The first MD-80 freighter is coming into operation. The aircraft can be acquired at low market values, has a durable airframe, and low engine-related maintenance costs. Its nearest rivals are the 737-300 and -400. The revenue capacity & cash operating costs of these freighters is analysed.

MD-80SF: revenue-generating capacity & operating economics versus its rivals

Nearly 1,200 MD-80s were built from 1978 to 1999. About 530 passenger-configured aircraft remain in service, while another 249 are parked. Its durability, and low acquisition and maintenance costs have contributed to the MD-80's longevity. These factors may have influenced Delta's recent decision to extend the life of its 117-strong MD-88 fleet with enhanced navigation and flight management systems, despite the large number of alternative narrowbody aircraft on the market.

Continued passenger services are not the only revenue-generating option for MD-80 operators, as a passenger-to-freighter modification is now available. The MD-80SF's payload, revenue-generating capacity, and operating economics versus its nearest rivals, the 737-300SF and -400SF, are examined.

AEI MD-80SF P-to-F

In February 2013 Aeronautical Engineers Inc (AEI) received the first Supplementary Type Certificate (STC) for MD-80 passenger-to-freighter conversions. The prototype aircraft has since been delivered to Everts Air Cargo.

There are five variants in the MD-80 family: the MD-81, -82, -83 and -88 have the same length fuselage; and the MD-87 is a short fuselage version.

The AEI conversion programme covers the MD-81, -82, -83 and -88, but not the -87. The MD-83 has the highest structural weight. The MD-88 is essentially a modified MD-82 with a glass cockpit. The MD-82 and -83 represent the largest segment of the active and parked passenger-configured fleet, with 340 and 256 aircraft respectively. There are only 11 passenger-configured, active and parked MD-81s remaining. "Due to the small number of MD-81s, I believe it is unlikely we will convert any," explains Robert Convey, vice president sales & marketing, at AEI.

Delta operates more than 80% of the 141 active and parked MD-88s. Its decision to extend the life of the aircraft in its fleet suggests that the main candidates for freight conversion are the MD-82 and MD-83. This is reinforced by AEI's orders to date.

"So far we have had orders to convert seven MD-82s and eight MD-83s, from the US, Europe, Africa and South America," explains Convey. "We believe we will convert more than 100 MD-80s to freighters over the next 10 years."

The MD-80's main competition in the short-haul freighter market is converted 737-300s and 737-400s. Convey believes that the availability of an MD-80 conversion will halve the 737's share of this market. AEI, IAI Bedek and Pemco offer conversion programmes for the 737.

To identify which type represents the best value, *Aircraft Commerce* has analysed the payload, revenue-generating capacity and operating economics of the MD-80SF against the 737-300SF and -400SF.

Freight characteristics

Air cargo is generally classified in two categories: express package freight and general freight.

Express package or integrator operations are often based on hub-and-spoke-style systems, with route lengths of 400–700nm. Typical aircraft utilisation might be about 630 flight cycles (FC) or 1,050-1,250 flight hours (FH) per year.

Express package freight is generally packed in main deck containers or unit load devices (ULDs). An average packing density of about 6.5lbs per cubic foot (cu ft) means that an aircraft often reaches volumetric capacity before exceeding its net structural payload. This is known as 'cubing' or 'bulking out'.

General freight tends to be carried on a point-to-point basis. Although average route lengths are similar to express package services, rates of annual aircraft utilisation can be higher, typically about 945FC. General freight items can be bulky and are often carried on pallets. An average packing density of 7-9 lbs per cu ft means that an aircraft carrying general freight may reach its net structural payload limit before maximising the available volumetric capacity. This is known as 'grossing' out.

"We see the MD-80 as a general freight aircraft, with operators more likely to be using pallets rather than containers," predicts Convey.

There are currently no containers or ULDs optimised for the MD-80 freighter. "The MD-80 has a narrower fuselage than the 737, 727 and 757," explains Stephen Fortune, principal of Fortune Aviation Services LLC. "Standard 88-inch X 125-inch containers were designed around the narrowbody Boeing product, and specially contoured to fit these aircraft. These can be loaded on an MD-80 freighter, but this would have to be done longitudinally, rather than laterally, resulting in a loss of cubic capacity."

