The inherently complex nature of freight often results in aircraft wasting volume or structural payload. Economic sensitivity means that freight airlines must use aircraft with maximum efficiency. But few types do this in small package operations.

Freighters with the optimum configuration for small packages

Small package carriers have used particular types of aircraft for a number of years. But as air traffic continues to grow these carriers are having to re-assess their fleets and operations. Since the nature of freight payload is inherently complex, freighter types have to be assessed carefully for their payload characteristics and for their efficient small package operations.

The important issues for small package operations are the ability to provide enough payload and revenue-generating capacity and interline containers with other aircraft. Aircraft can be used with maximum efficiency if their structural payloads and container volumes can be fully utilised.

Payload configuration

The key to suitability for small packages is the volumetric payload permitted by the aircraft's structural payload and the containers it uses. The choice of containers is dictated by the aircraft's internal dimensions. The largest containers possible have to be used for maximum efficiency and for best utilisation of space.

The ideal small package aircraft has a containerised volume that gives the aircraft a maximum packing density slightly higher than the typical packing density of small packages in normal operations.

If packed in ideal conditions, small packages can have a packing density of about 12lbs per cubic foot. In real situations, however, packing densities are more likely to be about 6.5–7lbs per cubic foot.

Aircraft that have high structural payloads will use all their available volume, or will 'bulk out'. That is, their volumetric payload limit will be reached before their structural payload limit. Not all the aircraft's structural payload will be utilised.

Aircraft with packing densities lower than 7lbs per cubic foot will not be able to use all their container volume and will carry light loads that will impede revenue generation. Small package operators therefore have to make a compromise between the containers they can use on their aircraft and the utilisation of available payload with freight packed at 7lbs per cubic foot.

Each aircraft has several types of container that it can use. This means the internal volume available for containers is variable. Most containers and pallets are not, however, used for small packages.

The containers determine the aircraft's package volume. The packing density is then influenced by the structural payload. The aircraft's maximum zero fuel weight (MZFW) less the operating empty weight (OEW) is the structural payload.

However, other weight has to be deducted from this. The weight for flight crew, flight crew equipment and some catering also has to be taken into account. These items increase OEW to aircraft prepared for service (APS) weight. Small package operations rarely carry loadmasters.

The tare weight of the containers will then be calculated as the final reduction in gross structural payload to determine the net structural payload.

Tare weight is relatively high for aircraft configured to carry small packages. This is because containers and not pallets are used, and containers are heavier.

Aircraft analysis

The payload characteristics of widebodies and narrowbodies in small package operations have been analysed.

This analysis has taken into consideration specification weights, APS weights and the containers used for small packages.

The specification weights are standard for each type. The APS weights are the standard OEWs for the aircraft plus an estimate for crew, equipment and catering. Crew weight is estimated at 190lbs per member. Each type analysed is assumed to carry the normal flight crew complement. Crew equipment is a further 55lbs per crew member and an allowance of 50lbs is made for catering.

Widebodies

The main widebody types used for small packages and other types of freight are the MD-11, DC-10, L-1011, 767, A300-600, A300B2/4 and A310. The 747 is also widely used, but only by one carrier for small packages. It is more often used for bulk cargo.

Small package airlines operate in hubbing networks and so can sometimes require different aircraft types to interline containers. Others might be prepared to unpack and sort packages from large containers used in widebodies and repack them in smaller containers for narrowbodies.

Interlining limits the size of containers on large aircraft, since they have to be compatible with smaller types. Small containers on large aircraft waste cabin space and structural payload.

