The large narrowbody market is now contested between the 737-900 and A321-200. These aircraft can complement or replace the 757-200. The fuel burn and operating performance of the three types are analysed and compared on six routes with mission lengths between 300nm & 1,500nm.

737-900ER, A321-200 & 757-200 fuel burn & operating performance

The demand for narrowbody aircraft remains high, encompassing small, medium and large aircraft. Airlines are increasingly operating on less dense routes that serve smaller cities. This partly explains the development of many next generation regional jets. Passenger demand on current routes is still increasing. Airlines are increasing aircraft size on some popular routes.

Traditional staples of a short-haul fleet are the 737 and A320. The A321-200 and newer 737-900ER are stretched examples, with higher seat counts. The 757 has been traditionally used on high-density, short-haul routes, and still serves many routes in the US. The 757 also continues to be popular on holiday charter routes. The 757-200, A321-200 and 737-900ER represent the three generations of large narrowbody jets, with each being first delivered in the 1980s, 1990s and 2000s, respectively. These three aircraft also have the advantage of long-range performance, with many medium-haul routes being possible.

The 737-900ER and A321-200 have similar ranges of 3,200nm at maximum payload. The 757-200 has a little more range, at 3,900nm. The passenger load is also very similar across all three aircraft models, with seating of 215-239 available in an all-economy configuration. While the 757-200 has both the longest range and largest passenger capacity, it is also the oldest of the three airframes and has the oldest technology and engines. It is also relatively heavy per seat. These factors combine to make its fuel burn per seat-mile relatively high.

The analysis will examine which of these three aircraft are the most efficient performers on various routes in terms of fuel burn, available payload and block time. This in turn will give an insight into which aircraft is suited to different operational requirements.

All the aircraft are capable of carrying belly freight payload in addition to full dual-class passenger loads. The exact amount of additional cargo and the resultant fuel burn will differ on each route according to permitted take-off weight, permitted payload and fuel required to complete the mission. As they are more recently developed and lighter than the 757, the 737-900ER and A321 will generally have better engine technology. This is likely to result in better fuel burn and operating performance. This is examined for the three types on a variety of short and medium-haul routes.

Not surprisingly, the 737-900ER being the latest generation and lightest aircraft, has lower fuel burn per seat-mile than the A321-200 and 757-200. The difference in capacity between the 737-900 and the largest 757-200, in typical airline configurations, is nine seats.

737-900ER, A321-200 & 757-200 CONFIGURATIONS

	737-900ER	A321-200		757-200	
Seats:					
OEM - one-class	215	220		239	
OEM - two-class	180	185		186	
Airline - av. two-class	173	178		181	
Maximum range-nm	3,265	3,200		3,900	
Engine option	CFM56-7B26	CFM56-5B	V2533-A5	PW2037	RB211-535E4
Max. thrust (lbs)	27,300	33,000	32,000	37,200	40,200
Weights (lbs):					
MTOW	187,700	206,000		220,000	255,000
MZFW	149,300	163,000		184,000	188,000
OEW	98,495	107,000		130,875	136,940
Max. structural payload (lbs)	50,805	56,000		53,125	51,060
Max. fuel capacity (USG)	7,837 (2 aux. fuel tanks)	7,935		11,276	
Belly freight capacity:					
Containers	-	10xLD3-46W		-	
Bulk loaded volume (cu.ft.)	1,587 (1,826lbs with no aux. fuel tanks)	1,828 (LD3 only = 1,300)		1,790	

