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**OPERATORS SURVEY**

# Embraer Legacy 650

Jetliner heritage provides 'value for money'



# Embraer Legacy 650

## Jetliner heritage provides 'value for money'

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**E**mbraer Legacy 650 operators concede that there are more luxurious, larger cabin, higher flying, faster cruising and longer range large-cabin business aircraft than the aircraft they fly. But nothing comes close in terms of "value for money."

seating zones, an optional forward crew lav and transatlantic range. With a base price under \$32 million, it can fly eight passengers 3,800 nm, making possible nonstop flights between London and New York, Dubai and London, São Paulo and Miami, or Singapore and Sydney.

typical for a first-generation regional jet.

Operators, though, say that their passengers love the aircraft, especially commercial customers who closely compare cabin comfort to charter cost. The copious 240-cu.-ft. aft baggage compartment accommodates most anything passengers want to bring along, making the aircraft ideal for transporting entertainers on tour. There's another 46 cu. ft. of carry-on luggage volume in the cabin. A typically configured cabin seats up to 13 passengers. For overnight trips, pairs of facing chairs and the aft divan convert into six flat berths for sleeping.

To create the Legacy 650, Embraer modified its EMB-135BJ Legacy 600 by fitting a stronger wing, installing more-robust landing gear and adding 2,430 lb. more fuel in extended forward belly tanks and new twin aft fuselage tanks. The aircraft also has 13% more-powerful Rolls-Royce AE3007A2 engines with an improved fan and better specific fuel economy. The changes add only 136 lb. to aircraft empty weight.

Honeywell Primus Elite avionics replace the Primus 2000 package in the original EMB-135BJ. The kit includes high-resolution flat-panel displays that support electronic charts and XM radio weather graphics, plus an upgraded FMS with WAAS/LPV, FANS 1/A, CPDLC, RNP 0.3 and coupled VNAV capabilities. Dual CMC PilotView EFVBs are available to permit paperless operations, but most operators now use iPads if they need that capability.

Embraer engineers devoted considerable time to reducing cabin sound levels. Operators say the interior is much quieter than the original aircraft, with Embraer paying close attention to eliminating harmonic vibration in cabinets, doors and drawers.

Well aware of the tradeoffs that make the Legacy 650 a bargain to buy and fly, here's what else we learned from operators and about the fleet.



**Honeywell Primus Elite features five, 8-by-7-in. LCD screens. The layout has left- and right-side PFDs and MFDs, along with a central EICAS.**

"You want to fly out of Aspen to Europe on a hot day? Get yourself a three-hole airplane. Need to cruise at Mach 0.82 and climb into the mid-40s? This is not your airplane. Routinely fly between Paris and Dallas? You need another airplane," says Michael Mahan, who flies serial number 1165 managed by Million Air Dallas.

"But, for average users, there is no comparison. Our all-up operating cost, excluding the mortgage, is \$3,400 per hour, including pilots, hotels, meals and rental cars. You can't touch that in any other large-cabin aircraft."

The Legacy 650 is the only business jet priced under \$41 million with three

That's about 500 nm more range than its predecessor Legacy 600 offers.

"Pound for pound, dollar for dollar, it's much less expensive than the competition," says Glyn Anderson, deputy director of flight operations for London Executive Aviation, a U.K. firm that operates three Legacy 650s and five Legacy 600s among its 70 aircraft fleet.

Embraer positions the Legacy 650 as a large-cabin business aircraft because of its payload and range. The 42.4-ft. overall cabin length indeed is greater than any business jet priced under \$50 million. However, the cabin cross-section is strictly super-midsize and its Mach 0.74 long-range cruise speed is

## Operator Profiles

A large number of operators said they upgraded to the Legacy 650 from the Legacy 600 because they were pleased with the performance, reliability and utility of the original aircraft. Passenger acceptance of the original model also was a big factor. Almost everyone said that Embraer has strong commitment to product support and continuous product improvement. They upgraded to the Legacy 650 mainly to get the additional range. The extra fuel transforms it from a transcontinental airplane into a transatlantic jet.

