The fuel burn & operating performance of a narrowbody freighter is a key criteria in its selection. The performance of the MD-83F, four 737 freighter variants, and the high gross weight RR-powered 757-200PCF are analysed on European and Latin American-US routes.

Narrowbody freighter fuel burn & operating performance

Freight and cargo carriers have up to six main narrowbody types to choose from: the MD-80, 737-300, 737-400, 737-700, 737-800, and 757-200. The operating performance, and so revenue-generating potential, and fuel burn performance of these six types are analysed here on typical, intra-European freight routes, and from hot-and-high airfields in Latin America on routes into Miami.

Several passenger-to-freighter (P-to-F) conversion programmes are available for these types, which will be joined over the next few years by the A320 and A321.

These six types have gross structural payloads that vary from 43,000lbs to 84,000lbs. The 757-200 has a gross payload about 31,000lbs higher than the next largest type, the 737-800. The payloads of the other five narrowbodies range from 43,000 to 53,000lbs.

Aircraft performance

Freight operators will select a type or several types mainly based on the established or anticipated demand levels on their route networks. The three main factors that will influence aircraft selection are: operating performance, fuel burn performance, and maintenance costs. The operator and fuel burn performance of each type are linked.

Operating performance will primarily determine the payload a type can carry from each departure point on a route network. An aircraft will experience a payload limitation on routes that are long and in the zone of its payload-range profile that requires the aircraft to depart at maximum take-off weight (MTOW), or where the departure is from an airfield or in conditions where the aircraft's take-off weight is restricted to less than MTOW. The most usual causes of restricted take-off weight are a short runway, hot temperature at take-off, a high airfield elevation, or a combination of two or all of these factors.

The payload that can be carried by each type over an operator's route network in the most testing of weather and temperature conditions will therefore give a prospective operator an indication of its revenue-generating potential and capacity. In the case of an operation in a temperate climate, payload restrictions can be expected at departure airfields with relatively short runways, as well as departures in hot temperatures in summer months for daytime departures. Payload restrictions are unlikely or less likely for night-time departures, even in months with the highest daily temperatures. Many North American and European freight operations are based on night-time operations, especially those of small and express mail packages.

Payload restrictions are more likely to

Large numbers of 737-400s have been converted following a shortage of 737-300s that are regarded as good quality conversion candidates. The 737-400F has good operating performance on routes oF up to about 1,700nm.

occur for departures from hot and high airfields. The high ambient temperatures and thin air due to high elevations will limit an aircraft's take-off weight, and so result in a payload that is less than its maximum gross payload. Examples of payload limitations due to departures from hot and high airports are operations from various airfields in Latin America.

The operating performance of the six main types listed has been examined on eight European routes with tracked distances from 190nm to 780nm *(see table, this page)*; and from seven hot and high airfields in Latin America, with elevations from 3,021 feet to 8,360 feet, all to Miami with route lengths from 1,006nm to 2,705nm.

AIRPORT-PAIRS FOR NARROWBODY FREIGHTER OPERATING PERFORMANCE ANALYSIS

Departure airfield	Departure elevation - ft	Destination airfield	Gt circle distance - nm	Tracked distance - nm
Liege - LGG		Amsterdam - AMS	104	190
Liege - LGG		Hamburg - HAM	246	329
Liege - LGG		Milan - MXP	328	422
Liege - LGG		Copenhagen - CPH	397	480
Liege - LGG		Toulouse - TLS	452	522
Liege - LGG		Dublin - DUB	465	509
Liege - LGG		Stockholm - ARN	689	773
Liege - LGG		Madrid - MAD	716	778
San Jose - SYQ	3,021	Miami - MIA	972	1,006
Mexico City - MEX	7,316	Miami - MIA	1,108	1,153
Caracas - CCS	2,739	Miami - MIA	1,182	1,218
Bogota - BOG	8,360	Miami - MIA	1,309	1,353
Guadalajara - GDL	5,012	Miami - MIA	1,309	1,401
Quito - UIO	7,874	Miami - MIA	1,552	1,594
La Paz - LPB	13,325	Miami - MIA	2,519	2,705

Aircraft types

The six main types in this analysis differ in popularity. Those with the highest levels of demand, in terms of the number of P-to-F conversions, are the 737-300, 737-400 and 757-200. Since the start of 2012, 44 737-300s have been converted under two different modification programmes offered by Aeronautical Engineers Inc (AEI)/CommercialJet; and 90 737-400s have been converted under three different programmes. These are Pemco, AEI/CommercialJet and Bedek Aviation.

