Rolls-Royce Trent family fuel burn performance

The Rolls-Royce Trent family has several applications. The fuel burn performance of several common types is analysed here.

The Rolls-Royce (RR) Trent engine family is used by five aircraft families and 10 types. These include the: A330-200/-300, A340-500/-600, A380, 777-200/-300, and 787-8/-9. The Trent XWB will be used on the A350XWB *(see Rolls-Royce Trent family specifications, page 4)*.

The A340-500/-600 use variants of the RR Trent 500, the A330-200/-300 utilises the Trent 700, the 777 family (except the 777-200LR and 777-300ER) utilises variants of the Trent 800 engine, the A380 uses the RR Trent 900 engine, while the 787-8 uses the Trent 1000.

The fuel burn performance of some RR Trent 500, 700, 800 and 900 engines on examples of the aircraft they power is examined here on sample routes of increasing distance. The Trent 1000 has only recently entered service, so it is too early to analyse this engine type.

Aircraft analysed

There are several weight and fuel capacity variants of each aircraft type. The aircraft specifications of the aircraft analysed here are summarised *(see table, page 14)*. An international tri-class seat configuration has been used for each aircraft due to the long-haul nature of the routes used, together with the average number of seats used by airlines' configurations.

The A340-500 analysed here uses Trent 553 engines, with a maximum take-off weight (MTOW) of 804,700lbs. It has a maximum structural payload of 113,900lbs, and a fuel capacity of 56,750 US gallons (USG), and 238 seats on-board *(see table, page 14)*.

The A340-600 is a further stretched variant of the A340, and is powered by the Trent 556. The A340-600 has the same MTOW as the A340-500 of 804,700lbs. Maximum payload is higher, however, at 139,100lbs, with a lower fuel capacity of 51,480USG. The average airline three-class layout of the A340-600 is 300 seats *(see table, page 14)*.

The A330 family uses Trent 700 engines. The A330 variants analysed here are the A330-200 and -300, both powered by Trent 772B engines. Both aircraft have an MTOW of 513,765lbs.

The A330-200 has a higher fuel capacity, however, of 36,744USG, compared to a fuel capacity of 25,858USG for the A330-300 *(see table, page 14)*.

The A330-300 has a maximum payload of 108,282lbs, compared with 107,819lbs for the A330-200. The three-class average number of seats for the A330-200 is 231, compared with 257 for the A330-300 *(see table, page 14)*.

Two variants of the Trent 800 are analysed here, powering 777-200ER aircraft. The Trent 884 powers a lower gross weight version of the 777-200ER with an MTOW of 580,000lbs.

Also examined here is the Trent 892 engine, powering a higher gross weight 777-200ER with an MTOW of 656,000lbs. Both aircraft have a fuel capacity of 31,000USG, with 285 seats on-board *(see table, page 14)*.

The Trent 970 powering the A380-800 is also included. The MTOW of the aircraft is 1,235,000lbs, carrying a payload of 200,000lbs, including 486 seats in a three-class layout. Fuel capacity is 84,600USG *(see table, page 14)*.

Routes analysed

Routes chosen for analysis are a variety of common long-haul routes, of increasing distance. These will show the fuel burn performance of the aircraft on an absolute basis in USG, as well as at a rate of USG per seat-mile, when distance increases on the different aircraft types.

Three long-haul routes from Frankfurt (FRA) have been chosen. These are to: New York JFK (JFK), Chicago O'Hare (ORD) and Los Angeles (LAX). A route between Singapore (SIN) and London Heathrow (LHR) has also been included as the longest distance route.

All routes are analysed in a westerly direction, where headwinds increase the effective distance of the route.

It is important to note here that aircraft cover a longer tracked distance than the great circle distance between two points. This is due to Air Traffic Control (ATC), following airways and transatlantic tracks, and extended-range twin-engine operations (ETOPs) requirements. It is also due to the effects of departure and arrival routeings.

The distance an aircraft actually flies is the tracked distance. The tracked distance is affected by en-route winds.

The Trent 892- & 895-powered 777-200ER has the lowest fuel burn per seat mile compared to the Trent-powered A330-200, A330-300, A340-500 and A380.