SUMMARY OF AIRPORT PARAMETERS FOR THE PERFORMANCE ANALYSIS

	Runway	Runway length (ft)	Temperature - Av. Daily highs - June (deg.C)	Airport terminal elevation (ft)
Chicago-O'Hare (ORD)	10/28	13,001	27	672
	14L/32R	10,005		
	14R/32L	9,685		
	4R/22L	8,075		
	9R/27L	7,967		
	4L/22R	7,500		
	9L/27R	7,500		
Minneapolis-St. Paul (MSP)	4/22	11,006	26	841
	12R/30L	10,000		
	12L/30R	8,200		
	17/35	8,000		
Lincoln, Nebraska (LNK)	18/36	12,901	29	1,219
	14.32	8,649		
	17/35	5,800		
La Guardia, New York (LGA)	13/31	7,003	26	21
	4/22	7,001		
Dallas-Ft. Worth (DFW)	17C/35C	13,401	32	607
	17R/35L	13,401		
	18L/36R	13,400		
	18R/36L	13,400		
	13R/31L	9,301		
	13L/31R	9,000		
	17L/35R	8,500		
Denver (DEN)	16R/34L	16,000	27	5,431
	7/25	12,000		
	8/26	12,000		
	16L/34R	12,000		
	17L/35R	12,000		
	17R/35L	12,000		
Miami (MIA)	9/27	13,016	31	9
	8R/26L	10,506		
	12/30	9,355		
	8L/26R	8,600		
Los Angeles Intl. (LAX)	06L/24R	8,925	27	126
	06R/24L	10,285		
	07L/25R	12,091		
	07R/25L	11,096		

Range performance

Few aircraft are operated to their full range capability. Some fuel is required to be reserved for operational and safety requirements, including: in-flight delays; waiting for permission to land; having to operate at less than optimum speed, climb performance, or altitude; contingency for issues such as stronger-than-forecast headwinds; and having to divert to a suitable alternative airfield after a failed landing attempt at the destination airfield.

The distance to a suitable diversion airport has a major effect on the quantity of reserve, and therefore the total, fuel required. In turn it affects the remaining weight of the payload that an aircraft can carry on the mission as belly freight.

With pressure on revenues, it is vital that an airline can maximise its revenue-generating potential. This means flying the aircraft with a full load of of passengers and belly freight on as many routes as possible.

While a route may seem possible for an aircraft when the great circle distance is compared to its payload-range performance, it has to be remembered that a route's tracked distance will be longer. An aircraft cannot follow the great circle track, but must follow certain paths via waypoints, which can easily increase the route length by 5%.

Winds also need to be taken into consideration. The westerly direction of upper winds generally decreases the equivalent still air distances (ESADs) that aircraft have to fly when operating eastwards, due to tailwinds. This effectively shortens the distance that the aircraft is required to fly. Likewise, when an aircraft flies westward, the ESAD will increase because it is flying into headwinds.

Performance limitations such as long ESADs, high departure airport temperatures or airfield elevations can all combine to restrict the payload and the revenue-generating potential of an airline. The longer the ESAD, the more challenging the route will be for an aircraft and its payload.

Aircraft types

The 737-900ER is a Next Generation variant of the 737 family. It is also the largest 737 variant, and competes directly with the older 757 and A321. The ranges of the three types vary from 3,200nm to 3,900nm, while they have similar maximum one-class seat capacities. These factors, together with the structural weights and fuel burn rates, will determine the payload that each aircraft is able to carry on each route.

All aircraft have been compared using the same routes, weather, operating

The fuel burn per seat-mile performance of the A321-200 powered by either engine options is close to the PW2037-powered 757-200. The RB211-535E4-powered 757-200 has about a 8% higher fuel burn per seat-mile than its PW2037-powered counterpart.

conditions and passenger weights.

The objective is to identify the permitted take-off weight, actual take-off weight, available payload and the fuel used for each aircraft on each route. This then allows an analysis of the fuel burn per ton-mile and seat-mile to be carried out, and a determination of the weight of belly freight that can be carried.

The MTOW weights for the aircraft analysed are: 187,000lbs for the 737-900ER; 206,000lbs for the A321-200 220,000lbs for the PW2037-powered 757-200 and 255,000lbs for the 757-200 with RB211-535E4 engines.