The largest concentrations of the Legacy 650 fleet are in Brazil and China, according to records compiled by Amstat. Neo Taxi Aereo Ltda., bio fuels giant Industrial e Comercial Brasileira Ltda. and Riachuelo department stores, plus financial services company BWSA, mining and heavy construction firm Estrutural, and Colt Aviation, among other Brazilian firms, fly the aircraft. In China, Minsheng Financial Aircraft Leasing and China Eastern Airlines Executive Air control most of the aircraft.

TAG Aviation Asia, Man Sang International based at Kowloon and an unknown operator in Anhui, China, with a Cayman Islands-registered airplane also fly the jets.

Next in fleet size are the U.K. with six aircraft and the U.S. with a half dozen. London Executive Aviation, Hangar 8 at Oxford, TAG Aviation U.K. and Air Charter Scotland fly the aircraft. In the U.S., single aircraft are operated by Delta Private Jets, Million Air Dallas, Swift Aviation, Johnsonville Sausage and UP Management.

Also in Europe, ABS Jets operates two based in Prague, Vienna-based Avcon Jets flies two, one is managed by MJET in Schwechat, Austria, Russian firms fly two and Air Hamburg Aviation operates one.

Four are flown by Empire Aviation and Falcon Aviation Services in the UAE, one is operated by Arab Wings in Jordan and a single ship is based with Samco Aviation in Riyadh, Saudi Arabia.

Most other Legacy 650 aircraft are based in India, Pacific Rim nations, East Asia and Africa.

Firms that fly the aircraft view them

as basic business transportation, with a sizable portion being used in part-time or full-time air charter operations. Operators typically carry four to six passengers, but often they fill up all 13 seats. The most-common cabin configuration is Embraer's standard layout with four club chairs up front, a four-seat conference grouping and credenza in mid-cabin, and an aft private stateroom with a three-place divan and a pair of facing chairs.

A few operators with whom we spoke, such as London Executive Aviation, have aircraft with a second four-chair club section in place of the four-seat conference grouping and credenza in mid-cabin.

The forward crew lav is a \$300,000, 118-lb. option. Operators say that while it eliminates the need for pilots and cabin crew to walk through the cabin to the aft lavatory used by the passengers, it adds weight to an already nose-heavy aircraft. When the forward lav needs to be used, it shares space with the galley. It might be called a hybrid galley/lavatory system.

Anyone not using the lav in the compartment must vacate the galley area and move forward to the optional fold-down





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cabin crew seat in the entryway or move aft into the main cabin. Then, the user of the forward lav must unfold and secure a forward stowable privacy door and close and lock the pocket door between the galley and the main cabin, essentially converting the galley into a full width lavatory compartment.

Operators also say that food and beverage storage aboard the aircraft is limited. The forward crew lav occupies a large section of the left-side galley annex that otherwise could be used for catering and galley supplies. One operator said he worked with Embraer to fit the forward lav with folding racks to store supplies when needed.

The forward crew lav, among other typical options, along with operational stores, spares and supplies, may add 500 to 900 lb. to basic operating weight. Most operators with whom we spoke report basic operating weights of 31,750 to 32,100 lb., well in excess of the 31,217-lb. BOW quoted by Embraer for our May 2015 *Purchase Planning Handbook*. Some of the weight increase is due to inclusion of discretionary passenger comfort and convenience items.

Such a weight hike might impose a significant operating limitation for less-capable aircraft, but it's not a problem for most Legacy 650 operators. The aircraft still can carry five to six passengers with full fuel. Most operators say they can comfortably stretch the aircraft's range to 3,600 nm to 3,700 nm at long-range cruise, assuming favorable weather at the destination airport. Aircraft endurance is up to 9 hr. on such trips. And on long missions, they seldom carry more than six passengers, the maximum number of full flat berths in the cabin.

While the aircraft can fly from London to New York, assuming ISA temperatures, historical winds, an ideal climb/cruise/descent profile and no air traffic control delays or holding, most operators say they're uneasy planning for such transatlantic trips on a routine basis. Long-range cruise speed averages Mach 0.74, so mild increases in headwinds can have a notable impact on ground speed and, thus, cruise range.