FUEL BURN PERFORMANCE OF THE ROLLS-ROYCE TRENT SERIES

Route	Aircraft type	Engine model	MTOW (lbs)	Fuel capacity (USG)	Passenger payload (seats)	Tracked distance (nm)	ESAD (nm)	Wind (kts)	Block time (hr:min)	Block fuel (USG)	Fuel burn USG per seat-mile
FRA-JFK	A340-500	RR Trent 553	804,700	56,750	238	3,501	3,714	-27	08:24	21,187	0.0240
	A340-600	RR Trent 556	804,700	51,480	300	3,501	3,723	-28	08:25	22,906	0.0205
	A330-200	RR Trent 772B	513,765	37,644	231	3,501	3,725	-28	08:31	16,270	0.0189
	A330-300	RR Trent 772B	513,765	25,858	257	3,501	3,726	-28	08:32	16,893	0.0176
	777-200ER	RR Trent 884	580,000	31,000	285	3,501	3,727	-29	08:18	19,099	0.0180
	777-200ER	RR Trent 892	656,000	31,000	285	3,501	3,728	-29	08:20	19,342	0.0182
	A380-800	RR Trent 970	1,235,000	84,600	486	3,501	3,717	-28	08:13	35,319	0.0196
FRA-ORD	A340-500	RR Trent 553	804,700	56,750	238	3,964	4,121	-18	09:13	23,718	0.0242
	A340-600	RR Trent 556	804,700	51,480	300	3,964	4,130	-19	09:14	25,620	0.0207
	A330-200	RR Trent 772B	513,765	37,644	231	3,964	4,132	-19	09:20	18,217	0.0191
	A330-300	RR Trent 772B	513,765	25,858	257	3,964	4,132	-19	09:21	18,416	0.0173
	777-200ER	RR Trent 884	580,000	31,000	285	3,964	4,118	-18	09:04	19,321	0.0165
	777-200ER	RR Trent 892	656,000	31,000	285	3,964	4,128	-19	09:07	21,541	0.0183
	A380-800	RR Trent 970	1,235,000	84,600	486	3,964	4,117	-18	09:00	39,321	0.0197
FRA-LAX	A340-500	RR Trent 553	804,700	56,750	238	5,279	5,476	-17	12:05	32,914	0.0253
	A340-600	RR Trent 556	804,700	51,480	300	5,279	5,475	-17	12:02	35,409	0.0216
	A330-200	RR Trent 772B	513,765	37,644	223	5,279	5,479	-17	12:17	22,045	0.0180
	A330-300	RR Trent 772B	513,765	25,858	190	5,279	5,479	-17	12:18	22,489	0.0216
	777-200ER	RR Trent 884	580,000	31,000	250	5,279	5,473	-17	11:56	26,188	0.0191
	777-200ER	RR Trent 892	656,000	31,000	285	5,279	5,463	-16	12:02	28,759	0.0185
	A380-800	RR Trent 970	1,235,000	84,600	486	5,279	5,471	-17	11:49	54,112	0.0204
SIN-LHR	A340-500	RR Trent 553	804,700	56,750	238	6,037	6,153	-9	13:21	37,705	0.0257
	A340-600	RR Trent 556	804,700	51,480	300	6,037	6,153	-9	13:20	39,553	0.0214
	A330-200	RR Trent 772B	513,765	37,644	49	6,037	6,143	-8	13:44	22,533	0.0753
	A330-300	RR Trent 772B	513,765	25,858	16	6,037	6,143	-8	13:46	22,972	0.2400
	777-200ER	RR Trent 884	580,000	31,000	47	6,037	6,140	-8	13:16	26,808	0.0923
	777-200ER	RR Trent 892	656,000	31,000	225	6,037	6,152	-9	13:08	29,443	0.0213
	A380-800	RR Trent 970	1,235,000	84,600	486	6,037	6,151	-9	13:06	58,075	0.0194

Source: Navtech

The tracked distance is represented by the equivalent still air distance (ESAD). Against a headwind, the ESAD will be longer than the tracked distance, whereas with a tailwind, the ESAD will be shorter than the tracked distance.