Over the same period, 127 757-200s have been modified. This is the largest number of all narrowbody types converted.

The MD-80 has had little demand and interest in contrast. The modification is offered by AEI/CommercialJet. Only 12 have been modified over the past five years, with five conversions in 2017.

Conversions for the 737-700 are offered by Bedek and Pemco, and the first two aircraft were converted by Bedek in 2017. Conversions of the 737-800 have also just begun, and are offered by AEI/CommercialJet, Boeing, and Bedek. The first aircraft has been converted by Boeing.

MD-80F

The MD-80 is available as a freighter via a P-to-F conversion from AEI. AEI offers conversions for the MD-82 and -83, which have a maximum zero fuel weight (MZFW) of 122,000lb. The MD-82F has an operating empty weight (OEW) or aircraft prepared for service (APS) weight of 75,400lbs, while the MD-83F's is 76,900lbs. These result in gross structural payloads of 46,600lbs and 45,100lbs, similar to the gross structural payload of the 737-400 following modification.

It has a total main-deck containerised volume of 4,416 cubic feet (cu ft), a lower deck volume of 1,253 cu ft, and so a total cargo volume of 5,669 cu ft. The MD-82F and -83F have a maximum packing density of 8.2lbs per cu ft and 8.3lbs per cu ft.

The aircraft included in this analysis is the MD-83F, with a gross structural payload of 45,312lbs.

The total tare weight of the main deck unit load devices (ULDs) is 4,416lbs. This results in a net structural payload of 40,896lbs *(see table, page 58)*. Total fuel capacity is 7,140 US Gallons (USG).

737-300F

There are three P-to-F modifications for the 737-300. With the highest MTOW of 139,500lbs and an MZFW of 109,600lbs, the converted aircraft have a gross structural payload of 42,900-43,100lbs, with an average OEW of 66,500-66,700lbs.

The 737-300 can hold various container and ULD configurations, but the main one used is a row of eight 88-inch by 125-inch contoured ULDs that provide an interval volume of 438 cu ft, a total of 3,504 cu ft. The length of the main deck also allows an additional smaller container. Total main deck containerised volume is 3,650 cu ft.

The lower deck provides another 873 cu ft of bulk capacity, with the aircraft's total volume of 4,5238 cu ft *(see table, page 58)*. The aircraft therefore has a packing density of 8.0-8.2lbs per cu ft.

The aircraft included in this analysis has a MZFW of 109,600lbs and an OEW of 66,500lbs, and so a gross structural payload of about 43,100lbs *(see table, page 58)*.

The standard ULDs have a total tare weight of 4,608lbs, so the aircraft has a maximum net structural payload of 38,492lbs *(see table, page 58)*. It is equipped with CFM56-3B2 engines.

737-400F

The 737-400 has a longer fuselage than the -300, so it can accommodate 10 88-inch by 125-inch ULDs on its main deck, providing 4,380 cu ft of capacity. There is also enough main deck length to carry an additional smaller container.

Overall, the aircraft has a main deck volume of 4,540 cu ft. Lower deck bulk capacity takes the total to 5,800-5,900 cu ft, depending on the conversion programme used.

There are two MZFW options for the 737-400. These are the same for all three modification programmes. The standard gross weight (SGW) -400 has a MZFW of 113,000lbs. This gives the aircraft a gross structural payload of 43,100-45,750lbs, and an OEW of 67,250-69,900lbs following conversion.

The high gross weight (HGW) version has a higher MZFW of 117,000lbs. This adds up to 4,000lbs more gross structural payload for the aircraft converted by AEI and Bedek. Under Pemco's modification, the aircraft also has a marginal increase in OEW, and so overall an increase in gross structural payload of 2,140lbs.