As for the aircraft's relatively slow long-range cruise speed, operators say it's not a problem for their passengers. Cabin comfort trumps top performance as a priority for corporate passengers and charter customers.

On shorter missions, such as transcontinental U.S. hops, operators say they fly at Mach 0.78, only 3 kt. less than optimum cruise speed for Airbus 320 series

and Boeing 737 next-gen transports.

The aircraft has plenty of thrust, but wing performance is a limiting factor. The AE3007A2 engines have ample thrust to climb the aircraft into the high 30s, even on warm days, using the standard 270 KIAS/Mach 0.65 flight level change climb schedule. Once you're up there, however, the aircraft may not be able to accelerate to desired cruise speed from the Mach 0.65 climb speed.

Operators say it's much better to climb at 270 KIAS and transition to Mach 0.70, or slightly faster, when operating at heavy weights, for better wing performance. They also say they load as much weight aft as possible, particularly in the baggage bay, to help offset the aircraft's nose-heavy

the end of the flight.

Such cruise speeds and altitudes look lackluster compared to the performance of purpose-built large-cabin business aircraft. But operators counter that they can operate their aircraft for \$3,000 to \$3,400 per hour all up, assuming they fly 400 hr. or more per year.

### Likes and Dislikes

Cabin size frequently tops the list of operator's five favorites. Cabin volume is 1,410 cu. ft., but that includes the forward galley and aft lavatory. Net volume for seated passengers in the three sections is closer to 1,015 cu. ft.

The cabin has a 2-in. dropped aisle to



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**The forward galley seems amply sized for passengers' needs with large work areas, but operators say they still could use more storage space for stores, catering and beverages.**

tendencies. They level off at FL 370 to FL 390 for the first hour of cruise and accelerate to Mach 0.76 for long-range cruise. First hour fuel flow is 3,300 lb.

After 60 to 90 min. in the high 30s, they climb their aircraft to FL 400 to FL 410 and settle into long-range cruise. Second hour fuel flow is 2,200 lb., decreasing to about 2,000 lb. per hour near the end of the flight as they pull back to Mach 0.72 to 0.74 for maximum range performance.

On shorter flights, such as transcontinental U.S. missions, they can climb their aircraft directly to FL 400 to FL 410 and cruise at Mach 0.76 to 0.78 depending upon aircraft weight. On such missions, fuel flows are about 3,300 lb. for the first hour, 2,400 lb. for the second hour and decrease to 2,200 lb./hr. near

increase maximum headroom to 6.0 ft. Outside of the Gulfstream G280, this is the only business aircraft priced above \$25 million that doesn't have a flat floor. Operators don't mind the dropped aisle, but many wish the aircraft had a couple of inches more headroom. The cabin seems airy, though, as it has 22 cabin windows with 28.5 sq. ft. of total area to flood the interior with ambient light.

Operators say the galley layout is much improved over the Legacy 600. It features larger potable water and trash containers, more working surfaces and more-efficient space utilization in the galley annex. That's because Honeywell Ovation cabin management system controls, emergency equipment and the infotainment kit have been repackaged more efficiently. But they say they still could

use more storage space for stores, catering and beverages.

There is uniform enthusiasm for the 240-cu.-ft. Class C aft baggage compartment. Operators say they've seldom, if ever, had to leave passenger baggage on the ramp. Charter operators say their customers get used to bringing large amounts of luggage with them, enough to require supplemental ground transportation to and from the airport.

"The Brazilians are great engineers, but they're still learning about corporate flight operations," says one operator. "The new galley is an improvement, but it still needs work," says Rick Bell, director of operations for Phoenix-based Swift Aviation, which operates s.n. 1167. "But Embraer understands they have to improve constantly because they don't yet have the brand name," says George Galanopoulos, managing director of London Executive Aviation.

