The steady rise of fuel prices over the past 10 years has caused a resurgence of turboprop orders. The fuel burn performance and unit fuel costs per ASM of currently available turboprops are compared with equal-sized RJs on routes between 170nm & 650nm at three different fuel prices.

The fuel burn performance & costs of turboprops versus RJs

With the price of crude oil consistently exceeding $100 per barrel, the operating economics of turboprops can be increasingly attractive for regional airlines. They are a more economic option than regional jets (RJs) on short sectors. The higher the fuel price, the longer the average route length over which turboprops maintain a total cost per available seat-mile (ASM) advantage. An analysis is made here of the difference in operating performance and fuel burn characteristics of some of the most popular turboprops and RJs in service, and their relative fuel costs per ASM on a range of typical regional route lengths. These differences are examined at three fuel prices of $1.50, $2.25 and $3.30 per US gallon (USG). The fuel burn advantage of turboprops over jets is also examined.

Regional aircraft fleet

The analysis will focus on turboprops with a capacity of 40 seats or more. These are the most likely types to be considered as alternatives to RJs, with smaller turboprops no longer being manufactured. There are more than 1,600 active passenger turboprops in this size category. The largest markets for these aircraft are the Asia Pacific and Europe. The most common turboprops in this size category are the ATR72, Q400, ATR42 and Dash 8-300.

About 95% of the global RJ fleet has a capacity in excess of 40 seats. This represents more than 3,300 aircraft. In the late 1990s, 50-seat RJs became increasingly popular, particularly in North America where they replaced smaller turboprops.

As fuel prices have increased, however, 50-seat RJs have become increasingly less economically competitive against larger RJs and new generation turboprops. 50-seat RJs still represent a large segment of the active RJ fleet, but they are being increasingly supplanted by larger aircraft. The most numerous 50-seat RJs in operation include the CRJ-100/-200, ERJ-145, E-190 and the CRJ-700. North America is by far the biggest market for RJs.

Regional aircraft economics

"Orders for turboprops are correlated to fuel prices," says Bertrand Pabon, market strategy manager at turboprop manufacturer ATR. When fuel prices rise, orders for turboprops rise as well. In 2012 ATR delivered 64 aircraft, including 60 ATR72s and four ATR42s. ATR expects to deliver about 80 aircraft.

"As airlines have worked to realise savings in other areas, the cost of fuel as a percentage of total costs per ASM has increased," says Pabon. "Even if the price per barrel of oil goes down, airlines have now become more aware and sensitive to aircraft fuel burn performance. No executive would bet on a low fuel price scenario in long-term fleet planning. Environmental constraints are also a consideration." These include carbon-trading schemes. If turboprops burn less fuel than RJs, turboprops also produce fewer carbon emissions, and so may realise savings in this regard.

"When the price of oil rose to $100 a barrel, turboprops found a new lease of life after a period of small sales volumes," says Richard Dussault, vice president of marketing at Pratt & Whitney Canada. "Airlines have since realised the economic arguments for operating turboprops on short sectors, where they can be 25-40% more fuel efficient than RJs.

"Turboprop and turbofan engines share the same basic components: compressors, a combustor, a first set of turbines which extracts energy to drive the compressors, and a second set that drives either a propeller or an intake fan," explains Dussault. The compressors, combustors and turbines are all within a core engine. Turboprops and turbofans both bypass most of the accelerated air mass around the core engine with a propeller or an intake fan. Bypassed air therefore has a slow exit speed, while air accelerated through the core engine has a high exit speed. Turbofans channel the bypassed air through a bypass duct.

The propulsive efficiency of a turboprop engine with its propeller, or a turbofan engine with a fan and bypass duct, determines an aircraft's fuel burn characteristics. The propulsive efficiency is determined by the overall exit speed of the accelerated air mass compared to the aircraft's forward speed. The lower the overall exit speed, the higher the

AIRCRAFT CONFIGURATIONS

Aircraft	ATR42-600	ATR72-600	Q300	Q400	ERJ-145LR	E-175LR	CRJ-200LR	CRJ-701ER
Engine	PW127M	PW127M	PW123E	PW150A	AE3007A1-2	CF34-8E5A1	CF34-3B1	CF34-8C5B1
MTOW (lbs)	41,005	50,705	43,000	65,200	48,501	85,517	53,000	75,000
MLW (lbs)	40,344	49,272	42,000	62,000	42,549	74,957	47,000	67,000
MZFW (lbs)	36,817	46,296	39,500	58,000	39,462	69,887	44,000	62,300
OEW (lbs)*	25,353	29,762	26,683	39,284	26,706	47,774	31,132	44,245
Fuel Capacity (USG)	1,481	1,645	847	1,750	1,690	3,072	2,135	2,903

Notes: OEWs may vary

propulsive efficiency and the lower the fuel burn.