Overall, the HGW 737-400F has a gross structural payload of 47,100-

AIRCRAFT SPECIFICATIONS, WEIGHTS & FREIGHT CAPACITIES

Aircraft type	MD-83F	737-300F	737-400F HGW	737-700F	737-800F	757-200F
Engine	JT8D-200	CFM56-3B2	CFM56-3C1	CFM56-7B20	CFM56-7B26	RB211-535E4
MTOW - lbs	160,000	138,500	150,000	154,500	174,200	240,000
MZFW - lbs	122,000	109,600	117,000	121,700	138,300	200,000
OEW/APS - lbs	76,688	66,500	69,000	76,700	85,300	116,000
Gross structural payload - lbs	45,312	43,100	48,000	45,000	53,000	84,000
Main deck ULD volume - cu ft	4,416	3,650	4,540	3,800	4,977	6,570
Lower deck bulk volume - cu ft	1,013	873	1,256/1,373	966	1,555	1,790
Total freight volume - cu ft	5,429	4,523	5,796/5,913	4,766	6,532	8,360
ULD tare weight - lbs	4,416	4,608	5,330	4,578	5,841	7,665
Net structural payload - lbs	40,896	38,492	42,670	40,422	47,159	76,335
Volumetric payload @ 6.5lbs/cu ft - lbs	35,288	30,049	37,674/38,434	30,979	42,458	54,340
Volumetric payload @ 7.5lbs/cu ft - lbs	40,717	34,672	42,670	35,745	47,159	62,700

48,000lbs. The aircraft has the same volumetric ULD capacity, so the maximum density of freight that can be carried is 7.2-7.4lbs per cu ft.

The aircraft included in this analysis is the HGW variant with an MZFW of 117,000lbs, and an OEW of 69,000lbs. This gives it a gross structural payload of about 48,000lbs.

The tare weight of the main deck ULDs is 5,330lbs, leaving the aircraft with a maximum net structural payload of 42,670lbs. It has a fuel capacity of 5,756USG, and is powered by CFM56-3C1 engines *(see table, this page)*.

737-700F

There are three P-to-F modifications for the 737-700, available from Bedek Aviation and Pemco. The first two 737-700s were converted in late 2017 by Bedek Aviation.

The 737-700 has the same fuselage and therefore the same main deck container and ULD capacity as the -300. The total ULD and bulk volume of the main and lower decks is 4,766 cu ft for the Bedek-converted aircraft, and 4,629 cu ft for the Pemco-converted aircraft.

Following conversion with both programmes, the 737-700F has an MZFW of 121,700lbs, and an OEW of about 76,700lbs. This gives the aircraft a gross structural payload of 45,000lbs *(see table, this page)*.

The -700F's higher gross payload over the -300-F gives the -700F a higher packing density of 8.5-8.8lbs per cu ft.

The -700F variant included in this analysis has an MZFW of 121,700lbs, and an OEW of 76,700lbs. This gives it a gross structural payload of 45,000lbs.

The main deck ULDs have a tare weight of 4,578lbs, which gives the aircraft a maximum net structural payload of 40,422lbs. It also has a fuel capacity of 7,031USG, and is equipped with CFM56-7B20 engines *(see table, this page)*.

737-800F

The 737-800F is available via P-to-F programmes from Boeing, Bedek Aviation and AEI/CommercialJet. Following modification, the aircraft has an MZFW of 138,000lbs and OEW of 85,000-86,000lbs, depending on conversion provider. This gives it a gross structural payload of 52,000-53,000lbs. This is 9,000-10,000lbs more than the 737-300F, which has the smallest payload of these four 737 variants and MD-80F.

The 737-800 can hold 11 88-inch by 125-inch standard ULDs on its main deck. This provides a containerised volume of 6,570 cu ft. The lower deck provides a bulk volume of 1,790 cu ft, so the aircraft has a total volume of 8,360 cu ft. This allows the aircraft a maximum packing density of 7.7-9.1lbs per cu ft.

The aircraft included in this analysis has an MZFW of 138,300lbs, an OEW of 85,300lbs, and a gross structural payload of 53,000lbs.

The main deck ULDs have a total tare weight of 5,841lbs, leaving the aircraft with a maximum net structural payload of 47,159lbs. It also has a fuel capacity of 7,000USG, and is equipped with CFM56-7B26 engines *(see table, this page)*.

757-200F

The 757-200F is available as a converted aircraft via Precision Conversions, with its own programme; and via the Boeing modification, with aircraft converted by ST Aerospace.

Under the two main conversion programmes, the 757-200F has a standard MZFW of 184,000lbs. Depending on the conversion programme and the engine type fitted to the aircraft, there are various MZFW options. Small upgrades offered by Boeing take the MZFW up to 188,000lbs for aircraft without winglets, and up to 189,400lbs of 187,400lbs for aircraft with winglets, depending on the engine type fitted.

Aircraft with these lower MZFW options have gross structural payloads of 69,000-71,000lbs.

Precision Conversions' modification allows the MZFW to be upgraded to 200,000lbs for aircraft equipped with RB211-535 engines, and up to 198,000lbs for aircraft fitted with lighter PW2000 engines. This is for aircraft from line number (L/N) 210 and higher. L/N was built in December 1988. Depending on the engine type, this gives aircraft without winglets a gross structural payload of 84,000lbs/82,350lbs.