The operating empty weight (OEW) can vary between operators on the same aircraft type, due to: different seat and interior configurations (the number of galleys, toilets and crew rest areas); crew numbers; and the items loaded on board for cabin service (meals, entertainment, drinks and other cabin service items). The OEW is important, since an increased OEW means less available payload and higher fuel burn. The OEWs used here are realistic examples for each aircraft type and its operators.

Both single- and two-class layouts are seen on these aircraft, with all-economy configurations generally used by leisure and low-cost operators. A two-class layout has been used in this analysis because it is used more commonly on these aircraft when on scheduled routes, especially in North America where the missions are located. The manufacturer's standard two-class layout on the 737-900ER is 180, although currently the only North American operator, Continental Airlines, has a two-class layout totalling 173 seats. Airbus's standard two-class layout on the A321-200 has 185 seats. Most North American operators have nearer to 178 seats in a two-class configuration. For the 757-200, Boeing uses a two-class figure of 186, while a North American airline average is smaller at 181 seats.

Airlines have to consider a compromise between the number and weight of passengers (and their baggage) and the additional amount of belly freight that can be carried. Having more seats increases passenger revenue, but can decrease freight capacity and vice versa. Consideration also has to be given to the split between business and economy cabin sizes, depending on both the passenger demand and the revenue potential from each ticket type.

Other than the structural weights, the other major difference between the aircraft is their engine options. The 737-900ER is powered by the CFM56-7B26 with 27,300lbs of thrust. The A321-200 can be equipped with either CFM56-5B engines, or V2533-A5 engines. The CFM56-5B has an engine thrust of 33,000lbs, while the V2533-A5 is lower at 32,000lbs. The airframe and engine manufacturers offer a number of performance variables for operators to choose from. One aspect is the particular engine model and thrust rating. The A321-200 engines analysed in this article have higher thrusts than the 737-900ER option, but not as high as the 757-200s being analysed. The 757-200 can be powered by Pratt & Whitney PW2037s with a thrust rating of 37,200lbs or the Rolls Royce RB211-535E4, with a higher thrust rating of 40,200lbs.

The maximum zero fuel weight (MZFW) for each aircraft always remains the same, and determines maximum structural payload. For the 737-900ER the MZFW is 149,300lbs, and for the A321-200 it is 163,000lbs. For the 757-200 the MZFW is higher again at 184,000-188,000lbs.

Operating conditions

The performance of an aircraft is very affected by a number of situational factors. These can include the temperatures and wind speeds of both the departure and arrival airport, as well as an airport's altitude and runway length.

Standard rules have been followed for the flight plan analysis with long-range cruise (LRC) and average wind and temperature figures for the month of June. While LRC is not needed for the shorter routes, it is likely to be needed for longer routes, so to keep the variables in this analysis to a minimum, it has been used for all routes.

The seven routes used were selected for their gradually increasing great circle distance. This was so the aircraft could be analysed on both short- and medium-length routes, while also considering upper winds and the resulting ESADs. The seven routes have ESADs ranging from 349nm to 1,779nm, compared to great circle distances of 290-1,516nm and tracked distances of 321-1,571nm *(see table, page 28)*.

Chicago-O'Hare International Airport (ORD) is the departure point for all the flights, due to its central location within North America which makes it a good starting point for routes of various lengths. Minneapolis-St Paul International (MSP) is the shortest route, with ESADs of 349-358nm, depending on aircraft type.

This is followed by Lincoln, Nebraska, with ESADs of 436-466nm. Both these routes are in a westerly direction, and so are negatively affected by headwinds. ORD to La Guardia, New York (LGA) is an easterly route, with ESADs of 591-642nm. These represent a reduction on the tracked distance *(see table, page 28)*.

The next two routes are westerly again and so are affected by negative winds. They are Dallas-Ft. Worth (DFW), with ESADs of 759-781nm; and Denver (DEN) with ESADs of 842-901nm.

