ERJ 145 fuel burn performance

The fuel burn performance of the most numerous ERJ-145 family member variants are analysed on a range of mission lengths.

Analysis of the fuel-burn performance of three members of the ERJ-145 family reveals that for a given payload flown over a given distance, the fuel burn per seat-mile is influenced by several factors that include, but are not limited to: operating empty weight (OEW); engine power; weather; and cruise speed.

Aircraft variants

The three sub-types of the ERJ-145 family are the ERJ-135, ERJ-140 and the ERJ-145, with two, two and eight commercial passenger variants respectively. The –ER variants of all three main types are considered the standard or base-line models. Since only one ERJ-140ER has been produced, the fuel burn performance of just the ERJ-135ER and ERJ-145ER is assessed. The most popular variant of the ERJ-145 family is the ERJ-145LR, with over 400 aircraft in operation, so this is the third variant that will be assessed. The majority of the remaining variants are just adaptations of the –ER and –LR models.

All three variants are powered by the Rolls-Royce AE3007, but each have different engine variants and thrust ratings. The ERJ-135 is equipped with the AE3007A3 engine model and is rated at 6,495lbs of take-off thrust. The ERJ-145ER has the AE3007A1/1 engine model and is rated at 7,036lbs of take-off thrust, while the ERJ-145LR is equipped with the AE3007A1 and rated at 8,169lbs of take-off thrust.

The increase in engine thrust for these three models is echoed in the increase in maximum take-off weight (MTOW), which goes from 41,887lbs for the ERJ-135ER to 48,502lbs for the ERJ-145LR. The OEW and maximum payload for each aircraft variant also increase with thrust, although the range does not follow the same pattern. The fuel capacity is the same for all –ERs (9,109USG) or -LRs (11,322USG).

There are many thrust and MTOW variants, as mentioned above, used by different airlines. The basic specifications, as stated by the manufacturers, have been used for these calculations.

Flight profiles

Aircraft performance has been analysed both inbound and outbound for each route in order to illustrate the effects of wind speed and its direction on the distance flown. The resulting distance is referred to as the equivalent still air distance (ESAD) or nautical air miles (NAM).

Average weather for the month of June has been used, with 85% reliability winds and 50% reliability temperatures used for that month in the flight plans produced by Jeppesen. The flight profiles in each case are based on International Flight Rules, which include standard assumptions on fuel reserves, diversion fuel and contingency fuel. The optimum routes and levels have been used for every flight, except where it has been necessary to restrict the levels due to airspace or airway restrictions and to comply with standard routes and Eurocontrol restrictions.

A taxi time of 20 minutes has been factored into the fuel burns and added to the flight times to provide block times. This equates to additional fuel of about 300lbs on the ERJ-135 and about 350lbs on the ERJ-145, which is similar to the amount that is factored in by the large operators of this aircraft type. Long-range cruise (LRC) speed was used for these flight plans, because it enables an aircraft to use less fuel per nautical mile. It can mean longer block times, but this is the economical and operational compromise between fuel consumption and flight times. Economy cruise is more likely on the shorter routes, but for ease of comparison, LRC is used on all the flight profiles.

The aircraft being assessed are assumed to have a single-class cabin with a full passenger load of 35 on the ERJ-135 and 50 on the ERJ-145. The standard weight for each passenger and their luggage is assumed on these short-haul flights to be 200lbs per person, with no additional cargo in the hold. The payload carried is therefore 7,400lbs for the ERJ-135 and 10,000lbs for the ERJ-145. This is only varied when the ERJ-135 is assessed on the return sectors of the European routes. The payload on those three flights is reduced to allow the aircraft to stay within its landing weight restrictions. The reduction varies from 58-126lbs on each variant, and equates to less than one passenger.

The ERJ-145ER has lower fuel burn performance per seat and per seat-mile compared to the smaller ERJ-135 and heavier long-range ERJ-145LR variant.

