Most freight operators have no choice but to purchase the cheapest, older, aircraft. But what happens when maximum available payload becomes undependable? This article looks at freighter performance from hot and high airfields and discovers that old and new types can have similar economics.

Freighters: how they stack up in hot and high operations

When deciding between new and used aircraft, fleet planning and aircraft selection for freight operations are almost always a foregone conclusion. Most freight operators can only afford aircraft with the lowest acquisition cost.

The issue changes when maximum available payload cannot be relied on. After all, economic suitability is a question of revenue-earning potential, not just operating costs.

One type of operation in which maximum available payload cannot be taken for granted is when operating from hot and high airfields. Although the economics of the oldest aircraft are nearly always the lowest when it comes to freight operations, older types tend to have poorer field and take-off performance. Poor performance limits payload and, in turn, revenue. This can bring the economics of older and newer types closer together. This is a classic example of technical differences being directly translated into economic and financial ones.

Under normal circumstances an aircraft, such as the A310-300, still cannot economically justify itself as a replacement for, say, the 707 or DC-8 *(see Can the 707 and DC-8 justify another life extension programme? Aircraft Commerce, November/ December 1998, page 42)*. The A310 has several advantages over the 707 and DC-8. For example, it is a twin-engined aircraft, so its take-off performance in hot and high situations is stronger and much less adversely affected.

Airlines with a large percentage of their operations in such specialised environments would do well to look to the A310. It may have enough of a payload advantage across a route network to make it economically superior to older types.

Performance degradation

The acid test for freighter types is to analyse what their take-off weight and available payloads are on some of the most challenging routes departing from hot and high airfields.

Challenging airfields which have high elevations, runway lengths shorter than average and high ambient temperatures, will certainly limit take-off weight. For most aircraft the restricted take-off weight (RTOW) from an airfield will be less than maximum take-off weight (MTOW).

Whether an aircraft's RTOW on a particular route means it will be prevented from carrying a full payload depends on several factors, an important one being route length and fuel required. In all cases route lengths at the edge of an aircraft's payload-range profile mean payloads will be less than the aircraft's maximum. However, the reduction will be greater when the RTOW is punitive. The actual available payload on these routes departing from hot and high airfields has to be calculated.

All aircraft types will suffer some degree of RTOW and payload. It is the degree of degradation, however, between competing types that will have a large impact on aircraft selection. That is, if the payload of 707s and DC-8s are adversely affected on only a few routes then they are still likely to be the preferred type to an expensive A310. Severe payload restrictions on the 707 and DC-8 on many routes, with strong performance by the A310 in the

SPECIFICATION, WEIGHT CONFIGURATION AND OPERATING ASSUMPTIONS OF AIRCRAFT TYPES

Aircraft type	707-320C	DC-8-54F	A310-300F	L-1101-200F	DC-10-30CF	MD-11F	747-200F
Engine type	Stg 2 JT3D	Stg 2 JT3D	CF6-80C2	RB211-524B	CF6-50C2	CF6-80C2	CF6-50C2
MTOW (lbs)	332,895	330,000	361,554	465,995	572,000	630,500	832,990
MLW (lbs)	246,915	249,999	273,370	367,996	421,000	491,500	639,839
MZFW (lbs)	229,940	233,998	251,324	338,000	401,000	461,300	590,000
APS (lbs)	139,992	137,347	167,781	229,278	248,500	263,000	359,932
Net available payload (lbs)	89,948	96,551	83,543	108,897	152,500	198,300	230,068

same circumstances, will favour the younger aircraft by its ability to generate revenue.

Analysis basis

The table *(see page 42)* shows all aircraft analysed together with their specifications. The aircraft included are the 707-320C, DC-8-54F, A310-300F, L-1011-200F, DC-10-30CF, MD-11F and GE-powered 747-200F.

There are literally hundreds of factors which ultimately determine an aircraft's performance on an actual operation. Therefore, in this table only the major specifications of MTOW, aircraft prepared for service (APS) weight and consequent available payload have been listed.