The route to Miami (MIA) is slightly easterly, so it has small tailwinds. This

FUEL BURN & OPERATING PERFORMANCE FOR THE 737-900ER, A321-200 & 757-200

Route	Aircraft model	Engine model	Great circle distance (nm)	Tracked distance (nm)	ESAD (nm)	Wind (kts)	Block time (mins)	Block fuel burn (USG)	Actual TOW (lbs)	Available payload (lbs)	Seat numbers	Available cargo (lbs)	Fuel burn (lbs) per ton-mile	Fuel burn (USG) per seat-mile
ORD-MSP	737-900ER	CFM56-7B	290	322	358	-60	78	954	160,132	50,000	173	11,940	0.8000	0.0154
	A321-211	CFM56-5B3P	290	321	350	-34	75	1,081	173,196	56,000	178	16,840	0.8279	0.0174
	A321-231	V2533-A5	290	321	349	-32	75	1,089	174,064	56,000	178	16,840	0.8360	0.0175
	757-200	PW2037	290	322	357	-49	78	1,134	197,145	53,125	181	13,305	0.8988	0.0176
	757-200	RB211-535E4	290	321	354	-36	77	1,220	200,422	51,060	181	11,240	1.0129	0.0190
ORD-LNK	737-900ER	CFM56-7B	405	406	466	-59	90	1,134	159,979	50,000	173	11,940	0.7307	0.0141
	A321-211	CFM56-5B3P	405	405	440	-33	87	1,278	174,656	56,000	178	16,840	0.7783	0.0163
	A321-231	V2533-A5	405	405	436	-29	87	1,288	175,545	56,000	178	16,840	0.7917	0.0166
	757-200	PW2037	405	406	456	-48	89	1,342	197,771	53,125	181	13,305	0.8335	0.0163
	757-200	RB211-535E4	405	405	443	-34	89	1,443	202,084	51,060	181	11,240	0.9575	0.0180
ORD-LGA	737-900ER	CFM56-7B	637	653	642	11	115	1,501	162,922	50,000	173	11,940	0.7017	0.0135
	A321-211	CFM56-5B3P	637	652	595	38	112	1,707	177,796	56,000	178	16,840	0.7690	0.0161
	A321-231	V2533-A5	637	652	595	38	112	1,723	178,665	56,000	178	16,840	0.7760	0.0163
	757-200	PW2037	637	648	615	27	115	1,795	201,183	53,125	181	13,305	0.8269	0.0162
	757-200	RB211-535E4	637	652	591	40	114	1,932	205,642	51,060	181	11,240	0.9608	0.0181
ORD-DFW	737-900ER	CFM56-7B	697	716	759	-31	130	1,731	163,996	50,000	173	11,940	0.6844	0.0132
	A321-211	CFM56-5B3P	697	759	781	-12	132	2,057	179,699	56,000	178	16,840	0.7059	0.0148
	A321-231	V2533-A5	697	751	773	-12	131	2,032	181,029	56,000	178	16,840	0.7046	0.0148
	757-200	PW2037	697	734	768	-22	131	2,105	202,862	53,125	181	13,305	0.7747	0.0152
	757-200	RB211-535E4	697	751	773	-12	133	2,297	208,395	51,060	181	11,240	0.8735	0.0164
ORD-DEN	737-900ER	CFM56-7B	772	795	901	-59	145	2,006	166,002	50,000	173	11,940	0.6684	0.0129
	A321-211	CFM56-5B3P	772	783	842	-31	137	2,184	181,259	56,000	178	16,840	0.6951	0.0146
	A321-231	V2533-A5	772	783	842	-31	136	2,180	182,081	56,000	178	16,840	0.6938	0.0145
	757-200	PW2037	772	789	878	-47	142	2,348	204,904	53,125	181	13,305	0.7564	0.0148
	757-200	RB211-535E4	772	783	849	-34	138	2,447	209,363	51,060	181	11,240	0.8471	0.0159
ORD-MIA	737-900ER	CFM56-7B	1,040	1,114	1,113	1	176	2,466	170,555	50,000	173	11,940	0.6650	0.0128
	A321-211	CFM56-5B3P	1,040	1,069	1,045	10	167	2,656	184,803	56,000	178	16,840	0.6811	0.0143
	A321-231	V2533-A5	1,040	1,067	1,040	11	166	2,644	185,507	56,000	178	16,840	0.6812	0.0143
	757-200	PW2037	1,040	1,092	1,073	8	172	2,857	209,358	53,125	181	13,305	0.7529	0.0147
	757-200	RB211-535E4	1,040	1,067	1,033	14	168	2,966	213,279	51,060	181	11,240	0.8438	0.0159
ORD-LAX	737-900ER	CFM56-7B	1,516	1,571	1,772	-54	261	3,831	179,277	50,000	173	11,940	0.6489	0.0125
	A321-211	CFM56-5B3P	1,516	1,519	1,617	-27	241	4,024	194,787	56,000	178	16,840	0.6670	0.0140
	A321-231	V2533-A5	1,516	1,519	1,620	-28	240	3,963	195,147	56,000	178	16,840	0.6555	0.0137
	757-200	PW2037	1,516	1,547	1,706	-43	253	4,395	219,477	52,731	181	12,911	0.7335	0.0142
	757-200	RB211-535E4	1,516	1,519	1,632	-31	242	4,516	224,618	51,060	181	11,240	0.8133	0.0153