Reliability and redundancy received raves. The 28-volt DC electrical system, for instance, has dual 400-amp generators on each engine and a 400-amp starter/generator on the APU. Each wing fuel tank has triple-redundant electric boost pumps. Left and right 3,000-psi hydraulic systems are each powered by an engine-driven pump backed up by an electric-driven pump. Accumulators provide backup power for emergency landing gear extension, wheel braking and parking brake. The ailerons and rudders are hydraulically boosted, but in the event of a total hydraulic system failure, they can be operated by mechanical reversion. The master minimum equipment and configuration deviation lists are comprehensive, designed for air carrier operations. Few single-point failures can cause AOG failures that would adversely affect dispatch rates.

"We have some Embraer 135/145 regional jets with more than 40,000 flight hours and 31,000 cycles," says an airline captain who moonlights as a Legacy 650 pilot. ERJs at work with the airlines fly 3,000 hr. per year or more. "Anything that can go wrong, has gone wrong at the regionals and Embraer has fixed it." Embraer 145-series aircraft, including the Legacy 600 and Legacy 650, now have logged more than 15 million flight hours.

Operators like the anti-ice and rain removal systems. The Legacy 650 is one of the very few aircraft in its class to have anti-ice protection for both the wing and horizontal stabilizer leading edges. Ice detectors are incorporated to make airframe anti-ice system operation completely automatic. Windshield wipers



**The Legacy 650 is the only business jet priced under \$41 million with three seating zones, an optional forward crew lav and transatlantic range.**

sweep away rain, a significant benefit during ground operations.

This is a low workload airplane, operators say. It's designed for high-cycle regional airline operations with short checklists and quick turnarounds. Once you've preflighted the aircraft and you're

**The aft lav has an externally serviced toilet, lighted vanity, power outlet, wet sink and storage cabinets for linen and other service elements.**



strapped into the cockpit, all procedures are contained on a two-page checklist. Pilots say it takes more time for the dual inertial reference units to align than they need to complete pre-taxi checklists.

Operators like the 3,300-lb. increase in maximum landing weight compared to the Legacy 600. The 44,000-lb. maximum landing weight allows them to tanker more fuel. Marcelo "Roma" Romanelli, a long-time former Embraer pilot who now flies s.n. 1175 for UP Management, says he can fly roundtrip from Moline, Illinois, to Carlsbad, California, without taking on fuel during the stopover.

Runway performance is a strong suit, according to operators. While the aircraft needs 5,741 ft. for takeoff at MTOW, assuming ISA/sea-level conditions, it needs less than 3,600 ft. for a 1,000-nm trip. Landing distance, assuming NBAA IFR reserves, is under 2,400 ft. with eight passengers. Some pilots, though, complained that the Legacy 650's VREF landing approach speeds are higher at light weights than they are in the Legacy 600 because the engine's extra thrust increases VMCA minimal control speed-airborne.

Crosswind handling may be challenging on landing, says Anderson. "You have to positively control the aircraft." Others said aileron response is sluggish at slow speed. "Some new pilots look like they're whisking a cake mixture," quips Anderson.

Embraer's product support and parts availability, with some exceptions, earned positive reviews. Operators laud local Embraer tech reps for their proactive



support. “Jeff Tinsley is awesome,” says Michael Mahan, who flies s.n. 1165 managed by Million Air Dallas. But others said that working directly with representatives at Embraer’s São José dos Campos headquarters can be tedious. Parts availability in the U.S. is excellent, operators report. Response from Embraer’s parts depot at Paris Le Bourget, though, may not be as quick. In addition, some warranty claims and parts requests processed through the Embraer Executive Care (EEC) fixed-rate, maintenance-by-the-hour program may require negotiation.

“It’s improving all the time,” says LEA’s Anderson. But, Galanopoulos says, “While EEC was off to a good start, it’s getting pricey. They’re charging back list price for parts. We’re spending as much as \$25,000 per month on EEC for each aircraft.” So he’s exploring other maintenance programs. Galanopoulos, though, credits Embraer for listening to such customer concerns at its Operator Advisory Committee meetings held periodically at its Melbourne, Florida, U.S. headquarters.