"Given the same amount of propulsion or thrust, propulsive efficiency is therefore higher when a larger mass of air is accelerated by a small amount to a low exit speed, and is lower when a smaller volume or mass of air is accelerated to a higher exit speed," explains Gianfranco Barone, product and business development director at ATR.

Increasing massflow and reducing exit speed are achieved by increasing propeller or intake fan diameter. Turboprops have high bypass ratios, and so high propulsive efficiency, because of their wider propellers and smaller core engines. "The propulsive efficiency of turboprop engines is about 20% higher than that of jet engines," explains Mario Formica, vice president of marketing and airline studies at ATR. "This translates into as much as 40% lower fuel burn compared to jets on a 200nm route, 35% lower on a 300nm route, and 32% lower on a 400nm route."

The higher propulsive efficiency of turboprops means they will have lower fuel burn than jet engines, but this only occurs when forward speeds are 370-400 knots (kts). "At these speeds you start to experience transonic effects on the tips of the propeller blades, with a consequent loss of lift and increase in drag," explains Barone. "Beyond speeds of 400kts jet propulsion is generally more efficient."

"ATR turboprops are optimised for short-range missions and cruise speeds of 300kts," adds Barone. "It is possible to design turboprops to fly faster, but if you want higher speed you need to increase the number of propeller blades, the sweep of the blade tips, the blade dimensions and, of course, increase the engine power. This increases weight and complexity, which leads to higher operating costs. To maintain simplicity, lower weights, acceptable noise levels and lower engine-related maintenance costs, it is better to accept lower speeds."

"Since turboprops are optimised for short routes they have lower speed and altitude requirements than RJs," says Pabon. "This means they need less engine power, which results in lower engine weight and complexity. They also have a lighter airframe." The lower weights contribute to reducing fuel burn, but also landing and navigation charges which are based on the aircraft's maximum take-off weight (MTOW). Maintenance costs will also be lower for less complex turboprop engines. Turboprops therefore have lower cash operating costs than RJs.

"Turboprops are designed for short sectors, so their maintenance costs are generally hour-based, rather than cycle-driven like RJs," says Philippe Poutissou, vice president of marketing, at Bombardier Commercial Aircraft. "This would give turboprops a maintenance cost advantage on short sectors."

Typically turboprops are optimised for sector lengths up to 350nm. "Our main market is routes below 300nm," says Pabon. "Turboprops can compete with RJs up to 350-400nm, but beyond this the savings in cash operating costs that turboprops offer may not always offset the jets' advantage in flight time and seat-mile productivity."

Bombardier believes the Q400's faster speed makes it competitive over longer route lengths than other turboprops because it has higher ASM productivity. "Whereas 350nm is about the limit for the Q300 and ATR aircraft, the Q400 can compete with RJs up to 500nm," claims Poutissou. "With its faster speed, the Q400's block time remains within 15 minutes of an RJ's at this mission length."

When sector lengths go beyond the optimum range of turboprops, the RJ's speed and ASM-generating advantage begin to outweigh the disadvantage of their higher fuel burn characteristics.

Turboprops are limited to lower speeds to maximise their cash operating cost efficiencies. "Turboprops begin to surrender their advantage in ASM productivity to RJs once the block time difference between them exceeds more than 15 minutes," says Poutissou. With this level of time saving, over the course of a day an RJ may be able to operate more sectors than a turboprop, and so generate more ASMs. This would allow an RJ operator to spread its fixed costs of lease rentals or financing charges and other costs over more flights and ASMs.

The extent to which a carrier might benefit from this depends on its business model. Being able to fit extra flights into a daily schedule might be more useful for a point-to-point, rather than a hub-and-spoke operation. This is because carriers with hub-and-spoke networks operate their flights in waves or banks. It is possible that extra flights might not fit into the schedule of connecting flights.

Fuel-burn analysis

The fuel-burn performance of four turboprops and four RJs operating on five typical European regional routes is analysed. Where possible, seat numbers are based on typical single-class examples of European operators of each type.

Aircraft analysed

The turboprops analysed are the ATR 42-600, ATR72-600, Dash 8-315 (Q300) and the Q400.