AEI claims that an 88-inch X 108-inch X 78-inch container would maximise the volumetric capacity of an

PAYLOAD CHARACTERISTICS OF AEI-CONVERTED MD-80 & 737 FREIGHTERS

Aircraft Type	MD-82/-88SF	MD-83SF	737-300SF 9 position	737-300SF 10 position	737-400SF SGW	737-400SF HGW
MTOW (lbs)	149,500	160,000	139,500	139,500	143,500	150,000
MZFW (lbs)	122,000	122,000	109,600	109,600	113,000	117,000
OEW (lbs)	75,900	77,400	67,200	67,200	70,500	71,500
Gross structural payload (lbs)	46,100	44,600	42,400	42,400	42,500	45,500
Pallets	12 (88"x108")	12 (88"x108")	9 (88"x125")	8 (88"x125") + 2 (53"x88")	10 (88"x125") +1 (53"x88")	10 (88"x125") +1 (53"x88")
Upper deck freight volume (cu ft)	4,416	4,416	3,960	3,840	4,560	4,560
Tare Weight (lbs)	2,160	2,160	1,800	1,790	2,095	2,095
Lower deck volume (cu ft)	1,253	1,013	1,068	1,068	1,373	1,373
Total volume (cu ft)	5,669	5,429	5,028	4,908	5,933	5,933
Total tare weight (lbs)	2,160	2,160	1,800	1,790	2,095	2,095
Net structural payload (lbs)	43,940	42,440	40,600	40,610	40,405	43,405
Max packing density (lbs/cu ft)	7.75	7.82	8.07	8.27	6.81	7.32
Volumetric payload @ 6.5lbs/cu ft	36,849	35,289	32,682	31,902	38,565	38,565
Volumetric payload @ 7.0lbs/cu ft	39,683	38,003	35,196	34,356	40,405	41,531
Volumetric payload @ 7.5lbs/cu ft	42,518	40,718	37,710	36,810	40,405	43,405
Volumetric payload @ 8.0lbs/cu ft	43,940	42,440	40,224	39,264	40,405	43,405

Assumptions:
1) OEW includes 500lbs for crew (plus their food and drinks).
2) Tare weight for 88 x 125 pallet = 200lbs, volume =440 cu ft.
3) Tare weight for 88 x 108 pallet = 180lbs, volume = 368 cu ft.
4) Tare weight for 53 x 88 pallet = 95lbs, volume = 160 cu ft.
5) MD-83SF fitted with 1,130USG aux fuel tank.
6) Pallet volumes and weights, & aircraft weights may vary

MD-80SF, but admits this is not currently available. Different container sizes would make interlining with narrowbody Boeing freighters difficult. The MD-80SF's likely operating environment will probably not, however, involve much, if any, interlining with other aircraft types.

Payload

The payload characteristics of the most likely candidates for conversion, the MD-82SF and -83SF, were considered against those of AEI's 737-300SF and -400SF freighter conversions *(see table, this page)*. Since it has the same capacity as the MD-82SF, the MD-88SF was also included. The MD-83 model analysed here includes an auxiliary fuel tank of 1,130 US Gallons (USG).

The comparison is based on aircraft configured with pallets due to the current lack of an optimised container for the MD-80SF. Although it is unlikely that express freight would be carried on pallets, it is still possible. Payloads were therefore analysed at different packing densities, ranging from 6.5 to 8.0lbs per cu ft. This covers average operations for both express and general freight services.

AEI offers nine- and 10-position configurations for 737-300SF conversions. Its 737-400SF conversion offers an 11-position configuration. AEI distinguishes between standard gross weight (SGW) and high gross weight (HGW) 737-400 aircraft.

Net structural payload is an important indicator of an aircraft's cargo-carrying capacity. It represents the actual weight of the freight that can be carried, and is calculated by subtracting the tare weight of on-board containers from the aircraft's gross structural weight.

The MD-82SF and -88SF have the highest net structural payload of 43,940lbs *(see table, this page)*, followed by the HGW 737-400SF at 43,405lbs and the MD-83SF at 42,440lbs. The SGW 737-400SF has the lowest at 40,405lbs.