The 757-200's main deck can hold 15 standard 88-inch by 125-inch ULDs. These provide a main deck containerised volume of 6,570 cu ft. The aircraft also has a lower deck bulk volume of 1,790 cu ft, and so a total volume of 8,360 cu ft. This provides a maximum packing density of 8.9-9.1lbs per cu ft for aircraft that have been modified by Precision

For aircraft above line number 210, the 757-200PCF can have a gross payload of up to 84,000lbs. This high payload means the aircraft will have the lowest fuel burn per ATM or ATK of any narrowbody freighter type in service.

Conversions, and whose MZFW has been upgraded to 198,000/200,000lbs.

The aircraft in this analysis is modified by Precision Conversions, and is equipped with RB211-535E4 engines. The aircraft has the highest possible MZFW of 200,000lbs. This gives it a gross structural payload of 84,000lbs.

The main deck ULDs have a tare weight of 7,665lbs, leaving the aircraft with a maximum net structural payload of 76,335lbs. The aircraft also has a fuel capacity of 11,510USG *(see table, page 58)*.

Basis of comparison

The performance of the aircraft is analysed using the Lufthansa Systems Lido/Flight solution on two sets of routes, to examine how its maximum available payload is affected by route length and mission parameters, in particular departure airport; and each aircraft's fuel burn on a per ton-mile basis.

The first set of routes departs from Liege (LGG) airport in Brussels to eight different destinations: Amsterdam (AMS), Hamburg (HAM), Milan Malpensa (MXP), Copenhagen (CPH), Toulouse (TLS), Dublin (DUB), Stockholm Arlanda (ARN), and Madrid (MAD). These eight routes have tracked distances of 190nm to 780nm *(see table, page 57)*, and are representative of a typical European freight operation.

Although the operating conditions used for the flight plans are daytime departures in June with relatively high temperatures, the aircraft are unlikely to experience any performance take-off weight (TOW) or payload limitations. The departure point of LGG has an airfield elevation of 659 feet. The elevation of seven of the eight destinations ranges from minus 11 feet (AMS) to 767 feet (MXP). MAD has an airfield elevation of 2,000 feet.

Four of the six aircraft experience a small payload limitation of 1-3% when departing from LGG to ARN. These are the MD-83F, 737-300F, 737-400F and 757-200F. The 737-700F and -800F do not experience a payload limitation.

The relative fuel burns per ton-mile of each aircraft can therefore be examined and compared when they are operating with their maximum allowable payloads.

The second set of routes has been chosen to examine the effects of operating factors that cause significant performance limitations. These are seven routes that all have departure points from hot and high airfields in Latin America: San Jose, Costa Rica (SYQ); Mexico City, Mexico (MEX); Caracas, Venezuela (CCS); Bogota, Colombia (BOG); Guadalajara, Mexico (GDL); Quito, Ecuador (UIO); and La Paz, Bolivia (LPB). These airfields have elevations of 3,021 feet to 13,325 feet *(see table, page 57)*.

The aircraft are examined on routes from these seven departure points to Miami (MIA). The seven routes have tracked distances of 1,006nm to 2,705nm.

The high elevations of the departure points are expected to result in performance limitations on most or all aircraft types. This is especially the case on routes where the departure point has a particularly high elevation, the route length is long, or both departure elevation are high and route length are long. The 7,316 ft elevation at MEX is an example, with MEX-MIA having a tracked distance of 1,153nm; while the UIO elevation of 7,874 ft and the route length to MIA of 1,594nm is another example.

Despite the high elevations of all seven departure airfields, the aircraft only experience a payload limitation on the longest route when departing from LPB.

Operating assumptions

Flight plans can be performed to examine the performance of an aircraft with a specified payload on each route, or to determine the maximum level that can be carried on each route. This analysis has been conducted to examine the permitted payload on each route.

The flight plans therefore have to consider the various issues that will affect and determine the aircraft's operating performance, permitted TOW, required fuel, and therefore maximum allowable payload at the departure airfield. The issues that have to be considered are:

- Flight rules
- Required fuel reserves
- The flight track used
- The altitude or flight level (FL) used
- The cruise speed and flight profile
- The winds and temperatures at departure and en route
- The taxi time and rate of taxi fuel burn

International flight rules are used, and are the semi-circular rules for cruising altitudes and FLs that relate to the direction of travel, and the vertical separation between cruising altitudes of 4,000 feet in the same direction or semi-circle, and 2,000 feet in the opposite direction or the two different semi-circles.