Both aircraft in the new ATR-600 series are powered by PW127M engines *(see table, this page)*. The ATR42-600 has an MTOW of 41,005lbs and a fuel capacity of 1,481USG. Its maximum single-class capacity is 50 seats.

In contrast, the ATR72-600 has an MTOW of 50,705lbs and a fuel capacity of 1,645USG. Typical capacity in a single-class cabin is 72 seats.

The Q300 is similar in size to the ATR42-600, with a typical configuration of up to 50 seats. This aircraft is powered by PW123E engines, and has an MTOW of 43,000lbs. The fuel capacity of the Q300 is 847USG.

The Q400 is the largest turboprop to be analysed with a typical single-class capacity of 78 seats. It has PW150A engines and an MTOW of 65,200lbs. The Q400 has a fuel capacity of 1,750USG.

The RJ aircraft analysed are the ERJ-145LR, the E-175LR, the CRJ-200LR and the CRJ-701ER.

The ERJ-145LR and CRJ-200ER both have a 50-seat layout. The CRJ-200LR is a heavier aircraft. It has an

The ATR72-600 has the lowest fuel cost per ASM of all eight aircraft analysed here, including another three turboprops and four RJs. Moreover, the ATR72-600 has lower fuel burns than the 22-seat smaller CRJ-200LR and ERJ-145LR.

MTOW of 53,000lbs compared to the Embraer's 48,501lbs. The CRJ-200ER has a fuel capacity of 2,135USG, compared to the ERJ-145LR's 1,690USG. The CRJ-200LR has CF34-3B1 engines, while the ERJ-145LR has AE3007A1-2 powerplants.

The CRJ-701ER typically seats 72. It is powered by CF34-8C5B1 engines, and has a MTOW of 75,000lbs. Its fuel capacity is 2,903USG, and it has the fastest cruise speeds in this analysis.

The largest RJ analysed is the E-175LR with a typical capacity of 82 seats. It has CF34-8E5A1 engines and a fuel capacity of 3,072 USG. The MTOW is 85,517USG.

Assumptions

The main assumptions used for the creation of these flight plans include international flight rules, average temperatures for the month of June, and 85% reliability winds. There were also standard assumptions for fuel reserves, diversion fuel and contingency fuel.

Long-range cruise speed (LRC) was used, as this allows the aircraft to achieve the most efficient fuel-burn rate. Optimum routes and flight levels based on the shortest flight time were used. All airway rules and restrictions were within compliance.

A taxi time of 20 minutes per sector has been assumed. Block time is then equal to the flight time plus 20 minutes. The block fuel analysed is the fuel burnt during flight plus the taxi fuel burn.

Routes analysed

A selection of potential regional routes operated from Paris Orly (ORY) were chosen for the analysis. The selected destinations were Brussels (BRU), Lyon (LYS), Frankfurt (FRA), Toulouse (TLS) and Rome-Fiumicino (FCO). Four of the five routes have tracked distances within turboprops' 350nm principal operating envelope, while ORY-FCO has a tracked distance of more than 600nm. This route mix should demonstrate the differences in fuel burn performance, both on an absolute and on a burn per ASM basis, between turboprops and RJs on short routes. It should also highlight the advantages of RJs on longer sectors.

The sector lengths are given in tracked distance and equivalent still air distance (ESAD). The tracked distance is that flown, based on air traffic control (ATC) and airway restrictions. These include following airways and departure and arrival routeings. The ESAD also takes into account the effect of en-route winds, and so indicates the effective distance flown. When there is a headwind the ESAD is longer than the tracked distance. When there is a tailwind it is shorter. The ESAD has been used to calculate ASMs in this analysis.

The tracked distance for ORY-BRU is 168nm *(see table, page 19)*. Variable tailwinds of 3-7 kts contributed to the ESAD ranging from 163nm for the Q300 to 166nm for the Q400, E-175, CRJ-701 and ERJ-145.

The tracked distance on ORY-LYS is 221nm. There were tail winds of 7-11 kts, and ESAD ranged from 210nm for the Q300 to 214nm for the ATR72-600, E-175LR, CRJ-701ER and CRJ-200LR.

The tracked distance for ORY-FRA is 289nm. Tail winds varied from 11-14 kts. The ESAD ranged from 275nm for the Q300 and Q400, to 279nm for the E-175LR, ERJ-145LR, CRJ-200LR and CRJ-701ER *(see table, page 19)*.

ORY-TLS has a tracked distance of 311nm. Some aircraft experienced a minimal headwind on this sector. The ESAD flown ranged from 311nm for the ATR72-600, ATR42-600 and Q400 to 313nm for the Q300 and E-175LR *(see table, page 19)*.