The DC-8 and 727 have the same cabin cross-section and use the same

WIDEBODY SMALL PACKAGE FREIGHT AIRCRAFT PAYLOAD CHARACTERISTICS

Aircraft type	MD-11	DC-10-30	L-1011-200F	767-200B ABX	A300-600	A300B4-200	A310-300
OEW lbs	250,000	235,000	221,915	161,300	173,800	177,780	162,900
APS lbs	250,490	235,710	222,625	161,790	174,290	178,490	163,390
Max structural payload lbs	210,810	165,290	115,375	91,210	112,310	99,290	87,934
Upper deck containers							
Option 1							
Size-inches/type	96/125/96	96/125/96	96/125/96	ABX	88/125/96	88/125/97	88/125/97
Number	26	23	22	102	21	18	16
Internal volume	15,444	13,662	13,481	7,344	10,500	9,000	8,000
Tare weight lbs	20,540	18,170	17,855	13,566	11,130	9,540	8,480
Option 2-FedEx style							
Size-inches/type	AYY	AYY + SAA	n/a	n/a	AYY	AYY	AYY
Number	59	22 + 15	n/a	n/a	43	40	32
Internal volume	11,859	10,838	n/a	n/a	8,665	8,060	6,448
Tare weight lbs	17,759	15,247	n/a	n/a	12,943	12,040	9,632
Lower deck containers							
Type	LD-3	LD-3	LD-3	ABX	LD-3	LD-3	LD-3
Number	32	26	24	n/a	22	20	14
Internal volume	4,672	3,796	3,504	1,820	3,212	2,920	2,044
Tare weight lbs	6,880	5,590	5,160	4,060	4,730	4,300	3,010
Total payload							
Option 1							
Total volume cu ft	20,116	17,458	16,985	9,164	13,712	11,920	10,044
Total tare lbs	27,420	23,760	23,015	17,626	15,860	13,840	11,490
Net structural payload lbs	183,390	141,530	92,360	73,584	96,450	85,450	76,444
Maximum packing density lbs/cu ft	9.12	8.11	5.44	8.03	7.03	7.17	7.61
Volumetric payload @ 7lbs/cu ft	140,812	122,206	92,360	64,148	95,984	83,440	70,308
Option 2-FedEx							
Total volume cu ft	16,531	14,634	n/a	n/a	11,877	10,980	8,492
Total tare lbs	24,639	20,837	n/a	n/a	17,673	16,340	12,642
Net structural payload lbs	186,171	144,453	n/a	n/a	94,637	82,950	75,292
Maximum packing density lbs/cu ft	11.26	9.87	n/a	n/a	7.97	7.55	8.87
Volumetric payload @ 7lbs/cu ft	115,717	102,438	n/a	n/a	83,136	76,860	59,444

containers. This negates any problems of cabin space waste. The need to use widebodies and continue interlining containers means that airlines may have to accept less efficient use of the new aircraft compared to the current narrowbodies, or be prepared to unpack and repack containers at hubs.

MD-11 & DC-10-30

The MD-11 and DC-10-30 have been praised for their suitability as freighters. Both have high MZFWs relative to their OEWs and size. The MD-11 has a gross structural payload of 210,810lbs. It is therefore well positioned for high packing densities relative to its size. The DC-10-30 is also a strong aircraft and has a gross structural payload of 165,290lbs.

One common container used on the MD-11's and DC-10's maindeck is the 96 x 125 x 96-in container or AMJ, which fits in pairs. The L-1011 also uses the AMJ.

Each of these containers has an internal volume of 594 cu ft and tare weight of 790lbs.

The MD-11 can accommodate 26 of these on its maindeck and the DC-10-30, 23. This takes the maindeck container volume for the two aircraft to 15,444 and 13,662 cubic feet *(see table, page xx)*.

The MD-11 and DC-10-30 most commonly use LD-3 containers on their lower decks. These have an internal volume of 146 cu ft and weigh 215lbs.

The DC-8 can accommodate a high packing density of freight. Consequently it uses its payload relatively inefficiently when carrying small packages. However, the DC-8 had been the only large aircraft available to airlines for many years. Now there are several widebodies available that can make more efficient use of their payload capabilities when carrying small packages.

The MD-11 uses 32 LD-3s and the DC-10-30 26. This puts lower deck volumes at 4,672 and 3,796 cu ft.

The total volumes for this container configuration are 20,116 cu ft for the MD-11 and 17,458 cu ft for the DC-10-30. The respective tare weights are 27,420lbs for the MD-11 and 23,760lbs for the DC-10-30.

This gives the MD-11 a net structural payload of 183,390lbs, which, when evenly loaded in the containers, gives a maximum packing density of 9.12lbs per cu ft.

The DC-10-30 has a 141,530lbs net structural payload and maximum packing density of 8.11lbs per cubic foot. The MD-11 and DC-10-30 are therefore configured well for small packages with this container configuration. The MD-11 cannot, however, make quite as much use of its structural payload as the DC-10-30, although both aircraft are at least able to 'bulk out'.

At a packing density of 7.0lbs per cu ft the MD-11 and DC-10-30 have volumetric payloads of 140,812lbs and 122,206lbs, respectively.