Fuel reserves required depend on the contingency rules that are used. These can be the European Aviation Safety Agency (EASA) standards, or the Federal Aviation Administration (FAA) standards.

The reserve fuel carried is the sum of the contingency fuel for the planned trip, the fuel required to reach a suitable alternate airport, and final reserve fuel.

A 5% allowance of planned fuel for the planned trip is used as the standard amount for contingency. This provides for delays en route, and stronger than expected headwinds, and holding fuel before landing.

Alternate fuel is the fuel required to divert to the suitable diversion airfield. Final reserve is the amount of fuel required for a 30-minute hold at 1,500 feet at the alternate.

The route tracks, FLs and cruise speeds have been optimised by Lido/Flight solution to achieve the lowest total cost for fuel burn, time-related costs, and all navigation and air traffic control (ATC) charges.

This last category of costs is high in Europe, but lower in Latin America and the US and across the Gulf of Mexico.

Optimisation by Lido/Flight solution will therefore be different in various regions of the world. The solution will optimise flight profiles.

In particular, this includes the FL, cruise speed, and track used. This affects the tracked distance, and when combined with the en-route wind speeds and directions over the entire track, will determine the equivalent still air distance (ESAD).

The weather assumptions used include average temperatures and winds for the month of June, with 85% reliability winds on each route.

The block fuel used on each route *(see tables, pages 62 & 64)* is the sum of the trip, taxi fuel and fuel used for the auxiliary power unit (APU) prior to engine start. The assumption used by Lido is that both engines have been used during taxi-out by all aircraft. The taxi-out and -in times have been taken for each airport from the Lido/Flight solution database. This adds 440-1,160lbs of fuel per trip, depending on the aircraft type and taxi time.

The fuel density used is 6.55lbs per USG, and this is used to convert aircraft fuel capacity and trip and block fuel burns.

Aircraft performance

As described, the two prime reasons for running the flight plans are to assess the payload-carrying capability on a range of routes and operating conditions, and to assess the fuel burn on a USG per available ton-mile (ATM) basis. The data has also been converted to a fuel burn in kilograms (kg) per available tonne-kilometre (ATK) basis *(see tables, pages 62 & 64).*

European routes

The eight routes in the European route analysis have tracked distances between 190nm and 778nm. The last two routes, LGG-ARN and LGG-MAD, have different great circle distances but similar tracked distances *(see table, page 57).*

Aircraft are restricted to cruising altitudes of 24,000 fleet (flight level (FL) 240) on LGG-AMS and FL270 on LGG-HAM. The aircraft then have varying cruising altitudes between FL330 and FL370 on the remaining routes, except the longest LGG-MAD sector where some types types are restricted to slightly lower cruising levels.

First, all six aircraft types are able to carry a full payload on all routes except LGG-ARN. The payload restrictions experienced by the MD-83F, 737-300F, 737-400F and 757-200F are only 1-3%. This is because the aircraft arrive at ARN at their maximum landing weight (MLW) limits. In the scope of most freight airline operations, typical load factors mean that these small limitations are unlikely to affect airlines' revenue-generating capacity. Moreover, if the aircraft are being used to carry express packages, then these small payload limitations for four of the types will have no impact at all. This is because small packages have low packing densities of 6.5lbs per cu ft,