The longest sector analysed is ORY-FCO with a tracked distance of 652nm. Tailwinds of 16-30 kts were experienced. The ESAD flown ranged from 597nm for the Q300 to 614nm for the ATR42-600.

Performance at $3.30/USG

Block time, total fuel burn (block fuel), fuel burn per ASM and fuel cost per ASM are shown for each aircraft and each route *(see table, page 19)*. When comparing the operating economics of these aircraft, the most accurate judgements can be drawn from the fuel cost per ASM and block times.

On all of the five routes, the four turboprops have a lower fuel burn and fuel cost per ASM than the RJs *(see table, page 19)*. The ATR72-600 has the lowest fuel cost per ASM on all routes. Although the Q400 uses more block fuel than the 50-seat RJs in most scenarios, the Q400's larger seat capacity means it has a lower fuel cost per seat. Its cruise speed is also close to the RJs' on the shorter routes.

The RJs have the fastest block times on all the five routes. The 70-/80-seat E-175LR and CRJ-701ER, and the CRJ-200LR have the fastest block times of all *(see table, page 19)*.

A more effective analysis can be performed by splitting the aircraft into two groups according to size. This will allow each aircraft to be compared with some of its closest competitors. The 50-seat category considers the performance of the Q300, ATR42-600, CRJ-200LR and ERJ-145LR. The 70-/80-seat looks at the performance of the ATR72-600, Q400, E-175LR and CRJ-701ER.

50-seat aircraft

Not surprisingly, the two turboprops use less block fuel than the two RJs on all of the routes in this size category. The Q300 consistently burns the least fuel, and so has the lowest fuel cost per ASM. The ATR42-600 has the next lowest fuel cost per ASM, followed by the CRJ-200LR. The ERJ-145LR generally has the highest fuel burn and fuel cost per ASM, with the exception of the ORY-TLS route where it is equal with the CRJ-200LR.

Fuel costs per ASM

The difference in fuel costs per ASM between the turboprops and RJs is greatest on the shortest sectors. This is expected, since a larger proportion of the flight is used by the RJs for the climb and descent phases. A larger portion of the flight is in the cruise for the turboprops. Based on a current fuel price of $3.30 per USG, the Q300's cost per ASM on ORY-BRU is 6.70 cents *(see table, page 19)*. This is 2.25 cents lower than the CRJ-200LR, and 2.49 cents less than the ERJ-145LR. This is equal to the Q300's having a lower fuel cost per ASM that is 25% lower than the CRJ-200LR, and 27% lower than the ERJ-145LR.

On the same city-pair, the ATR42-600 has a fuel cost per ASM 1.28 cents less than the CRJ-200LR, and 1.52 cents less than the ERJ-145LR. The ATR42's fuel costs are thus 14% lower than the CRJ-200, and 16% lower than the ERJ-145.

As route length increases, the difference in fuel cost per ASM between turboprops and RJs falls, because a larger portion of the flight is in the cruise phase, where the RJ has better fuel burn efficiency. On the longer ORY-FCO sector, the Q300's fuel cost per ASM is 5.04 cents *(see table, page 19)*. This is 1.29 cents lower than the CRJ200-LR, and 1.43 cents less than the ERJ-145LR. These differences give the Q300 a 20% fuel cost per ASM advantage over the CRJ-200LR, and a 22% advantage over the ERJ-145LR.

The ATR42-600 has fuel costs that are 0.54 cents per ASM lower than the CRJ-200LR, and 0.68 cents lower than the ERJ-145LR on ORY-FCO. This gives the ATR42-600 an 8% advantage per ASM over the CRJ-200LR, and 10% over the ERJ-145LR.

Flight & block times

Fuel costs should not be considered in isolation. Block time is also important. The cruise speed for each aircraft at cruising altitude is shown *(see table, page 19)*. The RJs demonstrate the fastest block times across all five routes. The CRJ-200LR has the shortest block times of all, while the Q300 has the longest.

The difference in block times between the turboprops and RJs becomes more pronounced with increasing sector length. This is expected, with a larger proportion of the flight flown at cruise speed. On the two shortest sectors, ORY-BRU and ORY-LYS, the Q300 demonstrates block times within 14-16 minutes of the ERJ145LR and 16-18 minutes of the CRJ-200LR *(see table, page 19)*. The difference becomes more pronounced on the longer ORY-FRA route, where the ERJ-145LR and CRJ200LR operate their sectors 22 and 25 minutes quicker than the Q300. By the time the sector length increases to more than 600nm on ORY-FCO, the block time difference between the Q300 and RJs exceeds one hour *(see table, page 19)*.

