	35,112	1,824	277,248	294	3,443	0.0124
	A321ceo	CFM56-5B3/P	163	37,653	1,824	297,312	282	4,189	0.0141
	A321neo	CFM LEAP-1A32	163	37,653	1,825	297,475	283	3,369	0.0113
BOS-SEA	A320ceo	CFM56-5B4/P	136	31,416	2,518	342,448	375	5,096	0.0149
	A320neo	CFM LEAP-1A26	136	31,416	2,517	342,312	376	4,163	0.0122
	737-800W	CFM56-7B26	136	31,416	2,517	342,312	382	4,836	0.0141
	737-8	CFM LEAP-1B27	136	31,416	2,517	342,312	379	4,200	0.0123
	737-900ER	CFM56-7B27B3	152	35,112	2,518	382,736	379	5,338	0.0139
	737-9	CFM LEAP-1B27B1	152	35,112	2,515	382,280	388	4,716	0.0123
	A321ceo	CFM56-5B3/P	109	25,307	2,514	273,917	375	5,350	0.0195
	A321neo	CFM LEAP-1A32	163	37,653	2,517	410,271	375	4,631	0.0113
BOS-LAX	A320ceo	CFM56-5B4/P	127	29,432	2,728	346,456	403	5,448	0.0157
	A320neo	CFM LEAP-1A26	136	31,416	2,731	371,416	404	4,514	0.0122
	737-800W	CFM56-7B26	136	31,416	2,731	371,416	411	5,243	0.0140
	737-8	CFM LEAP-1B27	136	31,416	2,732	371,552	408	4,552	0.0123
	737-900ER	CFM56-7B27B3	152	35,112	2,731	415,112	408	5,791	0.0140
	737-9	CFM LEAP-1B27B1	152	35,112	2,731	415,112	418	5,121	0.0123
	A321ceo	CFM56-5B3/P	70	16,268	2,729	191,240	404	5,466	0.0286
	A321neo	CFM LEAP-1A32	163	37,653	2,732	445,316	404	5,025	0.0113

800 is not as large as the difference between the A320ceo and A320neo.

A higher engine bypass ratio will result in a more efficient engine. Due to airframe constraints, the 737 MAX has a smaller bypass ratio than the A320/321neo. The engine bypass ratio in the case of the 737 variants increases from 5.1:1 on the 737-800 to 9.0:1 on the 737-8 . This compares to a larger increase when going from 5.7:1 on the A320ceo to 11.0:1 on the A320neo.

The 737-8 has a block fuel burn improvement of 12.0% to 13.6% across the 14 sectors with the 85% passenger payload resulting in an average improvement of 13.1%. The 737-8 offers an improvement in fuel cost per ASM of 0.39 to 0.48 cents per ASM with an average improvement of 0.41 cents per ASM. Neither the 737-800 nor the 737-8 have any payload limitations on the routes or scenarios in this study.

737-900ER(W) versus 737-9

The performance improvement in the 737-9 compared to the 737-900ER(W) is lower than the difference on the smaller variant. The trend in engine thrust rating is the opposite to the Airbus aircraft.

On the 737-9, Boeing has increased the CFM LEAP-1B28B1's thrust rating to 28,000lbs compared to 27,000lbs for the CFM56-7B27B3 installed on the 737-900ER(W). This is despite the 737-8's OEW being 6,500lbs higher.

The 737-9 has an 11.2% to 12.7% lower fuel burn compared to the 737-900ER(W) across the 14 routes with the same passenger payload. The 737-9 has a greater improvement in fuel burn on the shorter sectors.

The improvement in fuel cost per ASM ranges from 0.47 to 0.33 cents, and is greater on the shorter sectors.

The 737-900ER(W) is payload-limited to 165 passengers on BOS-LAX. The 737-9 has no payload limitation on any of the 14 the sectors in this study.

This evaluation has been conducted using the same payload and seat configurations for these aircraft types. As with the newer types it is expected that cabin interior enhancements and changes to in-flight service levels will increase seat capacity on the later aircraft models and further improve the fuel cost per ASM difference.

A320ceo versus 737-800

The comparison of the A320ceo against the 737-800 is interesting. On the shorter sectors, the A320ceo has a better block fuel burn performance of up to 2.1%. On the longer sectors, however, the 737-800 is more efficient with up to a 5.1% benefit in fuel burn with the heavier payload in scenario 1.

The average over the 14 sectors is a 2.5% lower fuel burn for the 737-800.

In the 85% passenger payload scenario, the difference in fuel burn increases to an average of 3.3% for the lighter aircraft. The lower fuel burn on the 737-800 results in a fuel cost per ASM that is 0.01 to 0.15 cents better than the A320ceo.

The A320ceo is payload-restricted to 127 passengers on the longest sector, which is BOS-LAX, whereas the 737-800 can carry the 150-passenger payload.