FUEL BURN PERFORMANCE OF ERJ-135ER & ERJ-145ER/LR - OUTBOUND SECTOR

City-pair variant	Aircraft	Engine model	MTOW lbs	TOW lbs	Fuel burn USG	Block time mins	Passenger seats	ESAD nm	Fuel per seat	Fuel per seat-mile	Wind speed
DFW-ABI	ERJ-135ER	AE3007A	41,887	35,719	203	48	37	158	5.5	0.03778	-41
EWR-MHT	ERJ-135ER	AE3007A	41,887	35,368	224	54	37	186	6.1	0.03172	11
DFW-LIT	ERJ-135ER	AE3007A	41,887	36,305	288	68	37	278	7.8	0.02796	2
DFW-JAN	ERJ-135ER	AE3007A	41,887	36,448	348	81	37	365	9.4	0.02570	2
ORD-SYR	ERJ-135ER	AE3007A	41,887	37,272	462	107	37	531	12.5	0.02295	12
LIS-AGP	ERJ-135ER	AE3007A	41,887	36,377	307	73	37	307	8.3	0.02691	7
LIS-VLC	ERJ-135ER	AE3007A	41,887	37,046	427	100	37	474	11.5	0.02402	6
LIS-TLS	ERJ-35ER	AE3007A	41,887	38,052	524	120	37	596	14.2	0.02362	3
DFW-ABI	ERJ-145ER	AE3007A	45,415	39,666	214	47	50	155	4.3	0.02952	-22
EWR-MHT	ERJ-145ER	AE3007A	45,415	39,435	239	53	50	189	4.8	0.02497	9
DFW-LIT	ERJ-145ER	AE3007A	45,415	40,333	312	68	50	278	6.2	0.02244	1
DFW-JAN	ERJ-145ER	AE3007A	45,415	40,514	379	82	50	367	7.6	0.02068	1
ORD-SYR	ERJ-145ER	AE3007A	45,415	41,387	502	107	50	529	10.0	0.01845	12
LIS-AGP	ERJ-145ER	AE3007A	45,415	40,392	330	72	50	307	6.6	0.02141	7
LIS-VLC	ERJ-145ER	AE3007A	45,415	41,121	462	99	50	477	9.2	0.01924	5
LIS-TLS	ERJ-145ER	AE3007A	45,415	42,173	564	119	50	598	11.3	0.01882	2
DFW-ABI	ERJ-145LR	AE3007A	48,502	41,299	231	49	50	154	4.6	0.03191	-25
EWR-MHT	ERJ-145LR	AE3007A	48,502	40,930	257	54	50	187	5.1	0.02696	10
DFW-LIT	ERJ-145LR	AE3007A	48,502	41,980	328	68	50	278	6.6	0.02362	2
DFW-JAN	ERJ-145LR	AE3007A	48,502	42,137	396	81	50	365	7.9	0.02162	2
ORD-SYR	ERJ-145LR	AE3007A	48,502	43,053	523	105	50	530	10.5	0.01922	13
LIS-AGP	ERJ-145LR	AE3007A	48,502	42,037	350	73	50	306	7.0	0.02271	8
LIS-AGP	ERJ-145LR	AE3007A	48,502	42,778	481	98	50	474	9.6	0.02003	6
LIS-TLS	ERJ-145LR	AE3007A	48,502	43,920	588	117	50	596	11.8	0.01961	3

Source: Jeppesen

Route analysis

Eight routes with varying lengths were analysed with tracked distances of 145-600nm. Five of the routes were in the USA and three were in Europe, and all were picked to examine the fuel burn per seat-mile with increasing mission length. All the routes are typical of the operators of these aircraft, which tend to have average FC times of just over 1.0FH. All routes have been analysed in both directions, to gain a better picture of each aircraft's fuel burn and the effect of wind.

The first American route to be analysed is Dallas Fort Worth, TX (DFW) to Abilene, TX (ABI). This has a tracked distance of 145nm on the outbound sector and 211nm on the return. This is a route on which American Airlines often uses its ERJ-145 aircraft. Although there were strong headwinds on the outbound sector, the block time was still about 10 minutes quicker than the return sector. This was because of a much longer return routeing, and nominal tailwinds on the return sector. These winds had the effect of not changing the distance, so the ESAD is the same as the tracked distance.

The second American route is an example from ExpressJet's network, and is Newark, NJ (EWR) to Manchester, NH (MHT). The tracked distance is 191nm on the outbound sector, and a much longer 271nm on the return. The difference between the outbound ESAD and the return sector ESAD is even more pronounced at more than 116nm - an increase of more than 60%. This comes from longer routeings and a massive headwind of 65-68kts on the return sector. This is compared to a tailwind of 9-11kts and a block time of 53-54 minutes, which is about 20 minutes faster than the return sector's block time *(see tables, this page & page 14)*.