Assumptions in these flight plans include average temperatures from June being used, with 85% reliability winds. International Flight Rules are used, and include standard assumptions on fuel reserves, diversion fuel, and contingency fuel.

Optimum routes and flight levels have been used where possible. Long-range cruise (LRC) speed is used for each aircraft on each route. Although this may mean less than optimal block time, LRC enables the aircraft to achieve the optimum fuel burn rate per nautical mile. A total taxi time of 30 minutes has been assumed, with this added to the actual fuel burn figures for the flight to give total fuel burn.

The shortest route analysed here is between FRA and JFK, with a great circle distance of 3,350nm, and a tracked distance of 3,501nm. Due to headwinds of 27–29 knots (kts), the ESAD for this route ranges from 3,714nm to 3,728nm. Block times range from 8 hours, 13 minutes (08:13) to 08:32 *(see table, this page)*. Block times vary between aircraft due to differences in climb, cruise and descent speeds.

FRA-ORD is the second route analysed, with a longer great circle distance of 3,774nm. Tracked distance is 3,964nm, with headwinds of 18/19kts contributing to an ESAD of 4,117nm to 4,132nm. This gives block times a range of 09:00 to 09:21 *(see table, this page)*.

Increasing distance still further is FRA–LAX. Great circle distance is 5,045nm, with a tracked distance of 5,279nm. Headwinds of 16/17kts increase the ESAD to 5,463–5,479nm. Block times are about 12 hours, ranging from 11:49 to 12:18 *(see table, this page)*.

The longest route examined here is between SIN and LHR. Great circle distance is just short of 6,000nm at 5,951nm. Tracked distance is 6,037nm, with a small headwind of 8-9kts increasing the ESAD to between 6,140nm and 6,153nm. The shortest block time for this route is 13:06, with the longest being 13:46 *(see table, this page)*.

Fuel burn performance

Total fuel burn (block fuel), as well as fuel burn per seat-mile are shown for each aircraft and engine type, for each route *(see table, this page)*. Block fuel used is related both to aircraft weights and route distance, with block fuel increasing for each aircraft type when route distance increases.

To make a fair comparison between aircraft and engine types, therefore, the fuel burn per seat-mile can be used.

The twin-engined A330 and 777 aircraft, powered by Trent 700 and 800 models respectively, show slightly lower fuel burn in most cases than their four-engined counterparts, the A340 and A380, powered by Trent 500 and 900 respectively.

The A330-300 was the best performer on the FRA–JFK route, burning 0.0176USG per seat-mile, compared with 0.0189USG per seat-mile on the A330-200 *(see table, this page)*. This is despite the A330-300 burning about 600USG more in total block fuel. The difference in seat-mile fuel burn is because the A330-300 is carrying 26 more passengers than the A330-200.

The two 777-200 models analysed had the second and third lowest fuel burn per seat-mile respectively in this analysis, and had similar fuel burn figures. The Trent-884-powered model burned 0.0180USG per seat-mile, while the Trent-892-powered model burned

The Trent 900 has a lower sfc than the earlier-generation Trent 700 and 800. Despite this, the A380 has a higher fuel burn per seat-mile than the smaller, twin-engined A330-200/-300 and 777-200ER.

0.0182USG per seat-mile *(see table, page 14)*. This higher fuel burn represents the higher gross weight variant of the 777-200 that the Trent 892 is powering.

The A380 was the best performing quad jet on the FRA–JFK route, burning 0.0196 USG per seat-mile, compared to 0.0205 USG per seat-mile for the A340-600 and 0.0240 USG per seat-mile for the A340-500 *(see table, page 14)*. These aircraft burn slightly more fuel than their twin-engined counterparts due to the extra weight of carrying four engines across similar numbers of seats. The A380 makes up for this through larger seat numbers.

A similar pattern can be seen on the FRA–ORD route, where fuel burn per seat-mile across the aircraft types and engine variants remained consistent.

Again the twin-engined A330s and 777s had slightly lower fuel burn per seat-mile than the quads.