BLOCK FUEL BURN PERFORMANCE OF MD-83F, 737-300F, 737-400F, 737-700F, 737-800F & 757-200PCF ON EUROPEAN ROUTES FROM LIEGE

City-pair	Aircraft variant	ESAD nm	Payload carried lbs	ATMs	Block time min	Block fuel USG	Fuel USG /ATM	ATKs	Fuel Kg /ATK
LGG-AMS	MD-83F	195	40,896	3,469	61	889	0.2562	7,429	0.364
	737-300F	195	38,492	3,265	61	654	0.2003	7,066	0.281
	737-400F	195	42,670	3,619	61	682	0.1886	7,950	0.261
	737-700F	195	40,422	3,429	61	631	0.1841	7,378	0.260
	737-800F	195	47,159	4,000	62	699	0.1749	8,689	0.245
	757-200F	195	76,335	6,475	63	938	0.1448	13,913	0.205
LGG-HAM	MD-83F	327	40,896	6,007	73	1,205	0.2006	12,457	0.294
	737-300F	327	38,492	5,654	74	904	0.1600	11,849	0.232
	737-400F	327	42,670	6,270	73	939	0.1499	13,196	0.216
	737-700F	327	40,422	5,937	74	874	0.1472	12,372	0.215
	737-800F	327	47,159	6,926	75	965	0.1393	14,571	0.201
	757-200F	327	76,335	11,212	76	1,293	0.1153	23,093	0.170
LGG-MXP	MD-83F	420	40,896	7,705	97	1,395	0.1810	16,000	0.265
	737-300F	420	38,492	7,252	97	1,083	0.1494	15,219	0.216
	737-400F	420	42,670	8,039	97	1,138	0.1415	16,949	0.204
	737-700F	420	40,422	7,615	96	1,040	0.1365	15,890	0.199
	737-800F	420	47,159	8,884	96	1,156	0.1301	18,715	0.188
	757-200F	420	76,335	14,381	97	1,563	0.1087	29,661	0.160
LGG-CPH	MD-83F	476	40,896	8,763	97	1,535	0.1752	18,134	0.257
	737-300F	475	38,492	8,248	98	1,168	0.1416	17,212	0.206
	737-400F	475	42,670	9,144	98	1,230	0.1345	19,169	0.195
	737-700F	478	40,422	8,662	96	1,116	0.1289	18,084	0.188
	737-800F	478	47,159	10,106	97	1,240	0.1227	21,210	0.178
	757-200F	475	76,335	16,358	98	1,682	0.1028	33,546	0.152
LGG-TLS	MD-83F	535	40,896	9,530	102	1,639	0.1720	20,381	0.244
	737-300F	535	38,492	8,970	103	1,267	0.1413	19,386	0.199
	737-400F	535	42,670	9,944	103	1,338	0.1345	21,590	0.188
	737-700F	535	40,422	9,420	101	1,200	0.1274	20,241	0.180
	737-800F	535	47,159	10,990	102	1,330	0.1210	23,839	0.170
	757-200F	535	76,335	17,789	103	1,829	0.1028	37,783	0.147
LGG-DUB	MD-83F	541	40,896	9,293	102	1,658	0.1784	20,610	0 244
	737-300F	542	38,492	8,747	104	1,272	0.1454	19,640	0.197
	737-400F	541	42,670	9,696	103	1,344	0.1386	21,832	0.187
	737-700F	538	40,422	9,185	101	1,199	0.1306	20,354	0.179
	737-800F	541	47,159	10,716	102	1,336	0.1247	24,107	0.168
	757-200F	541	76,335	17,346	103	1,829	0.1054	38,207	0.145
LGG-ARN	MD-83F	769	39,335	13,581	139	2,325	0.1712	28,299	0.250
	737-300F	769	38,157	13,168	140	1,736	0.1318	27,649	0.191
	737-400F	769	42,039	14,507	140	1,831	0.1262	30,625	0.182
	737-700F	774	40,422	14,039	137	1,650	0.1175	29,283	0.171
	737-800F	769	47,159	16,274	138	1,813	0.1114	34,266	0.161
	757-200F	769	75,436	26,032	138	2,475	0.0951	53,727	0.140
LGG-MAD	MD-83F	813	40,896	14,204	149	2,264	0.1594	30,972	0.222
	737-300F	811	38,492	13,421	149	1,941	0.1447	29,387	0.201
	737-400F	813	42,517	14,767	150	1,960	0.1327	32,704	0.182
	737-700F	810	40,422	14,003	146	1,726	0.1233	30,645	0.171
	737-800F	811	47,159	16,337	148	1,915	0.1172	36,138	0.161
	757-200F	811	76,067	26,352	149	2,623	0.995	57,092	0.140

Source: Lufthansa Systems' Lido/Flight

Lufthansa Systems provided block fuel figures in lbs. These have been converted to USG using 1 USG = 6.55lbs.

and the maximum volumetric payloads at this density are 90% or less than the maximum net structural payload *(see table, this page)*.

At a higher packing density of 7.5lbs per cu ft, volumetric payloads are close to net structural payload for the MD-83F and 737-400F. These two aircraft would only lose a maximum of 1-2% of payload on the LGG-ARN route.

The longer LGG-ARN and LGG-MAD routes are typical of average route lengths for European freight operators.

The European routes are all relatively short, and consequently are less than the aircraft's longest range that it operates with a maximum payload.

The only issue on these routes is therefore the fuel burns and relative fuel burns. The MD-83F's block fuel burn is higher than all four 737 variants.