An aircraft's maximum packing density indicates the maximum density at which freight can be packed, while making optimum use of the available volume and structural payload. It is calculated by dividing the net structural payload by the available volume.

The nine- and 10-position 737-300SF conversions have the highest maximum packing density at 8.07 and 8.27lbs/cu ft *(see table, this page)*. This is followed by the MD-83SF at 7.82lbs/cu ft and the MD-82SF and -88SF at 7.75lbs/cu ft. The SGW 737-400SF has the lowest packing density at 6.81lbs/cu ft.

6.5lbs per cu ft

At a typical express freight packing density of 6.5lbs/cu ft, all the MD-80 and 737 freighters cube out.

The 737-400SF is the most efficient choice at this packing density. The SGW and HGW versions both offer a volumetric payload of 38,565lbs, using 95% and 89% of their available structural payload respectively.

The MD-82SF and -88SF are the next best performers, offering a volumetric payload of 36,849lbs, at 84% of the available structural payload.

The 737-300SF is the least efficient at this packing density, having a payload of just 31,902lbs.

$ REVENUE GENERATING PERFORMANCE OF AEI-CONVERTED MD80 & 737 FREIGHTERS

Aircraft type	MD-82/-88SF	MD-83SF	737-300SF 9 position	737-300SF 10 position	737-400SF LGW	737-400SF HGW
Volumetric payload @ 6.5lbs/cu ft & 90% LF-lbs	33,164	31,760	29,414	28,712	34,709	34,709
Revenue generated @ $1.00/lb-$	33,164	31,.760	29,414	28,712	34,709	34,709
Volumetric payload @ 7.0lbs/cu ft & 90% LF-lbs	35,715	34,203	31,676	30,920	36,365	37,378
Revenue generated @ $0.60/lb-$	21,429	20,522	19,006	18,552	21,819	22,427
Volumetric payload @ 7.5lbs/cu ft & 90% LF-lbs	38,266	36,646	33,939	33,129	36,365	39,065
Revenue generated @ $0.60/lb-$	22,960	21,988	20,363	19,877	21,819	23,439
Volumetric payload @ 8.0lbs/cu ft & 90% LF-lbs	39,546	38,196	36,202	35,388	36,365	39,065
Revenue generated @ $0.60/lb-$	23,728	22,918	21,721	21,233	21,819	23,439

7lbs per cu ft

A packing density of 7lbs/cu ft represents the lower bulk end of the general freight market.

At this packing density, the HGW 737-400SF offers the highest volumetric payload at 41,531lbs, representing 96% of the aircraft's net structural payload.

The SGW 737-400SF offers the next highest payload of 40,405lbs, but is the only aircraft to gross out at this packing density. It uses 97% of the available volume before reaching the maximum structural payload.

The MD-82SF and -88SF again follow the 737-400SF with a volumetric payload of 39,683lbs. The 737-300SF conversions offer the lowest payloads of 35,196lbs and 34,356lbs.

At a general freight packing density of 7.5lbs/cu ft, the HGW 737-400SF offers the largest volumetric payload of 43,405lbs. It uses 98% of its available volume before grossing out, however.

The SGW 737-400SF also grosses out, reaching its net structural payload of 40,405lbs, having used only 91% of the available volume. The remaining aircraft all cube out at this packing density.

The MD-80 freighters sit between the HGW and SGW 737-400SFs in terms of available volumetric payload. At 42,518lbs, the MD-82SF and -88SF provide the second highest volumetric payload, followed by the MD-83SF with 40,718lbs.

The nine- and 10-position 737-300SF conversions provide the lowest volumetric payload.

8lbs per cu ft

The highest packing density analysed was 8lbs/cu ft, representing the higher bulk end of the general freight market. At this packing density all of the MD80 and 737-400SF conversion options gross out.

The MD-82SF and -88SF offer the largest volumetric payload at 43,940lbs, followed by the HGW 737-400SF at 43,405lbs and the MD-83SF at 42,440lbs.

The SGW 737-400SF is perhaps the least efficient freighter at this packing density. It only uses 85% of its available volume, to provide a volumetric payload of 40,405lbs. This is only 200lbs more than the nine-position 737-300SF conversion, which uses all of its available volume.