The third route is an American Airlines route from DFW to Little Rock, AR (LIT). The outbound distance is 278nm, and with small tailwinds, the ESAD does not differ. The return sector has a similar tracked distance of 289nm, but, due to large headwinds of about 39kts, the ESAD is increased to about 318nm and the block times are increased by four to six minutes *(see tables, this page & page 14)*.

The fourth US route is again an American Airlines example from its DFW base. The destination this time is Jackson, MS (JAN). The outbound sector has a tracked distance of 366nm and a tailwind of one or two knots, meaning that the ESAD stays roughly the same as the tracked distance. The return sector has a less forgiving headwind of 41-43kts. This increases the longer tracked distance of 432nm to an ESAD of about 473kts. These two aspects mean that the block time is 15-19 minutes faster on the outbound leg.

The final American Airlines route is Chicago (ORD) to Syracuse, NY (SYR), which is a route also flown by United and US Airways. Both sectors on this route have similar routeings, with the tracked distances being 544nm on the outbound sector and 536nm on the return. The outbound tailwind is 12-13kts, which means that there is an improvement in the ESAD, but the return sector has a strong 69kts headwind, resulting in a drastic increase of the ESAD to about 640nm, over 100nm more than the outbound ESAD. This also means an increase in the block time for the return of about 20 minutes.

The first European route is Lisbon, Portugal (LIS) to Malaga, Spain (AGP), which is flown by TAP Air Portugal and Spanair. The outbound tracked distance is 308nm and due to a tailwind of just 7-8kts, the ESAD is only 1-2nm less. The return sector has a stronger wind that is a headwind this time, so the 339nm tracked distance increases to an ESAD of about 369nm. This also increases the block time by about 10 minutes.

FUEL BURN PERFORMANCE OF ERJ-135ER & ERJ-145ER/LR - RETURN SECTOR

City-pair variant	Aircraft	Engine model	MTOW lbs	TOW lbs	Fuel burn USG	Block time mins	Passenger seats	ESAD nm	Fuel per seat	Fuel per seat-mile	Wind speed
ABI-DFW	ERJ-135ER	AE3007A	41,887	35,252	235	57	37	211	6.3	0.03009	3
MHT-EWR	ERJ-135ER	AE3007A	41,887	36,050	309	73	37	309	8.4	0.03081	-67
LIT-DFW	ERJ-135ER	AE3007A	41,887	35,790	311	74	37	318	8.4	0.02912	-40
JAN-DFW	ERJ-135ER	AE3007A	41,887	36,589	425	100	37	476	11.5	0.02658	-43
SYR-ORD	ERJ-135ER	AE3007A	41,887	37,440	545	127	37	647	14.7	0.02747	-69
AGP-LIS	ERJ-135ER	AE3007A	41,887	37,303	359	83	37	371	9.7	0.02859	-43**
VLC-LIS	ERJ-135ER	AE3007A	41,887	38,236	498	113	37	550	13.5	0.02746	-48**
TLS-LIS	ERJ-135ER	AE3007A	41,887	38,665	562	127	37	654	15.2	0.02596	-45**
ABI-DFW	ERJ-145ER	AE3007A	45,415	41,141	271	58	50	210	5.4	0.02569	3
MHT-EWR	ERJ-145ER	AE3007A	45,415	40,023	326	72	50	305	6.5	0.02408	-68
LIT-DFW	ERJ-145ER	AE3007A	45,415	39,975	335	72	50	318	6.7	0.02316	-37
JAN-DFW	ERJ-145ER	AE3007A	45,415	40,842	458	98	50	469	9.2	0.02120	-41
SYR-ORD	ERJ-145ER	AE3007A	45,415	41,704	578	122	50	643	11.6	0.02155	-69
AGP-LIS	ERJ-145ER	AE3007A	45,415	41,411	383	82	50	368	7.7	0.02257	-46
VLC-LIS	ERJ-145ER	AE3007A	45,415	42,452	530	110	50	550	10.6	0.02165	-48
TLS-LIS	ERJ-145ER	AE3007A	42,965	42,965	603	125	50	648	12.1	0.02063	-45
ABI-DFW	ERJ-145LR	AE3007A	48,502	39,402	253	56	50	211	5.1	0.02402	1
MHT-EWR	ERJ-145LR	AE3007A	48,502	41,668	349	72	50	307	7.0	0.02572	-65
LIT-DFW	ERJ-145LR	AE3007A	48,502	41,723	354	73	50	317	7.1	0.02447	-41
JAN-DFW	ERJ-145LR	AE3007A	48,502	42,612	480	97	50	474	9.6	0.02222	-43
SYR-ORD	ERJ-145LR	AE3007A	48,502	43,539	609	121	50	637	12.2	0.02272	-69
AGP-LIS	ERJ-145LR	AE3007A	48,502	43,081	404	82	50	367	8.1	0.02385	-45
VLC-LIS	ERJ-145LR	AE3007A	48,502	44,143	555	109	50	547	11.1	0.02265	-46
TLS-LIS	ERJ-145LR	AE3007A	48,502	44,673	630	123	50	648	12.6	0.02154	-45