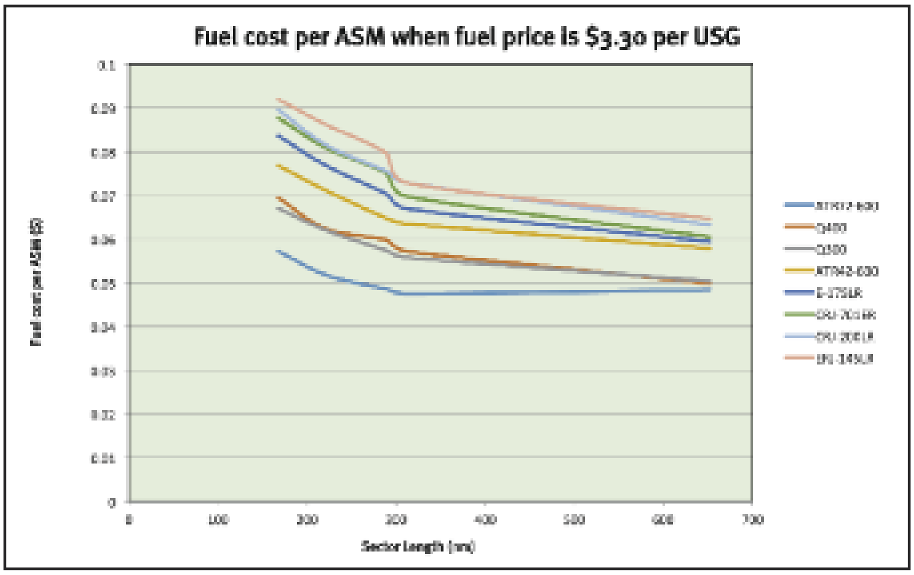
The ATR42-600 operates at a faster speed than the Q300. Its block times are within 15 minutes of the CRJ200LR up to and including the ORY-FRA sector. It is only when the city-pair exceeds 300nm in tracked distance that the block time difference between the ATR42-600 and the CRJ-200 exceeds 20 minutes. On the longest city-pair, ORY-FCO, the ATR42-600 takes 40 minutes longer than the ERJ-145LR, and 43 minutes longer than the CRJ200-LR *(see table, page 19)*.

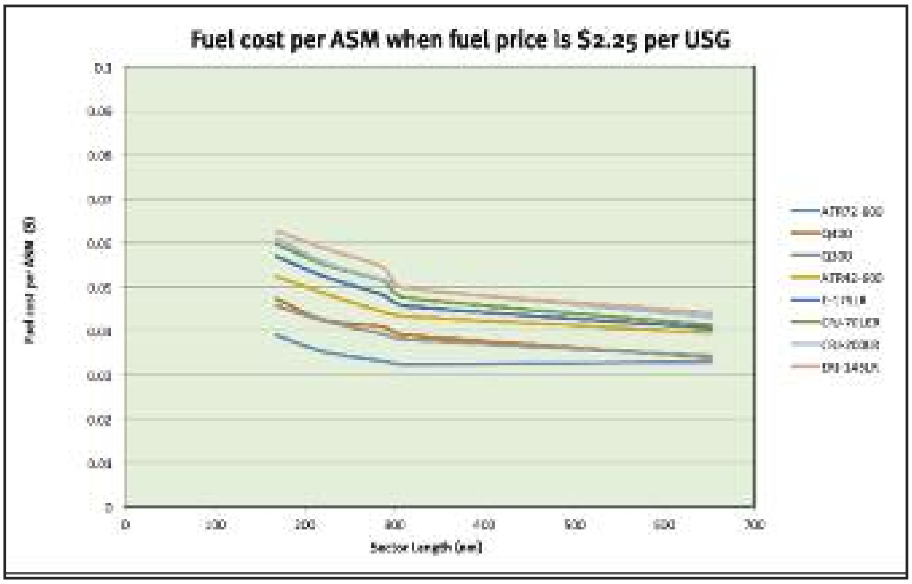
The Q300 and ATR42-600 have the lowest fuel burn across all five sectors, with lower fuel costs per ASM than the CRJ-200LR and ERJ-145LR. When block time is taken into account, the Q300 and ATR42-600 maintain their economic advantage on ORY-BRU and ORY-LYS, with block times within 15 minutes of the RJs.