The lower weight 777 had the lowest fuel burn per seat-mile of 0.0165USG, with the A330-300 burning slightly more per seat-mile at 0.0173USG *(see table, page 14)*. The higher weight 777 burns 0.0183USG per seat-mile, while the A330-200 burns 0.0191USG per seat-mile.

The four-engined A340 and A380 showed similar fuel burn rates on FRA–ORD as on FRA–JFK. The A380 burned 0.0197USG per seat-mile, compared with 0.0207USG per seat-mile for the A340-600 and 0.0242USG per seat-mile for the A340-500 *(see table, page 14)*.

The twin-engined aircraft have a 17.25% lower burn per seat-mile than the quads.

When route length further increases, however, on the FRA–LAX route, the lower gross weight 777-200ER (with Trent 884) and A330-200/-300 get closer to the edge of their payload-range envelopes.

This means that they must suffer payload restrictions in terms of passenger numbers to complete the route non-stop.

The A330-300 suffered the largest restriction on this route, being able to carry only 190 passengers out of a possible 257. This increases fuel burn per seat-mile for the A330-300 to 0.0216USG per seat-mile, which is comparable to the four-engined aircraft on the route, such as the A340-600, which also burns 0.0216USG per seat-mile *(see table, page 14)*, yet carried a full complement of 300 passengers. Airlines are unlikely to actually use the A330-300 on a route of this length.

The lower gross weight 777-200ER (with Trent 884) had its passenger load reduced to 250 (out of a possible 285) on the route, and as a consequence fuel burn per seat-mile increased to 0.0191USG per seat-mile, which is higher than the shorter routes *(see table, page 14)*.

The higher gross weight 777-200ER (with Trent 892 engines) could still carry a full passenger load on this route, and burns 0.0185USG per seat-mile *(see table, page 14)*.

The fuel burn per seat-mile of the four-engined aircraft remained consistent with previous routes.

On the longest route analysed here, SIN–LHR, fuel burn figures are skewed for the twin-engined aircraft, since they are close to the edge of their payload-range envelopes, and therefore suffer further restrictions in the number of passengers they carry. In practical airline operations the twin-engined aircraft would not be used on this route because of its length. The 777-200ER is, however, used on a large number of Europe-Asia Pacific routes.

The route length significantly increases fuel burn per seat-mile on this route. For example, the A330-300 burns 0.240USG per seat-mile, with the A330-200 burning 0.0753USG per seat-mile *(see table, page 14)*.

The lower gross weight 777-200ER also has a higher fuel burn on this route of 0.0923USG per seat-mile *(see table, page 14)*.

The four-engined aircraft, however, operate the route without restrictions and again show consistent fuel burn.

The A380 is the best performer on the SIN–LHR route, burning 0.0194USG per seat-mile on the route *(see table, page 14)*.

The higher gross weight 777-200ER (with Trent 892), with a seat number restriction of 60, shows almost identical fuel burn to the A340-600 on this route, at 0.0213 and 0.0214USG per seat-mile respectively. The A340-500 burns 0.0257USG per seat-mile *(see table, page 14)*, which is consistent with other routes in this analysis.

Overall, however, fuel burn across the RR Trent variants was similar on all routes where passenger numbers were not restricted. The rates of fuel burn per seat-miles between all aircraft and engine types on unrestricted routes from FRA were similar at 29%.

On FRA–JFK, the highest fuel burn per seat-mile was 0.0240 for the A340-500, whereas the lowest was 0.0176 for the A330-300 *(see table, page 14)*. This is a difference of 0.0063 USG for all engine variants analysed.

For FRA–ORD, this difference is 0.0077USG; and for FRA–LAX the difference was 0.0072USG.

The four-engined A340 and A380 are equipped with Trent 500 and 900 engines that have lower specific fuel consumption (sfc) rates than the Trent 700 and 800 engines powering the older-generation A330s and 777s. The lower sfc rates of the Trent 500 and 900 are offset, however, by the four-engined design of the aircraft they power. The Trent 500 and 900 have at least kept the fuel burn performance of the A340 and A380 at a competitive level. AC