The MD-82SF and -88SF offer the largest volumetric payload at packing densities in excess of 7.66lbs/cu ft. This makes them suitable for bulky general freight operations. At packing densities of 7.13lbs/cu ft to 7.65lbs/cu ft the MD-82SF and -88SF have less volumetric payload capacity than the HGW 737-400SF, but more than the SGW version.

The MD-83SF has an inferior volumetric payload to the MD-82SF, MD-88SF, and the HGW 737-400SF at all packing densities.

At packing densities in excess of 7.45lbs per cu ft, the MD-83SF has better payload availability than the SGW 737-400SF.

All the MD-80 conversion options have superior volumetric payload characteristics to those of the 737-300SF at both express and general freight packing densities.

The SGW and HGW 737-400SF are the most suitable types for express freight operations in terms of available payload. The HGW aircraft offers the best available payload up to a packing density of 7.65lbs per cu ft.

Revenue generation

Income generated from freight services can be expressed in terms of revenue per lb of freight. Yields from general freight are normally lower than those for express package operations. For this analysis a yield of $1.00/lb has been assumed for express operations, and $0.60/lb for general freight.

Lower yields mean that general freight operators will need to achieve high load factors to remain economic. Using the above revenue assumptions, the potential revenue-generating characteristics of the MD-80 and 737-300/-400 freighter variants were compared at different packing densities based on a load factor of 90% of the available volumetric payload *(see table, this page)*.

At an express freight packing density of 6.5lbs/cu ft and an assumed yield of $1.00/lb, the HGW and SGW 737-400SFs generate the highest revenue of $34,700 *(see table, this page)*. The MD-82SF and -88SF generate a revenue of $33,100, followed by the MD-83SF with $31,700. The 737-300SFs would generate the smallest revenue.

At a packing density of 7.0lbs/cu ft and an assumed yield of $0.60/lb, the lower revenues generated by general freight operations are clear *(see table, this page)*. The order of aircraft in terms of revenue capacity remains the same, with the HGW and SGW 737-400SFs providing the most revenue, followed by the MD-82SF and -88SF, then the MD-83SF, and finally the 737-300SF variants. At this packing density, the HGW 737-400SF generates $1,000 more revenue than the MD-82SF and -88SF.

At a higher bulk packing density of 8lbs/cu ft and an assumed yield of $0.60/lb, the MD-82SF and the -88SF generate the most revenue *(see table, this page)*. They generate $23,700 per sector, $300 more than the HGW 737-400SF.

The MD-83SF would generate the third highest revenue at $22,900, followed by the SGW 737-400SF and 737-300SF variants.

Operating costs

Operating costs, including those for fuel, maintenance, crew salaries, navigation and landing fees, and financing were considered for the MD-80

FUEL BURN PERFORMANCE OF MD-80 & 737 ON TYPICAL GENERAL FREIGHT ROUTE LENGTHS

Route	Aircraft	Available Payload (lbs)	Available Payload (Tons)	Tracked distance (nm)	ESAD (nm)	Wind (kts)	Block time (hr:min)	Block Fuel (USG)	Fuel burn USG per Ton-mile
EMA-FRA	737-400HGW	45,500	20.31	530	503	20	01:39	1,347	0.1318
EMA-FRA	737-300	42,400	18.93	530	503	20	01:40	1,271	0.1335
EMA-FRA	737-400SGW	42,500	18.97	530	503	20	01:39	1,318	0.1381
EMA-FRA	MD-88	46,100	20.58	530	503	20	01:40	1,588	0.1534
EMA-FRA	MD-82	46,100	20.58	530	503	20	01:40	1,614	0.1559
EMA-FRA	MD-83	44,600	19.91	530	503	20	01:40	1,588	0.1586
SCL-EZE	737-400HGW	45,500	20.31	699	617	52	01:53	1,495	0.1193
SCL-EZE	737-300	42,400	18.93	699	611	55	01:54	1,388	0.1200
SCL-EZE	737-400SGW	42,500	18.97	699	612	55	01:53	1,450	0.1249
SCL-EZE	MD-88	46,100	20.58	699	616	53	01:52	1,745	0.1376
SCL-EZE	MD-82	46,100	20.58	699	615	53	01:53	1,778	0.1405
SCL-EZE	MD-83	44,600	19.91	699	616	53	01:52	1,745	0.1423
MIA-MEM	737-300	42,400	18.93	816	836	-10	02:20	1,862	0.1177
MIA-MEM	737-400HGW	45,500	20.31	816	834	-9	02:18	2,002	0.1182
MIA-MEM	737-400SGW	42,500	18.97	816	836	-10	02:18	1,930	0.1216
MIA-MEM	MD-88	46,100	20.58	816	838	-11	02:18	2,265	0.1313
MIA-MEM	MD-82	46,100	20.58	816	838	-11	02:19	2,310	0.1340
MIA-MEM	MD-83	44,600	19.91	816	838	-11	02:18	2,265	0.1357