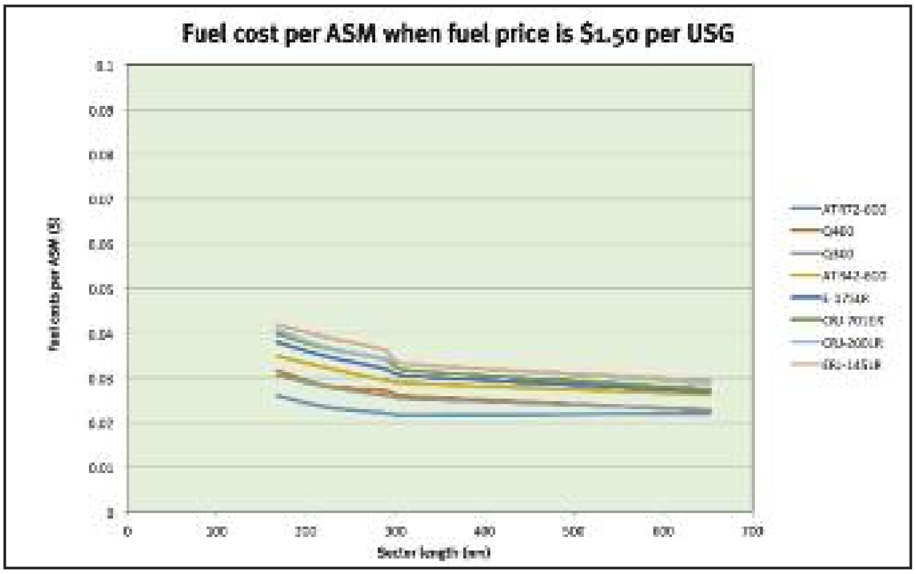
As route length increases and the block time difference between turboprops and jets grows, however, the economic argument for operating RJs becomes

FUEL BURN COMPARISON OF REGIONAL AIRCRAFT AT FUEL PRICE OF $3.30 PER USG

Route	Aircraft type	Available payload (lbs)	Passenger payload (seats)	Tracked distance (nm)	ESAD (nm)	Cruise speed (knots)	Block time (hr:min)	Block fuel (USG)	Fuel burn USG per seat-mile	Fuel cost Cents per seat-mile
ORY-BRU	50-seat									
	Q300	12,817	50	168	163	242	01:06	166	0.0203	6.70
	ATR42-600	11,464	50	168	164	295	00:59	191	0.0233	7.68
	CRJ-200LR	12,868	50	168	165	341	00:50	224	0.0271	8.96
	ERJ-145LR	12,756	50	168	166	325	00:52	231	0.0279	9.19
	70/80-seat									
	ATR72-600	16,534	72	168	165	245	01:02	206	0.0173	5.72
	Q400	18,716	78	168	166	287	00:56	272	0.0210	6.94
	E-175LR	22,113	82	168	166	358	00:50	345	0.0253	8.36
	CRJ-701ER	18,055	72	168	166	362	00:50	317	0.0266	8.77
ORY-LYS	50-seat									
	Q300	12,817	50	221	210	237	01:18	197	0.0188	6.20
	ATR42-600	11,464	50	221	212	294	01:10	229	0.0216	7.11
	CRJ-200LR	12,868	50	221	214	330	01:00	264	0.0247	8.15
	ERJ-145LR	12,756	50	221	213	320	01:02	278	0.0261	8.62
	70/80-seat									
	ATR72-600	16,534	72	221	214	229	01:17	242	0.0157	5.18
	Q400	18,716	78	221	213	286	01:07	314	0.0189	6.23
	E-175LR	22,113	82	221	214	339	01:00	409	0.0233	7.68
	CRJ-701ER	18,055	72	221	214	341	01:00	378	0.0245	8.09
ORY-FRA	50-seat									
	Q300	12,817	50	289	275	244	01:34	239	0.0174	5.74
	ATR42-600	11,464	50	289	277	291	01:24	272	0.0196	6.48
	CRJ-200LR	12,868	50	289	279	348	01:09	319	0.0229	7.55
	ERJ-145LR	12,756	50	289	279	335	01:12	337	0.0241	7.96
	70/80-seat									
	ATR72-600	13,963	70	289	276	243	01:29	284	0.0147	4.85
	Q400	18,716	78	289	275	296	01:18	389	0.0181	5.98
	E-175LR	22,113	82	289	279	358	01:09	488	0.0213	7.03
	CRJ-701ER	18,055	72	289	279	368	01:08	457	0.0227	7.50
ORY-TLS	50-seat									
	Q300	12,817	50	311	313	244	01:43	265	0.0169	5.58
	ATR42-600	11,464	50	311	311	291	01:31	299	0.0192	6.35
	ERJ-145LR	12,756	50	311	312	383	01:12	345	0.0221	7.29
	CRJ-200LR	12,868	50	311	312	407	01:09	345	0.0221	7.29
	70/80-seat									
	ATR72-600	13,819	69	311	311	243	01:37	309	0.0144	4.75
	Q400	18,716	78	311	311	296	01:25	421	0.0173	5.72
	E-175LR	22,113	82	311	313	422	01:09	521	0.0203	6.70
	CRJ-701ER	18,055	72	311	312	441	01:08	475	0.0221	6.98
ORY-FCO	50-seat									
	Q300	11,622	50	652	597	244	02:56	456	0.0153	5.04
	ATR42-600	10,893	50	652	614	293	02:34	538	0.0175	5.79
	CRJ-200LR	12,868	50	652	605	432	01:51	580	0.0192	6.32
	ERJ-145LR	12,756	50	652	611	430	01:54	598	0.0196	6.46
	70/80-seat									
	ATR72-600	11,753	59	652	611	243	02:52	529	0.0147	4.84
	Q400	17,288	78	652	611	301	02:29	719	0.0151	4.98
	E-175LR	22,113	82	652	608	422	01:53	897	0.0180	5.94
	CRJ-701ER	18,055	72	652	612	457	01:49	807	0.0183	6.05