Moreover, the MD-83F's fuel burn is only 5-14% lower than the 757-200F's fuel burn across these six routes, despite the MD-83F's net structural payload being 47% lower than the 757-200F's.

Besides the MD-83F, there is a relatively small difference between the 737-300F and -700F of 23-90USG on the first seven routes, and 215USG on LGG-MAD. The difference in absolute fuel burn between the 737-400F and -800F is smaller, and 10-45USG.

At current fuel prices of $1.80 per USG, the relative difference in terms of dollar cash operating cost can also be expressed. When compared to the MD-83F, the 737-300F and -400F have block fuel burn costs that are $423 and $371 lower on the shortest route, LGG-AMS, and $581 and $548 lower on the longest, LGG-MAD.

When compared to the MD-83F, the 737-700F and -800F have block fuel burn costs that are $464 and $341 lower on the shortest route, LGG-AMS, and $967 and $628 lower on the longest, LGG-MAD.

It is also interesting to note that across the eight routes, the 757-200F's fuel burn and fuel cash cost is only $88-645 per trip higher than the MD-83F's. This compares to the 757-200F's 35,500lbs higher available net payload.

The MD-83F's high block fuel burn means it has the highest fuel burn per ATM. Fuel burn per ATM is based on the available net payload. Available net payload is the gross available payload minus the tare weight of ULDs listed *(see table, page 62)*. The four 737 variants have fuel burn per ATM that is 17.8-34.9% lower than the MD-83F across the first seven routes. The exception is LGG-MAD, where the relative difference between the MD-83F and 737-300F is smaller, but the 737-300F's burn per ATM is still 9.2% lower.

The 757-200F shows its economies of scale by having a fuel burn per ATM that is 38-45% lower than the MD-83F. The 757-200F's fuel burn per ATM is also 65-75% of the 737-300F's, 70-75% of the 737-400F's and -700F, and 75-80% of the 737-800F's.

Latin American routes

The main purpose of analysing the six aircraft types on the Latin American routes is to examine their performance in challenging conditions at take-off. The seven routes are from airfields with elevations ranging from 2,739 feet to 13,325 fleet *(see table, page 64)*.

The first six routes, however, are from airfields with elevations of 2,739 feet to 7,874 feet; and the route lengths are 1,006-1,594nm. Despite these high elevations, all six aircraft types depart without any payload limitations.

Despite the operating conditions, the maximum allowed take-off weight for all six types is the same as each type's MTOW, so there are no take-off weight restrictions or limitations. There are also no landing weight limitations for the six types on these six routes. Moreover, all six types operate within the zone of their payload-range profiles where they operate at MZFW, and so can carry maximum structural payload.

The seventh route, LPB-MIA, departs from LPB at an elevation of 13,325 feet. All aircraft have a payload restriction. The 737-700F and -800F have their payloads limited by only 11-12% *(see table, page 64)*, and the 757-200F by 20%. The 737-300F's payload is limited by 39%, and the -400F by 54%; the largest limitation of all. The MD-83F has a limitation of 42%.

All six types operate at MTOW, while they depart at lower than MTOW on UIO-MIA.

All aircraft arrive at MIA with a landing weight less than MLW, so they suffer payload limitations because they depart at MTOW, with less than maximum payload.

The relative differences in block fuel burn between the types on the first six routes are similar to the European routes

BLOCK FUEL BURN PERFORMANCE OF MD-83F, 737-300F, 737-400F, 737-700F, 737-800F & 757-200PCF ON LATIN AMERICAN ROUTES FROM HOT AND HIGH AIRPORTS TO MIAMI