The MD-11's disadvantage is its size, in that it is too large for most airlines to consider. It also has a perceived disadvantage of having a high lease rate because of its age. Used MD-11s can probably be acquired for less than appraised fair market values.

FedEx configuration

With such a large operation based on a hub and spoke system, FedEx has to be able to interline containers between all of its fleet.

There are three types of container it uses on its MD-11s, DC-10s, A300-600s, A310s and 727s. These are the AYY, SAA and AMJ.

The AMJ has already been described.

The AYY is a curved profile container that fits two abreast across the maindeck of a 727. It fits three abreast in all of FedEx's widebodies. The AYY's curved profile is such that it makes use of all the 727's fuselage cross-section. Three of these abreast on a widebody will not make full use of a widebody's cabin volume. Volume and payload will therefore be sacrificed for the ability to interline.

The SAA is effectively two AYY containers put together, forming the full fuselage cross section of the 727. The widebodies can therefore also be configured with one SAA and one AYY container abreast on the fuselage's maindeck, with similar volume characteristics as three AYY containers.

The widebodies can also be configured with one AMJ and one AYY container abreast on FedEx's widebody maindecks.

The AMJ has a larger volume than the SAA. The AYY/AMJ configuration is therefore more desirable from a fleet mix point of view, but not always practicable with the different fleet sizes.

Using just AYY containers is the least efficient use of aircraft space, but it sometimes has to be done. The MD-11 can carry 59 AYYs on its maindeck. This provides a volume of 11,859 cu ft, which compares to 15,444 cu ft when using 26 AMJs. With LD-3s in the lower hold the aircraft has a total container volume of 16,531 cu ft and tare weight of 24,639lbs *(see table, page xx)*. Because of the reduction in volume, the MD-11 then has a maximum packing density of 11.26lbs per cu ft. With a packing density of 7.0lbs per cu ft, the aircraft has a volumetric payload of 116,000lbs. This is 25,000lbs less than the volumetric payload allowed by the larger containers.

The DC-10 can have a mix of 22 AYYs and 15 SAAs. The maximum packing density is 9.87lbs per cu ft in this configuration. The volumetric payload at 7.0lbs per cu ft is 102,438lbs, 20,000lbs less than allowed with the larger containers.

L-1011-200

The L-1011-200 has a lower payload compared to the DC-10-30, despite having a similar sized fuselage.

The L-1011-200's MZFW is about 63,000lbs less than that of the DC-10-30. Although the L-1011-200 also has a lower OEW, its structural payload is 115,375lbs, 50,000lbs less than the DC-10-30.

The L-1011-200 also accommodates one AMJ less than the DC-10-30. This gives the L-1011-200 an internal volume of 13,481 cu ft and a tare weight of 17,855lbs on the maindeck.

The L-1011-200 also carries two less LD-3s in its lower deck and overall the aircraft has a net structural payload of 92,360lbs and maximum packing density of 5.44lbs per cu ft.

If it were carrying small packages the aircraft would then 'gross out' before using all its container volume. The aircraft's volumetric payload for typical small package densities is therefore 30,000lbs less than the similar sized DC-10-30.

ABX 767-200

Airborne Express has applied its own unique container system, originally developed for the DC-8 and DC-9, to the 767.

When used by the 767-200, the aircraft's maindeck accommodates 102 specially designed containers that can pass through the original passenger door. After ABX's conversion, the 767-200 has a gross structural payload of 91,210lbs.

Similar types of container are used on the aircraft's lower deck. While the system avoids a conventional conversion

NARROWBODY SMALL PACKAGE FREIGHT AIRCRAFT PAYLOAD CHARACTERISTICS

Aircraft type	757PF	DC-8-73AF	DC-8-63AF	DC-8-62 ABX	DC-8-61 ABX	727-200	727-200 FedEx
OEW lbs	112,800	149,200	145,000	131,000	140,300	90,930	90,930
APS lbs	113,290	149,910	145,710	131,710	141,010	91,640	91,640
Max structural payload lbs	86,710	111,090	115,290	85,290	82,990	58,360	58,360
Upper deck containers							
Size-inches/type	125/88/82	125/88/82	125/88/82	ABX	ABX	125/88/82	SAA
Number	15	18	18	82	106	12	11
Internal volume	6,870	8,244	8,244	5,330	6,890	5,496	4,697
Tare weight lbs	3,750	4,500	4,500	10,496	13,568	3,000	6,325
Net structural payload lbs	82,960	106,590	110,790	74,794	69,422	55,360	52,035
Maximum packing density lbs/cu ft	12.08	12.93	13.44	14.03	10.08	10.07	11.08
Volumetric payload @ 7lbs/cu ft	48,090	57,708	57,708	37,310	48,230	38,472	32,879

to freighter, the containers utilise a low proportion of the aircraft's fuselage cross-section.