Notes:

1) Taxi fuel time assumed to be 15mins

2) Taxi fuel burn assumed to be 500lbs for all aircraft

3) 737-300/400 equipped with CFM56-3C1

4) MD-82 equipped with JT8D-217, MD83 & 88 equipped with JT8D-219

5) MD-83 is fitted with an 1,130USG auxiliary fuel tank

and 737 freighters. Since the MD-80 is most likely to be employed on general freight services, the costs were based on a route length typical of this sector: East Midlands (EMA) to Frankfurt (FRA). A typical general freight annual utilisation rate of 945FC was assumed.

Operating costs were calculated on a maximum payload basis with a packing density of 8.0lbs/cu ft. Particular focus was paid to the MD-82SF and -88SF and the 737-400HGW, which offered the highest payload and revenue-generating capacity at this packing density.

Fuel

"The MD-80SF's main disadvantage compared to 737 freighters is the 15% higher fuel burn," says Fortune. Fuel burn figures for three routes of typical length, on short-haul general freight services, show the difference between 737s and MD-80s *(see table, this page)*. Each 737 freighter variant would burn less block fuel than any of the MD-80s. On each route the HGW 737-400 burns 250–300lbs less than the MD-82 and -88.

Taking EMA-FRA as an example, and assuming a fuel price of $3.06 per USG, the HGW 737-400's would have a fuel cost of $4,122 to operate the sector with a maximum payload. This compares to $4,939 for the MD-82, a difference of $817.

Maintenance

Estimated costs, including those for line checks, base maintenance, engine reserves, heavy components and line replaceable units (LRUs) for the aircraft in service in freighter mode and at typical rates of utilisation were compared.

Line and A check costs are estimated to be $250 per block hour (BH) for the 737s, and $175 per BH for the MD-80s.

Assuming that the 737s are on their third base check cycle, base maintenance costs were estimated at $156/BH. This compares to $203/BH for the MD-80s. The 737 benefits here from its flight hour (FH) -based maintenance programme. Utilisation for freight operators is relatively low compared to passenger ones. This leads to relatively long calendar intervals between checks for the 737.

The MD-80 has a calendar-based maintenance programme, so it needs fewer FH between base checks than the 737's. This means that the MD-80's base check reserves are amortised over a smaller number of FH than the 737's.

Some operators may decide to retire ageing aircraft when the next D-check becomes due, at the end of a base check cycle. This would probably halve the base maintenance reserves.

Engine costs are an important consideration and can be a differentiator.

"The MD-80's advantage in terms of maintenance costs is that its JT8D-200 family engines are cheaper to buy and overhaul than the 737's CFM56-3s," says Fortune.

Engine reserves were estimated to be $157 per engine flight hour (EFH) for the CFM56-3, and $118/EFH for the JT8D-200. This is equivalent to $314/BH for a 737, and $236/BH for an MD-80. These reserve estimates do not include reserves for life limited parts (LLPs), however. It is assumed that it is possible to source time-continued replacement engines and modules, which would be cheaper than paying LLP reserves.

The MD-82SF has a higher volumetric payload at high packing densities than the 737-400SF. Combined with its low acquisition cost, the MD-80F has the prospect of being an economical general freight cargo aircraft.

Heavy maintenance costs were estimated to be $113/BH for the 737, and $97/BH for the MD-80. LRU costs were estimated at $220/BH for the 737, and $195/BH for the MD-80.