The APS weights in the table are the operating empty weight of the aircraft plus some allowance for crew and the typical tare weight of pallets or containers. This leaves a maximum net available payload weight for each aircraft.

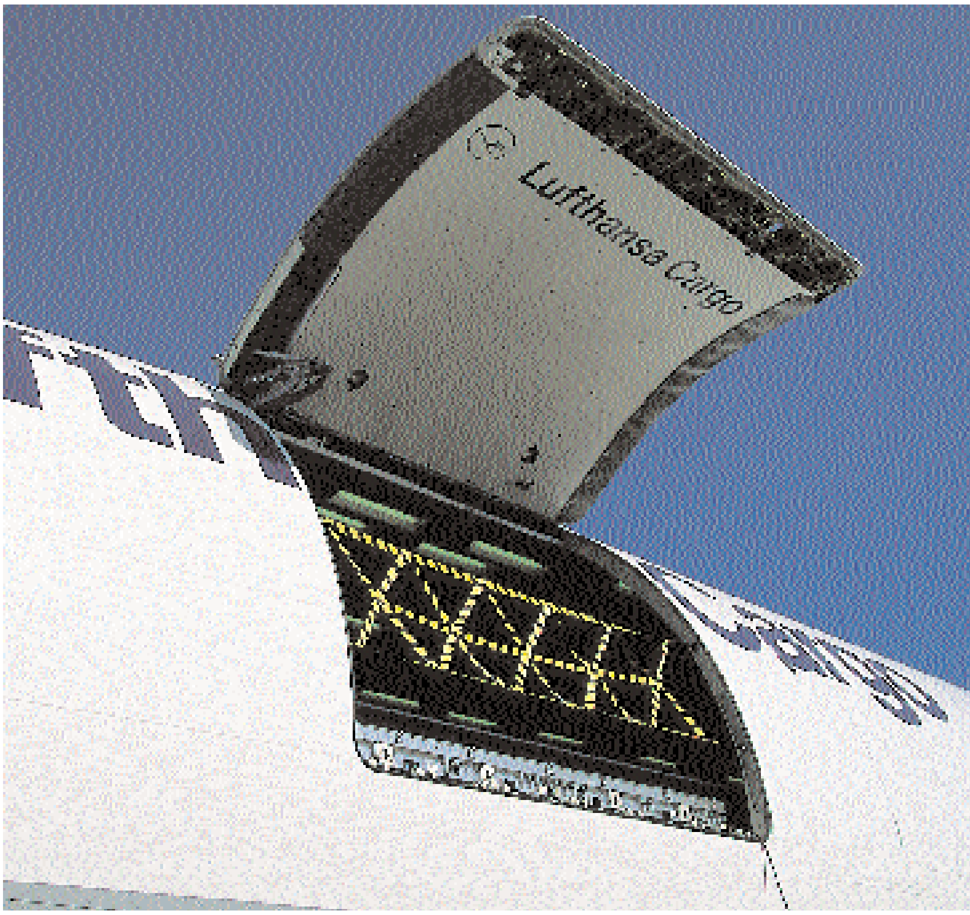
The most influential factors outside the aircraft's specification are runway length and airfield elevation, and ambient temperatures. The airports chosen and their characteristics are listed. The routes are ordered in terms of length from Miami *(see table, page 44)*. All these airfields are in countries in the equatorial zone and so experience high ambient temperatures.

High airfield elevations have to be treated with caution. Older aircraft types have to receive special certification when operating from airfields with an elevation of over 8,000 feet. This is because emergency oxygen is primed to come on with loss of cabin pressure above this altitude. Hence, an opening of the doors after landing at this elevation would cause oxygen masks to drop each time. The same re-certification threshold for newer types is 11,000 feet.

The temperature chosen for the analysis is based on international standard atmosphere temperature (ISA) plus 15°C. That is, a sea level temperature of 30°C (86°F). Although this is hot, it is still comparatively cool for airports in this part of the world. The ambient temperatures are then adjusted for airfield elevation.