This is illustrated by the fact that the aircraft has a total container volume of just 9,164 cu ft. The containers are also relatively heavy. The aircraft nevertheless has a net structural payload, after tare weight deduction, of 73,584lbs and maximum packing density of 8.03lbs per cu ft. With a packing density of 7.0lbs, the volumetric payload is 64,148lbs. This net structural payload illustrates that ABX's system uses the aircraft's gross structural payload reasonably efficiently.

This compares well with the A310-300, a similar sized aircraft. The ABX 767 also wastes relatively little payload capacity with a packing density of 7.0lbs per cu ft.

A300-600/A300B4-200/A310

The Airbus widebodies make more efficient use of the smaller containers used by the 727 in the FedEx configuration than the larger and wider MD-11 and DC-10.

The A300's and A310's conventional maindeck containers are similar to those on the MD-11 and DC-10. Although smaller, they are used two abreast to make full use of the aircraft's cross-section. These are 88 x 125 x 96-in containers. The A300-600 can accommodate 21, the A300B4 18 and the A310 16 of these containers.

With LD-3s in the lower deck, the A300-600 has a net structural payload of 96,450lbs, maximum packing density of 7.03 lbs and volumetric payload of 95,984lbs when packed at 7.0lbs per cu ft. This makes the A300-600 ideal for small package operations. Its biggest disadvantage is its current high lease rate.

The smaller A300B4 has a net structural payload of 85,450lbs and volumetric payload of 83,400lbs. Similar to the A300-600, the A300B4 is ideally configured for small packages because it has a maximum packing density of 7.17lbs per cu ft. The A300B4 freighter now also has the advantage of being available in large numbers and at lease rates of about $230,000 per month. The size, payload characteristics and finance charges of the A300B4 make it one of the most desirable small package aircraft.

The A310 has a net structural payload of 76,444lbs and volumetric payload of 70,308lbs. It makes slightly less efficient use of its structural payload at a packing density of 7.0lbs than the A300-600 or A300B4. The A310 is, however, well-placed in the market as the smallest widebody and offers additional capacity over the larger DC-8 variants and the 727-200 to absorb growth.

With the AYY FedEx containers on their maindecks, the A300-600 and A300B4 have volumetric payloads of 83,136lbs and 76,860lbs, respectively. These are the smallest reductions from volumetric payloads that any of the widebodies experience when using the FedEx containers. This underlines the efficiency of the A300-600 and the A300B4 as small package aircraft.

The A310 has a volumetric payload of 59,444lbs with AYY containers on its maindeck and a larger reduction in payload (from using standard containers) than its two larger counterparts. As when using other container configurations, the A310, nevertheless, provides an increase in capacity from the 727 that is not as excessive as other widebodies.

Narrowbodies

The DC-8 and 727 are the only widely used narrowbodies for small package operations. The 757PF is also available, but is regarded by most as having an excessive acquisition cost.

The DC-8, 757 and 727 all have the same fuselage cross-section and so use the same 125 x 88 x 82-in containers on the maindeck.

Airlines use little of the underfloor capacity, although a few bags of mail may be put in the lower hold just before departure.

Each of the containers has an internal volume of 458 cu ft and tare weight of 258lbs. The DC-8-73/-63/-61 all carry 18 of these containers. The smaller 757PF can only carry 15, while the DC-8-50 series can take 13. The 727-200 carries 12.

The 757PF's smaller payload relative to the DC-8-73 adds further to airlines' resistance to the 757PF. With growth in freight traffic, airlines will be looking to aircraft that are larger than the DC-8-73, such as the A300-600 or DC-10.

The 757PF has a net structural payload of 82,960lbs and maximum packing density of 12.08lbs per cu ft. This adds even more to the industry's dislike of the aircraft, since for small package operations the aircraft makes inefficient use of its structural payload. Its volumetric payload is therefore only 48,090lbs.