A320neo versus 737-8

In this comparison the passenger seat capacity has been configured as the same total seat count for these two types. This results in the same payload being carried in both payload scenarios.

In both cases, the A320neo has a lower fuel burn than the 737-8. This is larger than 3% on the shorter sectors, but as the distance flown increases, the fuel burn performance of the two reduces to 0.8%

The A321neo's large seat capacity and high bypass ratio engines provide it with the most superior fuel burn per seat-mile of all contemporary narrowbodies available on the market.

on the longest sector. The average fuel burn difference is 2.2%, and results in an average 0.06 cents per ASM advantage for the A320neo in the 85% payload scenario.

A321ceo versus 737-900ER(W)

Both the A321ceo and 737-900ER(W) have payload restrictions on the evaluation network. The A321ceo is restricted on four sectors as listed above, and the 737-900ER(W) is limited to 165 passengers on the longest BOS-LAX sector.

The comparison of the two aircraft types will only be made where unrestricted payloads can be carried. Over the nine sectors where a 170-passenger payload is evaluated for both types, the 737-900ER(W) has a 4.3% lower fuel burn than the A321ceo.

The 737-900ER(W)'s advantage in fuel cost per ASM ranges from 0.06 to 0.16 cents, with a network average improvement of 0.58 cents per ASM over the 14 routes in the evaluation. The seat configurations used for these aircraft types and the payload scenarios evaluated mean that in scenario 1 both aircraft carry 170 passengers. In scenario 2, the 85% payload case, the A321ceo is evaluated with 163 passengers and the 737-900ER(W) 152 passengers; thereby giving the A321ceo a revenue benefit of 11 passengers.

In the payload 2 scenario, the fuel burn difference between the aircraft types increases to 5.7% in favour of the 737-900ER(W) due to the heavier payload. The difference in fuel cost per ASM, however, reduces to an average 0.04 cents in favour of the Boeing aircraft, with the A321ceo performing better on the shorter sectors.

A321neo versus 737-9

The A321neo has a lower fuel burn performance than the 737-9. In the evaluation when carrying the same payload of 170 passengers, the A321neo burns an average 3.6% less fuel over the 14 sectors than the 737-9.

The fuel burn difference is greater on the shorter sectors at 4.6%, and reduces to a 3.3% advantage for the A321neo on the longest sector. The average fuel cost per ASM is 0.09 cents better for the A321neo.

As with the comparison of the A321ceo versus the 737-900ER(W), in the second payload scenario using the 85% load factor, the A321neo carries a heavier payload, due to its higher seat capacity, of 192 seats versus 179 on the 737-9.

Any seating configuration is defined by the aircraft operator, but in this evaluation the results show that the lighter payload on the 737-9 reduces the block fuel burn difference to an average of 2.1% over the 14 sectors.

The fuel cost per ASM difference increases to 0.22 to 0.29 cents or 8.7% better for the A321neo due to its increased capacity.

Summary

The A320 and the 737 families will remain key aircraft for many operators across the world, since they are proven to provide safe and efficient operations. Any final comparison of the two manufacturers would need to consider many more factors than is possible in this article.

A potential operator would need to evaluate the physical configuration of the aircraft in terms of engine rating, operating weights plus the interior cabin configuration, because this study shows that a difference in seat capacity has a big impact on the fuel cost per ASM. Other operational factors that also have to be considered include fleet commonality, original equipment manufacturer (OEM) support, operating procedures and financing.

Comparing the older Airbus and Boeing aircraft, the 737-800 has a 2.5% **trip-??** fuel burn benefit to the A320ceo and 4.3% better performance on the 737-900ER(W) compared to the A321ceo in this evaluation.

Both the younger generation of Airbus and Boeing aircraft benefit from the improved engine efficiency and offer 13.1% to 18.9% improvements in block fuel performance, which is beneficial to the operator. The reductions in fuel burn also translate into increased range and operating potential for these aircraft. The A321ceo was payload-limited on the route network used in this study, due to fuel tank capacity, whereas the A321neo, with the same maximum fuel capacity, had no payload reduction.

The thrust ratings on the engines show a different trend for the two manufacturers, with Airbus reducing the equivalent engine thrust ratings for the neo family of aircraft, despite increases in MTOW and OEW. In contrast, Boeing has increased the thrust ratings on the MAX series of aircraft compared to the equivalent NG family members. A lower thrust rating could provide the 737 MAX operator with additional savings in maintenance costs.

The A320neo family and 737 MAX remain competitive aircraft. In this evaluation, the 737-8 and 737-9 are 2.2% to 3.3% less efficient than the A320neo and A321neo respectively.

Since both the aircraft and engine manufacturers support these aircraft types in service with performance improvement packages, it will be interesting to re-evaluate the relative performance of these aircraft again in the future. AC