Source: Jeppesen and Navtech Flight Planning

results in ESADs of 1,033-1,113nm. These are only slightly shorter than the original tracked distances.

The longest route is ORD to Los Angeles (LAX). This is again westerly, and with headwinds of at least 27 knots, the ESAD is 1,617-1,772nm.

Average daily temperatures for June in ORD are 27 degrees centigrade while average temperatures at the other seven destinations vary from 26 to 32 degrees centigrade *(see table, page 26)*. The airport elevations vary from 9 feet at MIA to 5,431 feet at DEN.

All the routes are within the maximum range capabilities of all the aircraft, and are typical of the route lengths these aircraft operate on. There was no need for a reduction in passenger numbers, although the available belly freight payload was reduced by about 400lbs on the longest route for the 757-200 with PW2037 engines only.

Performance results

The performance results for each aircraft on each route provide a total available payload. This has been converted into passenger numbers using 220lbs per passenger, including baggage, as a standard weight. The surplus available payload represents the additional belly freight the aircraft could potentially carry on the flight. All the calculations show no reduction in payload on all seven routes, except for the 757-200 with PW2037 engines on the longest route.

This shows the aircraft can all deal with very short flights, as well as longer missions of about four hours. This was partly possible due to the use of LRC. If a faster cruise speed had been used, then block times would have been shorter. This would have raised fuel burn, and the payload would have been increasingly reduced on the longer routes. This is the compromise that an operator has to consider on every route, with regard to payload and scheduling needs.

Two different flight planning systems were used in order for all five aircraft combinations to be analysed side by side.

Despite being a 1980s generation aircraft, the 757-200's fuel burn performance is comparable to the A321-200's performance. The 757-200's fuel burn, however, is about 15% higher than the 737-900ER's.

The two main factors in the results are the available payload and the fuel burn. The fuel burn is both the fuel used in flight, and for 20 minutes of taxi time per sector. The block time includes 20 minutes of taxi time added to the flight time.

The 737-900ER, A321-200 and 757-200 show why they are popular short-haul aircraft on high-density routes, as belly freight seems to show little or no reduction, even on longer missions. The A321-200 in particular does well, with potentially an additional 16,840lbs of belly freight. The A321-200 also has the interlining advantage of being able to carry LD-3 containers in its belly. The 737-900 and 757-200 can only carry bulk cargo.