Complaints were few, but some patterns emerged. The solid bulkhead partition, forward of the divan in the aft cabin that separates the stateroom from the main cabin, must be removed for takeoff and landing to meet emergency egress requirements. Some operators chased down recurring oxygen system leaks. The function, fit and finish of interior items isn’t up to best industry standards.

Most operators, however, praise Embraer for its commitment to its customers. “It’s a privilege to work with the Embraer people. They’ve fallen all over themselves to meet or exceed our expectations, doing whatever needs to be done to solve problems,” says Million Air’s Mahan.



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**The Legacy 650’s aft Class C baggage compartment is 7.4-ft. long and the 240-cu.-ft. baggage bay has a 3.7-ft.-wide by 3.3-ft.-high roll-up external door below the left engine nacelle.**

## On Balance

The Legacy 650, in its current configuration, offers a virtually unbeatable blend of speed, range and cabin comfort versus acquisition and operating cost, operators say. “It’s a good general aviation aircraft that’s becoming more of a good aircraft,” says LEA’s Anderson. “We love this airplane. Our passengers love this airplane. It has a huge baggage hold. It’s a very good value for the money,” says Galanopoulos. “If there were a King Air of the jet world, this could be it,” says Mahan regarding the utility of the aircraft.

Embraer has succeeded in morphing its 1,300-nm to 1,500-nm range EMB-135 regional jet into a comfortable 3,600-nm to 3,800-nm business jet in large part by mastering the art and science of “parts bin engineering.” Engineers have adapted bits and pieces from several regional jet models to create the Legacy 650. The Brazilians have been very careful about non-recurring engineering cost control and they have passed the resulting savings onto their Legacy 600/650 customers.

Now, the Legacy 650 has reached a plateau in the evolution of the EMB-135 model line. It has the highest thrust, the highest take-off weight and the highest wing loading of any aircraft in this model series. With a wing loading of more than 97 lb. per square foot, high-altitude cruise performance is less than optimum. Its 9,020-lb.-thrust Rolls-Royce turbofans help offset its lack of leading edge slats to provide respectable runway performance. But having 13% more thrust than the Legacy 600 also means that VMCA becomes an important factor in determining other V speeds. It thus has an adverse effect on runway performance.

“We’re operating out of the design concept at the top margins,” Galanopoulos says.

Some operators wish Embraer would develop a larger, longer range, faster and higher flying jet as a step-up product. Call it a Legacy 700 or 750. But Roma Romanelli says that São José dos Campos is unlikely to launch a clean-sheet business jet that would compete with high-end models built by Bombardier, Dassault and Gulfstream. The Big Three have too much momentum.

For now, the Legacy 650 has created its own entry-level niche in the long-range, large-cabin business aircraft class. It’s more practical than posh, true to its jetliner family roots. It’s “tough as a boot,” according to operators, and easy to fix if it breaks. It has strong appeal to some CFOs who might wince at the price tag of some other large-cabin aircraft. Operators also say that no manufacturer is more committed to listening to customers than Embraer, more dedicated to continuous product improvement. In the short term, all that bodes well for this versatile, cost-effective performer. **B&CA**



# Embraer Legacy 600

Value, cabin and reliability may outweigh ultimate performance



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**THE LEGACY 600, BUILT FROM 2002 TO 2012, IS ONE OF THE MOST** successful jetliner conversions yet produced for the business aircraft market. It offers a three-zone cabin, a large aft lavatory with windows and a 240 cu. ft., full-time access, aft baggage compartment, by far the largest in its class. There's another 46 cu. ft. of carry-on luggage room in the cabin.

Embraer did all the business jet conversion work in house, adding belly tanks that boost fuel capacity by 6,646 lb. (6,847 lb. at s.n. 625, et seq., or with s.n. 145LEG-28-0010), developing several interior configurations, increasing operating weights and refining exterior features to slash drag. The fully integrated product is type certified as EMB-135BJ. It's not a hodge-podge of third-party STCs.