The DC-8-73 has a net structural payload of 106,590lbs and maximum packing density of 12.93lbs. The DC-8-73, like the 757PF, does not have optimal payload characteristics for small packages. At a packing density of 7.0lbs per cu ft the aircraft has a volumetric

Despite the ADs recently issued against the 727 freighter to limit floor loading in each container position, the typical packing density of small packages means payload limitations may not be excessive. Small package payloads means the 727 uses only about two-thirds of its structural payload capability.

payload of 57,708lbs, 49,000lbs less than its net structural payload. This is one of the largest amounts of unused payload capability of an aircraft in small package operations. The DC-8-73, however, has several advantages, including a low lease rate and an established placing in the market. The DC-8-73 is also the only aircraft of its size and has been the only large aircraft available to most freight operators for many years.

The DC-8-63 has the same payload characteristics as the DC-8-73, but has higher fuel burn and a lower lease rate.

ABX's freight conversion system for the DC-8 leaves the DC-8-61 with a gross structural payload of 82,990lbs. With the weight of the containers this is reduced to 69,422lbs and the aircraft has a maximum packing density of 10.08lbs per cu ft. The volumetric payload is 48,230lbs, which is less efficient use of the aircraft's gross structural payload than with the 767-200.

The shorter DC-8-62 has lower containerised volume by the same structural payload and so a smaller volumetric payload than the DC-8-61.

727-200

The 727-200's performance is currently being re-assessed following the Federal Aviation Administration's (FAA) issue of its Airworthiness Directives (AD) 98-26-18/19/20/21 with respect to the floor loading of the 727 freighter.

An analysis of the aircraft's standard payload characteristics shows that it has a gross structural payload of 58,360lbs. In the 12 containers accommodated on the aircraft, the 727-200 has a net structural payload of 55,360lbs. This translates to an average gross weight of 4,863lbs per container position. The aircraft has a maximum packing density of 10.07lbs per cu ft and so the volumetric payload of 38,472lbs means a lot of the aircraft's structural payload is wasted. The volumetric payload means the average weight per container position is reduced to 3,206lbs. This light loading has to be considered in respect of ADs 98-26-18/19/20/21.

Despite its inability to use a large portion of its structural payload, the 727-200 is in a unique position. It is the only aircraft in its size. This capacity is what the majority of airlines require and it can be acquired for less than smaller narrowbodies.

The SAA containers used by FedEx have a smaller total volume than regular containers and the aircraft's volumetric payload is 32,879lbs. The SAA is a bit more than twice the capacity of the AYY. SAA containers are therefore a more efficient configuration than AYYs.

The 727-200's volumetric payload is about 55% of the DC-8-73's capacity and just over half the A310's capacity when carrying AYY containers. This makes the A310 a good substitute for two 727-200s. The A310 offers several economic advantages, such as one less engine for which to provide reserves and one less flight crew member.

Summary

The Airbus widebodies have the best payload configurations with respect to packing densities and utilisation of structural payload in this mode.

While the MD-11 and DC-10 have high structural payloads, a portion of which cannot be used in small package operations, the aircraft are at least flexible for carrying other types of freight. Moreover, airlines may be able to achieve higher packing densities closer to 8.0lbs per cu ft with small packages. This will make the MD-11 and DC-10 efficient while at the same time making it impossible to gain any more revenue earning potential from the Airbuses.

The L-1011-200 is at a disadvantage in all types of freight operation in that it has a very low packing density and is therefore unable to use all its fuselage and container capacity.

Although the DC-8 variants and 727-200 are also unable to utilise a large portion of their structural payloads, the airlines had no other choice. The low lease rates of these types mean they still have good economics. The low lease rates of younger types, especially the A300B4, means they will be extremely attractive and efficient for airlines that can fill their capacity.

The A310 is an appropriate aircraft for airlines that find the A300B4 too big to gain additional capacity and with which to replace 727s. One alternative is the ABX 767-200, which has a 5,000lbs higher payload and the bonus of longer range. This freighter configuration is, however, unique and is only used by ABX.

The A300-600 is the next step up from the A300B4 and offers good payload efficiencies. The A300-600 can be acquired used and then converted to a freighter. The generally low popularity of the A300-600 as a passenger aircraft means used examples can be acquired at competitive rates. Now that the majority of high-quality A300B4s have been converted, the A300-600 could soon follow suit. AC