The airfields used were all high and had limiting runway lengths. Each aircraft's performance was then analysed based on the route into Miami International, since this is representative of an airline's operation in this region.

Data for the 707-320C, DC-8-54F, A310-300F, L-1011-200F and 747-200F came from the PACS computer system. Data for the DC-10-30CF and MD-11F came from Boeing.



The MD-11 has the largest available payload on the most challenging Central and South American routes, having a better performance than the CF6-powered 747-200.

Airports and routes

The resultant payloads for each aircraft type on chosen routes departing from various airfields in central and south America to Miami International are summarised *(see table, page 45)*.

Maximum available payload is compared with available payload on each route. Available payloads on these routes are not just affected by elevation and runway length, but also route length.

Not surprisingly all aircraft are adversely affected on routes departing from the most difficult airfields. These are Caracas, Brasilia, Calama, Quito and Arequipa.

The difficulties at Caracas are explained by a combination of a 6,475 feet runway and an elevation of 2,739 feet. Runway length is the biggest problem. But Caracas has the advantage of a route length of just 1,280nm from Miami. Since this is short by most aircraft standards, performance is mainly affected by its airfield restrictions. Because of this, Caracas causes some of the largest payload restrictions for all aircraft types in the analysis.

Brasilia has a runway which at sea level would cause few problems, although ideally it could even be a little longer. Brasilia is, however, at 3,473 feet, a height at which most aircraft types will experience performance degradation. Brasilia is also the furthest airfield from Miami in this analysis. These factors make the Brasilia-Miami route one of the most demanding.

Calama, Chile is one of two airports chosen which present the largest reduction in performance. The airport has an elevation of 7,606 feet, the fourth highest in this analysis, and has a runway length of only 9,478 feet. The airport is also 3,090nm from Miami, a long sector in terms of operating from such a challenging airport. These features place severe restrictions on all aircraft.

Quito, Ecuador is one of three airports above 8,000 feet, but it has a reasonable runway length of 10,236 feet. Although much higher than Calama, Quito has a longer runway and is also only 1,610nm from Miami. The airport's altitude causes large reductions in take-off weight and available payload.

Arequipa, Peru is the second highest airfield at 8,405 feet and has a runway length of just 9,777 feet. The airport is 2,680nm from Miami, which is at the limit of payload-range capability for smaller types of aircraft, such as the 707, DC-8 and A310.

Other airports in this analysis with limiting elevations and runway lengths are Bogota, Guatemala, San Jose and Mexico City.

DEPARTURE AIRPORTS AND ROUTE SECTOR DATA TO MIAMI (MIA)

Airport	Elevation (ft)	Runway length (ft)	Ambient temperature (c) (ISA + 15°C)	Route length (nm)
Guatemala, Guatemala	4,952	9,800	20	920
San José, Costa Rica	3,021	9,882	24	1,012
Mexico City, Mexico	7,341	12,795	15	1,143
Caracas, Venezuela	2,739	6,475	25	1,280
Bogota, Colombia	8,355	12,467	13	1,339
Guadalajara, Mexico	5,012	13,124	20	1,359
Cali, Colombia	3,162	9,842	24	1,406
Quito, Ecuador	9,223	10,236	12	1,610
Arequipa, Peru	8,405	9,777	13	2,680
Santa Cruz, Bolivia	1,371	9,144	27	2,910
Calama, Chile	7,606	9,478	15	3,090
Brasilia, Brazil	3,473	10,499	23	3,526

Bogota is particularly limiting. It is above 8,000 feet and so older aircraft need special certification. Runway length is, however, over 12,000 feet – one of the longest in the analysis. The airport has one advantage in that it is only 1,339nm from Miami.

Guatemala is high and has a short runway, but is close to Miami at just 920nm. San José is also close to Miami, which means its short runway of 9,882 feet poses virtually no problems.

Mexico City is a notoriously difficult airport because it is 7,341 feet above sea level, but only 1,012nm from Miami and so presents only small payload reductions to older freighter types.