** payload reduced to stay within landing weight.

Source: Jeppesen

The second European route is LIS to Valencia, Spain (VLC), operated by Iberia. Again on the outbound sector the ESAD decreases only slightly from the 480nm tracked distance due to a small tailwind. The return sector's tracked distance is only 10nm more than on the outbound, but due to headwinds of about 48kts, the ESAD increases to about 550nm. The block time also increases by 11-13 minutes.

The third and final European route is also from LIS, but this time to Toulouse, France (TLS), also operated by TAP Air Portugal. The outbound tracked distance is 600nm, with the return routeing giving a reduced distance of 585nm. The small tailwinds outbound mean little change in the ESAD. On the return sector, however, the ESAD increases to 648-654nm because of 45kt headwinds. This has less effect on the block times than would be expected and, assisted by the shorter routeing, the return sector's block time is just 6-7 minutes longer.

On all three European routes, as mentioned above, the ERJ-135ER has to have its payload reduced by the equivalent of less than one passenger.

Fuel burn performance

The fuel burn performance of the three ERJ 145 family variants is shown for all the routes across a range of mission lengths, together with the associated fuel burn per passenger and per passenger-mile for the outbound and return sectors on each route.

For every route the performance order is generally the same. The ERJ-145ER is the most fuel-efficient when looking at both the fuel burn per passenger and per seat-mile. The ERJ-135ER burns the least fuel, but it is also the least efficient per passenger and seat-mile.

The ERJ-145LR comes between the other two variants. It is likely that the ERJ-145LR comes into its own on much longer routes, or when weather conditions would necessitate the additional fuel capacity. Nevertheless, it is debatable whether airlines actually use this aircraft family regularly on much longer routes, since the average FC time of all the ERJ-145 family is about 80 minutes.

When looking at all the outbound American Airlines routes, the DFW-ABI sector has the lowest fuel burn per passenger for each variant. Then in terms of the burn per seat-mile, the ORD-SYR sector produces the best results for each aircraft variant. For the return American Airlines routes, the best fuel burn per passenger performance is again seen on the shorter ABI-DFW sector *(see table, this page)*. The best performance per seat-mile is not on the longest route, as would be expected, but on the JAN-DFW route. This is only by a fractional amount, however, and could be due to the longer route having a very large headwind and, therefore, additional workload.

The European routes follow the same patterns as the American Airlines routes, with the ERJ 145-ER producing the better results. On the outbound sector, ORD-SYR produces the lowest fuel burns per passenger-mile and on the return, TLS-LIS produces the lowest fuel burn per passenger-mile. Overall, the best fuel burn per passenger is seen on the DFW-ABI sector using the ERJ-145ER. The best fuel burn per passenger-mile is delivered by the ERJ-145ER, again on the ORD-SYR sector, closely followed by the same variant on the LIS-TLS sector.

Generally, the figures show that the shorter the route, the lower the fuel burn per passenger, as would be expected. Conversely, the longer the route the better the fuel burn per seat-mile, although JAN-DFW is the exception, since it produces fractionally better figures than the longer SYR-ORD route.

As with most aircraft, the larger the size, the more the thrust and weight increase and with it the fuel burn. But, with bigger aircraft, come more seats, which is why the ERJ 145 performs better on a per seat-mile basis. AC