City-pair	Aircraft variant	ESAD nm	Payload carried lbs	ATMs	Block time min	Block fuel USG	Fuel USG /ATM	ATKs	Fuel Kg /ATK
SYQ-MIA	MD-83F	1,020	40,896	18,367	172	2,762	0.1504	10,227	0.821
	737-300F	1,025	38,492	17,287	177	2,195	0.1270	9,673	0.690
	737-400F	1,021	42,670	19,182	175	2,336	0.1218	10,681	0.665
	737-700F	1,025	40,422	18,154	172	2,063	0.1136	10,158	0.617
	737-800F	1,025	47,159	21,179	173	2,275	0.1074	11,851	0.583
	757-200F	1,025	76,335	34,283	173	3,155	0.0920	19,182	0.500
MEX-MIA	MD-83F	1,148	40,896	21,050	194	3,025	0.1437	11,510	0.799
	737-300F	1,148	38,492	19,813	198	2,416	0.1219	10,833	0.678
	737-400F	1,148	42,670	21,964	197	2,572	0.1171	12,009	0.651
	737-700F	1,143	40,422	20,807	192	2,260	0.1086	11,327	0.606
	737-800F	1,143	47,159	24,274	194	2,492	0.1027	13,215	0.573
	757-200F	1,148	76,335	39,292	194	34,59	0.0880	21,484	0.489
CCS-MIA	MD-83F	1,246	40,896	22,237	205	3,380	0.1520	12,492	0.822
	737-300F	1,247	38,492	20,930	208	2,694	0.1287	11,768	0.696
	737-400F	1,247	42,670	23,202	208	2,848	0.1228	13,045	0664
	737-700F	1,257	40,422	21,979	204	2,519	0.1146	12,457	0.615
	737-800F	1,252	47,159	25,643	206	2,762	0.1077	14,475	0.580
	757-200F	1,246	76,335	41,507	203	3,870	0.0932	23,318	0.504
BOG-MIA	MD-83F	1,377	40,896	24,702	228	3,591	0.1454	13,806	0.791
	737-300F	1,378	38,492	23,250	232	2,906	0.1250	13,004	0.679
	737-400F	1,373	42,670	25,735	232	3,075	0.1195	14,468	0.646
	737-700F	1,388	40,422	24,380	227	2,729	0.1119	13,755	0.603
	737-800F	1,388	47,159	28,443	229	2,981	0.1048	16,047	0.565
	757-200F	1,377	76,336	46,108	226	4,166	0.0904	25,770	0.491
GDL-MIA	MD-83F	1,395	40,896	25,578	219	3,627	0.1418	13,986	0.788
	737-300F	1,395	38,492	24,075	223	2,896	0.1203	13,164	0.669
	737-400F	1,395	42,670	26,688	223	3,092	0.1159	14,593	0.644
	737-700F	1,395	40,422	25,282	217	2,690	0.1064	13,824	0.591
	737-800F	1,395	47,159	29,495	218	2,967	0.1006	16,128	0.559
	757-200F	1,395	76,335	47,743	218	4,144	0.868	26,106	0.482
UIO-MIA	MD-83F	1,623	40,896	29,102	250	4,187	0.1439	16,272	0.782
	737-300F	1,624	38,492	27,391	256	3,358	0.1226	15,325	0.666
	737-400F	1,624	42,670	30,364	255	3,575	0.1177	16,989	0.640
	737-700F	1,630	40,422	28,765	250	3,134	0.1090	16,153	0.590
	737-800F	1,631	47,159	33,559	251	3,432	0.1023	18,857	0.553
	757-200F	1,623	76,335	54,321	269	4,812	0.0886	30,373	0.482
LPB-MIA	MD-83F	2,764	21,765	26,264	403	6,180	0.2353	14,748	1.274
	737-300F	2,768	21,548	26,021	405	5,031	0.1934	14,623	1.046
	737-400F	2,768	16,579	20,021	405	5,050	0.2522	11,251	1.364
	737-700F	2,777	35,198	42,505	398	5,123	0.1205	23,963	0.650
	737-800F	2,766	41,276	49,844	399	5,614	0.1126	27,990	0.610
	757-200F	2,765	59,149	71,454	396	7,598	0.1063	40,095	0.576

Source: Lufthansa Systems' Lido/Flight

Lufthansa Systems provided block fuel figures in lbs. These have been converted to USG using 1 USG = 6.55lbs.

where aircraft operate with no payload limitations. The cash fuel cost differences of the four 737 variants compared to the MD-83F are $1,021-1,492 lower for the 737-300F, $767-1,102 lower for the 737-400F, $1,259-1,895 lower for the 737-700F, and $877-1,359 lower for the 737-800F.

The 757-200F burns 39-40% more than the 737-800F, while the 757-200F's net payload is 62% higher.

Relative differences in fuel burn are skewed on LPB-MIA because of the payload limitations, and each aircraft being on a different part of their MTOW line on their payload-range profiles.

The relative differences in fuel burn per ATM between the six types are similar to the European routes, although not as large in some cases, because the Latin American routes are longer and so a larger portion of the flight is in the cruise phase.

Compared to the MD-83F, the 737-300F's burn ber ATM is 14-18% lower. The 737-400F's burn per ATM is 18-19% lower on all routes without a payload limitation. The 737-700% is consistently 24-25% lower per ATM than the MD-83F, while the -800F is 28-29% lower per ATM. The 757-200F also consistently has the lowest burn per ATM. - *CHW* AC