Aircraft performance

The available payloads on each route for each aircraft type are summarised *(see table, page 45)*. Like the table of route summaries *(see table, this page)*, the routes are listed in descending order of sector length. This allows the effects of length to be easily taken into account. As can be seen by the payload data there is a general reduction in payload from the shortest Guatemala-Miami route to the longest Brasilia-Miami sector.

Aircraft most affected by range alone are the 707 and DC-8. There are also imitations of elevation and runway length

Ultimately, the permitted take-off weight for each aircraft type will also be significantly influenced by factors unique to the aircraft. For example, all Pratt & Whitney engines are flat rated to 30°C. The 707 and DC-8-54F have a lower flat rating and so would not experience any reduction in available thrust.

Other unique factors of the 707 and DC-8 include their aerodynamics, flap settings, and high-speed take-off techniques. The latter permit higher take-off weights.

The vintage of the 707 and DC-8 are reflected in the available payloads on each route. Not one of the routes permits a full payload for the 707. The reductions are even bigger on the shortest sectors, with the exception of San José. The only two routes with small payload reductions for the 707 are the San Jose-Miami and Guadalajara-Miami routes. Cali and Guatemala also have reasonable payloads, but the majority of sectors analysed here only permit payloads less than half the maximum allowed.

Two of the routes, Arequipa and Calama, permit no payload at all for the 707. These sectors are not only long, but also operate from high-altitude airports.

The DC-8-54F is affected in a virtually identical way to the 707. In many respects the DC-8 is more adversely affected, since it has a larger maximum available payload but is permitted about the same weight on the same routes. The DC-8-54F therefore experiences a larger percentage payload reduction than the 707.

The closest aircraft in terms of maximum available payload and range performance is the A310-300F. The highest gross weight variant, studied here, has a range that can match the 707's and DC-8's in standard conditions. The A310's weakness is its high market value and subsequent lease rate required to amortise investment for a lessor. Since lease rates are dictated by market forces, the A310F is still unappealing in most scenarios.

One exception is the case studied here, where the A310F's performance and available payload is virtually unaffected. This contrasts favourably with the 707 and DC-8. The A310-300F's maximum payload of 83,453lbs is allowed on all routes except for three. Caracas and Arequipa sectors experience a reduction of just 6,000lbs and 10,000lbs, which is appreciable considering the short runway at Caracas and high elevation of Arequipa.

Calama-Miami is one route where the A310-300F suffers a serious reduction and this is because of the excessively high airfield elevation, short runway and long sector length. The reduction in payload the A310F suffers, however, is only about 24,000lbs. This underlines the A310F's suitability for this type of operating environment as the 707 and DC-8-54 cannot carry any payload on this route.

The A310-300F is a strong performer overall. Except for the Calama-Miami route the payload reduction is just a few thousand pounds, compared to severe reductions on all sectors for the 707 and DC-8.

The L-1011-200F is also a strong performer overall. This might be explained by the flat rating of its RB211 engines. However, the aircraft suffers greater percentage payload reductions than the A310 on the most adverse routes.

Out of the twelve routes analysed the L-1011-200F can carry a full payload on eight, including the longest Brasilia-Miami sector of 3,526nm. In fact, the L-1011-200F is the only aircraft here capable of a full payload on this route. This fact illustrates the L-1011's ability to perform well from high airfields when the available runway is not too short. The routes where the aircraft does get restricted is from airports, such as Calama, Arequipa and Caracas, which severely affects all types.

The feature these airfields all have in common is that they all have short runways. In the cases where the L-1011's payload is reduced it is severe. In fact, the reductions are so large that the A310-300F is capable of a larger payload on these routes. This emphasises the powerful performance of a modern generation twin-engined aircraft over all vintage machines.

The DC-10-30 is another good performer. The aircraft has payload restrictions on half the routes, but in many cases the reductions are not severe.

The DC-10-30 suffers a payload reduction on the longer sectors. The most severe sectors are the Arequipa and Calama routes, which is the case for all aircraft types.