Total maintenance trip costs on the EMA-FRA route were therefore predicted to be $1,750 for the 737s. The MD-80s were just over $200 less per trip, with costs of $1,500.

Another important consideration is ageing aircraft structural maintenance.

"The MD-80 is a robust airframe with virtually no ageing aircraft issues," says Fortune. In contrast, a number of airworthiness directives (ADs) and service bulletins (SBs) relating to structural issues have been issued for the 737-300 and 737-400 (*see Cherry picking 737 classics for conversion to freighter, Aircraft Commerce, Issue 86, February/March, page 64*). A revised SB relating to these is expected soon. It is thought that this SB might require eddy current inspections of certain areas of the fuselage before 40,000FC. These inspections could reveal delamination, corrosion and other problems, while any necessary repairs may be expensive. The revised SB may also require the replacement of window skin belts by 50,000FC. Costs could be so high as to represent a retirement watershed for the aircraft.

The main structural concerns might only apply to 737-300s and -400s up to line number 2,565. Potential operators could therefore view the MD-80 as a less risky investment than the earlier-built 737s.

Crew costs & user fees

Flightcrew costs will be similar for the 737 and MD-80. Both aircraft have a standard crew complement of two, and salaries will be fairly uniform between the types. It is assumed that a general freight operator will have 2.5 crews per aircraft. Crew costs for a general freight operation on EMA-FRA are estimated to be $416 per trip for the 737 and MD-80.

Navigation and landing fee estimates were based on charging per ton of maximum take-off weight (MTOW). This resulted in very similar per trip charges for the HGW 737-400 and MD-82.

Aircraft financing

AEI's MD-80SF conversion costs $2.35 million. This compares to $2.45 million for the nine-pallet 737-300SF, 2.53 million for the 10-pallet 737-300SF, and $2.75 million for the 11-pallet 737-400SF.

AEI estimates that monthly lease rates for the MD-80SF could be about $90,000. This compares to $110,000 for the 737-300SF and $135,000 for the 737-400SF. Due to the age and value of the aircraft, most potential MD-80 freighter operators are likely to finance an outright acquisition.

"The all-up cost to buy, service and convert an aircraft will probably be about ;$4 million for the MD-80SF, $7 million for the 737-300SF and $8-9 million for the 737-400SF," estimates Convey.

Based on these figures, financing on a full pay-out basis over five years with an interest rate of 8% would result in a monthly debt repayment of $80,000 for an MD-80. Assuming a general freighter utilisation, this is equivalent to $1,016 per trip. This compares to a finance cost of $2,044 per trip for a 737-400. The MD-80's finance costs are therefore half those of the 737-400 on a per trip basis.

Total trip costs

Despite its lower maintenance costs, the MD-80's higher fuel burn means that its cash operating costs for a general freight operating scenario are higher than those of the 737. The HGW 737-400's per trip cash operating estimate is $6,700, compared to $7,300 for the MD-82.

In terms of aircraft financing, the MD-80's considerably lower acquisition costs make it more competitive, however. On a total trip cost basis, all the MD-80 variants are cheaper to operate than the 737-400, and are competitive with the 737-300. The MD-82's total trip cost is estimated at $8,300, nearly $450 less than the HGW 737-400.

Summary

The MD-80 family's lower maintenance and acquisition costs mean it can have lower per-trip operating costs than the 737-400 in a typical general freight scenario. Its payload capacity and lack of structurally-related maintenance issues, mean that the MD-80 is an economically-competitive and low-risk alternative to 737-300 and -400 freighters. This is especially true for bulky, general freight operations.

The MD-82 and -83 are the most likely candidates for conversion from the MD-80 family. The MD-82 has superior payload and revenue-generating capacity. In a typical general freight scenario it also has better fuel burn performance, based on the MD-83 having a 1,130USG auxiliary fuel tank.

Assuming a pallet configuration, the MD-82 has greater payload and revenue-generating potential than both of AEI's 737-300 freighter options.

Up to a packing density of 7.65lbs/cu ft the HGW 737-400SF offers the largest payload and revenue-generating capability. Beyond a packing density of 7.66lbs/cu ft the MD-82SF is the best candidate, suggesting that the HGW and SGW 737-400SF are the best for express package services, and the MD-82SF for bulkier general freight. AC