stronger. This is because the RJ's higher ASM productivity is due to being able to complete more flights per day, resulting in overall lower costs per ASM.

On ORY-FRA, the ATR42-600's block time is close to the RJ's, but the Q300 is up to 25 minutes slower. On the two routes that exceed 300nm in tracked distance, the block time difference between the turboprops and RJs reaches proportions that, depending on the route network, might allow an RJ operator to fit more sectors into its daily schedule.

70-/80-seat aircraft

The ATR72-600 and Q400 burn less fuel than the CRJ-701ER and E-175LR on each of the five routes, giving turboprops lower fuel costs per ASM.

The ATR72-600 has the lowest fuel costs per ASM across all of the city-pairs in this size category, despite some small payload restrictions limiting the turboprop to a maximum of 70 passengers on ORY-FRA, 69 on ORY-TLS, and 59 on ORY-FCO. These small payload limitations are because the ATR72-600 can only reach the lowest cruising altitude of 21,000 feet permitted by Eurocontrol by the time it has reached particular waypoints on the route if its take-off weight is slightly restricted.

Permitted passenger numbers are based on the available payload in the simulated flight plans, and the International Civil Aviation Organisation's (ICAO's) recommended average passenger weight plus baggage of 200lbs (90kg).

Fuel burns & costs

As with the 50-seat aircraft, the turboprops have the advantage in fuel costs on the shortest sectors, but there is a trend for this to decrease as sector lengths increase. Based on a current fuel price of $3.30 per USG, the ATR-72-600 has a fuel cost of 5.72 cents per ASM on ORY-BRU. This is 2.64 cents less than the E-175 and 3.04 cents less than the CRJ-701ER. The ATR72-600 has a 32% lower cost per ASM than the E-175LR, and 35% lower than the CRJ-701ER.

On the same city-pair, the Q400 has a fuel cost per ASM that is 1.42 cents lower than the E-175LR, and 1.83 cents less than the CRJ-700ER. These differences are equal to the Q400 having 17% lower fuel costs per ASM than the E-175LR, and 21% lower than the CRJ-701ER.

When the route length exceeds 600nm on ORY-FCO, the difference in fuel costs per ASM between the types is reduced. The ATR72-600 now costs just 1.10 cents less in fuel per ASM than the E-175LR, and 1.21 cents less than the CRJ-701ER *(see table, page 19)*. The ATR's small payload restriction and the impact of this on ASM contributes to this reduced cost difference. This is equal to the ATR72-600 having 19% lower fuel costs than the E-175LR, and 20% lower fuel costs than the CRJ-701ER.

Q400 fuel costs are 0.96 cents per ASM cheaper than the E-175 on ORY-FCO. The Q400 also costs 1.06 cents less than the CRJ-701ER. Expressed in percentage terms, the Q400 has a 16% lower fuel cost per ASM than the E-175LR, and 18% lower than the CRJ-701ER on this city-pair.