On timings, the A321-200 also performs well, with the smallest block times on almost all flights. However, these differences only amount to a few minutes, even on the longer routes. The three types are therefore shown as being similar on flight times.

For the first three routes (ORD-MSP, ORD-LNK and ORD-LGA), the block times for both A321-200 aircraft are exactly the same. On subsequent longer routes, the V2533-A5-powered A321-200 is fractionally faster. In addition, as the route increases in length, the gap between the block times of the 757 and A321 closes.

As the number of passengers carried by an aircraft increases, it can be assumed that the fuel burn will increase too. The two A321-200 variants show similar absolute fuel burns on all routes, although on the shortest three routes a slight reduction is seen for the CFM56-powered aircraft.

This changed for the next four routes, with the V2533-A5-powered A321-200 burning slightly less fuel. The change occurs at a block time of about two hours and ESAD of about 700nm.

The 757-200 also had differing block fuel burns depending on engine type, with the PW2037 consistently performing better than the RB211 engine. The RB211, however, shows slightly improved block times on three routes and has more engine thrust. With the highest engine thrust of all the aircraft being analysed in this article, the 757-200 with RB211-535E4 engines is the most suited to hot and high operations.

When the block fuel burn is combined with the seat numbers and ESAD, a more detailed view of an aircraft's performance is given. This is the fuel burn in US Gallons (USG) per seat per mile, or per seat-mile. The longer the route, the lower the fuel burn per seat-mile for all aircraft types.

For every route, the 737-900ER shows the best results, although it might be seen to plateau on longer routes than the ones used for this analysis. The performance order is roughly the same for each route, with the 737-900ER having the lowest burn per seat-mile, followed by the A321s and then the two 757 variants.

The analysis shows that the 757-200 with PW2037 engines has a lower fuel burn per seat-mile than the V2500-powered A321-200 variant, and the RB211-powered 757-200 model, on the shortest four routes. Both A321-200 variants perform better than the two 757 variants on the last two routes.

With the two A321-200 models, the shortest three routes show the CFM56-powered aircraft as the better performer. Both engine-airframe combinations perform equally on the fourth and sixth routes ORD-DFW and ORD-MIA. On the fifth and last routes, ORD-DEN and ORD-LAX, the V2533-A5-powered aircraft shows more efficiency.

The available payload of each aircraft represents additional revenue potential for an operator. The A321-200 has the largest payload at 56,000lbs, followed by the PW2037-powered 757-200 at 53,125lbs. The heavier weight of RB211-535E4 engines means the aircraft's payload is lower at 51,060lbs.

The 737-900ER has the smallest available payload, but it is also the smallest of the three aircraft types. Once the weight of passengers and their baggage has been taken into consideration, the remaining available payload can be utilised for belly freight.

Again, the A321-200 has the highest available payload for belly freight, followed by the 757-200 with PW2037 engines. The 737-900ER has the lowest available belly freight. The RB211-535E4-powered 757-200s have the smallest available cargo potential.

Another way of analysing aircraft in detail is in terms of fuel burn for total available payload carried on a route. This is in terms of burn per ton per mile, or per ton-mile. That is, for total available payload.

Again, as the route length increases, the fuel burn per ton-mile decreases. The 737-900ER is again the most efficient on all seven routes. The aircraft follow the same order as for the fuel burn per seat-mile, with the A321-200s being the second most efficient, followed by the PW2037-equipped 757-200s. The 757-200s with RB211-535E4 engines share the highest burn per ton-mile.

The relative differences in fuel burn efficiency between types follow the same order as the generations of technology for each type and its engines. The 757-200 may not perform as well as the 737-900ER, but the 757 is still a popular workhorse and has more seats. The A321-200 has done consistently well in this analysis, but as the 757-200 retires, the A3210-200 will compete more directly with the 737-900ER. AC