Moreover, the DC-10-30 can carry a full payload on the same routes as the L-1011, with the exceptions of Bogota, Santa Cruz and Brasilia. Here, the DC-10-30's reductions are small. On the three routes where both aircraft have reduced payloads the DC-10-30 always has the better performance. The aircraft does, however, have a higher MTOW and 46,000lbs higher maximum available payload than the L-1011-200.

AVAILABLE PAYLOADS ON ROUTES FROM CENTRAL & SOUTH AMERICAN HOT AND HIGH AIRFIELDS TO MIAMI (MIA)

Aircraft type	707-320C*	DC-8-54F*	A310-300F*	L-1011-200F*	DC-10-30CF	MD-11F	747-200F*
Maximum Payload (lbs)	89,948	96,651	83,453	108,722	152,500	198,300	230,068
Route							
Guatemala	73,263	73,786	83,543	108,722	152,500	198,300	224,296
San Jose	88,277	88,627	83,543	108,722	152,341	198,300	230,068
Mexico City	72,157	76,982	83,543	108,722	152,162	198,300	230,068
Caracas	24,392	22,009	77,225	69,837	-	-	111,438
Bogota	52,216	52,831	83,543	108,722	142,596	184,640	219,355
Guadalajara	84,674	92,002	83,543	108,722	151,748	198,300	230,068
Cali	75,913	75,664	83,543	108,722	151,560	198,300	224,159
Quito	20,117	23,911	83,543	86,367	95,870	128,087	111,923
Arequipa	N/A	N/A	73,543	53,179	67,035	100,301	71,813
Santa Cruz	41,640	40,805	83,543	108,722	128,194	169,377	157,993
Calama	N/A	N/A	59,224	46,991	58,549	92,355	78,210
Brasilia	35,022	30,829	83,543	108,215	116,838	157,461	149,598

***Source: PACS database**

The DC-10-30 also has literally thousands of flap settings, since flaps can be set to decimals of a degree. This allows take-offs to be optimised, rather than having to use a flap setting that might be a compromise. Unlike the L-1011-200F, the DC-10-30's available payload on the most of the restrictive routes is more than the A310-300F's, with the exception of the Arequipa and Calama routes. In these cases the A310-300F is still the best performer, underlining even further the benefits of a twin-engined aircraft.

The MD-11 is an impressive aircraft in these conditions. The percentage available payload reductions it suffers on the longer and more difficult routes are smaller than that experienced by the 747-200. Moreover, the MD-11 has a higher payload than all other aircraft types on these five sectors, although it does still suffer payload penalty.

The MD-11 can carry a full payload on six of the 11 sectors analysed. The aircraft really comes into its own when competing with the 747-200 on the five longer and more difficult sectors described.

Otherwise the aircraft experiences similar scales of payload reduction as the DC-10-30CF.

The 747-200F is a large type for many of these routes and is less likely to be required than any of the other types analysed here. Because of its size the aircraft is only unaffected on three routes, and even suffers a reduced payload on the shortest Guatemala-Miami route. This point illustrates the aircraft's requirement for a long runway, although the airfield has high elevation. Nevertheless, only the DC-8 and 707 also experience a reduced payload on this route. This fact, and the 747's performance on all other routes, illustrates how four-engined aircraft suffer the largest restrictions on performance compared to three- and two-engined ones.

Like the DC-8 and 707, when the 747-200 does have a payload reduction it is large.

Summary

The payload reductions experienced by the aircraft on all routes longer than the Quito-Miami sector illustrate the severity of the operating conditions in this analysis.

The MD-11F, for example, has a range of 4,000nm with a full payload in standard sea level and ISA conditions. The analysis shows the MD-11F suffering reduced payloads on sectors as short as 1,610nm. This highlights the difficulties of the aircraft experience.

The most noticeable exceptions are the A310-300F and L-1011-200F. Both these aircraft can still carry a full payload on the longest Brasilia-Miami route, an exceptional performance compared to the other types.

Finally, the A310-300F comes top in terms of the number of routes on which it incurs no payload penalty at all. Again, this is probably explained most by its twin-engine configuration. AC

Four-engined aircraft, such as the DC-8, suffer the largest degradation in available payload