Flight & block times

The RJs fly the quickest block times in the 70-/80-seat category. The cruise speed

The E-175 has almost the same flight & block times as the CRJ-701ER, but the E-175 enjoys having the lowest fuel burn per ASM of all four RJs.

used at the cruise altitude portion of the flight of each aircraft is shown *(see table, page 19)*. The CRJ-701ER has the shortest block times on ORY-FRA, ORY-TLS and ORY-FCO. Along with the E-175LR, the CRJ-701ER shares the fastest block times on ORY-BRU and ORY-LYS.

As in the 50-seat segment, the difference in block times between the RJs and turboprops is further exaggerated as route lengths increase. The ATR72-600 has the longest block times of the four aircraft in this category. It remains close to the RJs with block times within 12 and 17 minutes of the jets on ORY-BRU and ORY-LYS *(see table, page 19)*. The gap widens to about 20 minutes on the longer ORY-FRA route. The ATR72-600 is less competitive on the two sectors longer than 300nm. The ATR72-600 takes nearly 30 minutes more than the RJs on ORY-TLS, and about an hour longer on ORY-FCO.

The Q400 has a higher LRC speed than the ATR72-600, and so the Q400 can operate ORY-BRU, ORY-LYS and ORY-FRA within 10 minutes' block time of the RJs *(see table, page 19)*. Even on ORY-TLS, the Q400 can stay within 20 minutes of the E-175LR and CRJ-701ER. It is only on ORY-FCO that the Q400 loses its competitive edge with the RJs, with the Q400 taking about 40 minutes longer to fly the route.

"Although the Q400 is capable of a high speed cruise of 360kts, it can also operate efficiently at lower speeds, closer to those of competing turboprops," claims Poutissou. "This will result in lower fuel burn rates."

If fuel costs were the only consideration, the turboprops, and in particular the ATR72-600, would be the best option to operate all five routes in the 70-/80-seat size category. When block times are also considered, the turboprops maintain their biggest economic advantage on the shortest sectors: ORY-BRU and ORY-LYS.

The Q400's faster LRC speed means its block times are more competitive with those of the two RJs than the ATR72-600s. This allows it to stay in contention with the jets on longer routes than the ATR.

The E-175LR's and CRJ-701ER's faster speed, and their resulting ability to increase ASM productivity, become a factor on the two city-pairs that are more than 300nm in length when compared with the ATR72-600, and on ORY-FCO when considering the Q400.

Performance at low fuel prices

Aircraft Commerce also examined how higher fuel prices have impacted comparative turboprop and RJ fuel costs. The performance of the four turboprops and four RJs was considered at three fuel prices. Fuel costs per ASM were analysed at a current price of $3.30 per USG, and historic levels of $1.50 per USG and $2.25 per USG *(see charts, page 20)*.

On ORY-BRU, the ATR72-600's fuel cost per ASM is 1.38 cents lower than the CRJ-701ER's at a fuel price of $1.50 per USG. When the fuel price is increased to a current level of $3.30 per USG, the turboprop's advantage in cost per ASM rises to 3.04 cents.

On the longer ORY-FCO route, the ATR72-600's fuel cost per ASM is 0.55 cents lower than the CRJ-701ER at a fuel price of $1.50 per USG. If the fuel price is raised to $3.30 per USG the turboprop cost advantage increases to 1.21 cents per ASM.

It has already been established that the turboprops have lower fuel costs per ASM than RJs, and that this difference in cost is reduced as sector lengths increase. When the fuel price rises so does the difference in cost per ASM between turboprops and RJs. High fuel prices mean that fuel will account for a higher portion of total costs per ASM. This explains why there has been a resurgence in demand for turboprops for short-sector regional operations.

Summary

Because they are optimised for short sectors, turboprops do not have the same altitude and speed requirements as RJs. This means they have less complex engines that can result in lower maintenance costs. It also means the overall aircraft weight is lower than that of an equal-sized RJ. This can lead to lower landing and navigation charges and lower fuel burn. The high propulsive efficiency of turboprop engines is an important factor in fuel-burn performance.

This analysis has shown that turboprops are cheaper to operate in terms of fuel costs per seat mile than similar-sized RJs.

In most cases the economic advantages of turboprops are particularly apparent on sector lengths up to approximately 300nm.

The disparity in fuel costs per ASM between turboprops and RJs reduces as route length increases. Turboprops, however, still have an advantage of fuel cost per ASM over the jets. When the price of fuel rises, the difference in cost increases in favour of turboprops.

Turboprops have to sacrifice speed to optimise overall operating cost efficiency. There comes a point where an RJ's faster speed increases its productivity by allowing it to operate extra flights. This makes most turboprops uncompetitive overall on all costs per ASM on route lengths beyond 350-400nm. AC