This is an aircraft that can fly 12 to 14 passengers between the U.S. east and west coasts, assuming average winds. Range with a full-fuel payload of 1,500 lb. is 3,200 nm, assuming spec completion weights. The Legacy 600 is a charter operator's dream machine because it has unsurpassed dispatch reliability, easy maintenance and rock-bottom operating costs.

True to its roots as a work-a-day regional airliner, though, it initially climbs only into the mid-thirties and cruises at Mach 0.74 on long-range missions. Embraer says to plan on 7+30 block times and 14,200 lb. fuel burns for 3,000 nm equivalent still air distance missions. Operators can bank on 400-kt. block speeds for shorter trips and 420-kt. block speeds for long-range missions. Average fuel burn is 2,000 lb./hr. and direct operating cost is \$4,000 per hour, assuming 2+00 average missions and 600 flight hours per year.

On shorter trips, operators can push it up to Mach 0.78, but fuel consumption increases considerably. Redline is a modest Mach 0.80, but VMO is 320 KIAS so you can keep up with jetliner traffic while descending on arrivals.

Interior fit and finish is not the best in class, but Embraer sought to keep purchase price in check so quality trade-offs were necessary. Most aircraft are configured with a forward galley, a forward four-chair club section, a central four-seat conference grouping flanked by a cross-side credenza and an aft section with a convertible sofa sleeper plus two facing chairs. Outside of the Gulfstream G280, this is the only aircraft in the super-midsize class to have a dropped aisle. But, the 42 ft. net interior length and large number of cabin windows give the interior a spacious feel.

Cockpits feature Honeywell Primus 2000 avionics, including dual radio management units, dual Laseref IRSes, dual FMZ2000s and dual digital air data computers. The aircraft is Cat II approach capable. Early models have CRT displays and later ones were upgraded to LCD screens. Embraer's display color conventions and user interfaces quite clearly were designed by seasoned test pilots and not lab engineers. The

flight decks are relatively unsophisticated, but very ergonomic. CMA-1100 PilotView Class 2 EFBs with stand-by battery packs were optional, but most operators just use iPads for e-charts, XM radio weather, aircraft flight manuals and other required documents.

Designed for quick turn-arounds, checklists are short and systems are highly automated. Notably, a reduced takeoff thrust rating decreases engine wear and thus maintenance expense. Full-rated thrust is available if available runway length or climb gradient is a factor.

Legacy 600 has jetliner-like runway performance. Assuming standard day conditions, it needs 3,800 ft. of pavement for a 1,000-nm mission and 5,614 ft. of runway when departing at MTOW. The engines are flat-rated to ISA+22°C, so hot-and-high departures seldom result in reduced weight takeoffs.

Basic maintenance intervals are 500 hr. or 6 months and 900 flight cycles/2,000 flight hour. Heavy maintenance, such as corrosion inspections, are due at 4,000 flight hours or 48 months, 8,000 flight hours or 72 months and 4,000 flight cycles or 96 months. More than half the fleet is enrolled in one of the three levels of Embraer Executive Care, a comprehensive maintenance program that provides predictable operating costs, including coverage for APU, avionics, tires, brakes, batteries, cabin systems and optional equipment. Most aircraft also are enrolled in Rolls-Royce Corporate Care or JSSI AE3007 engine maintenance programs. Notably, while engine maintenance is "on-condition," mean time between scheduled removals for engines is 6,500 hr. Most maintenance can be done on pylon.

The Legacy 600's main competitors are the Bombardier Challenger 850, a converted CRJ200, having a longer and wider cabin but poorer runway performance, plus purpose-built business jets such as the Gulfstream IV, IV-SP and G450, the Bombardier Challenger 601 and the Dassault Falcon 900B. The Legacy 600, though, has unbeatably low direct operating costs, unrivaled dispatch reliability and airline-frugal replacement parts costs. Early 2002 models sell for as little as \$6 million and 2012 models command as much as \$17 million. These aircraft are bargains because resale prices tanked when Embraer introduced the Legacy 650, an aircraft that offers 500 nm more range.

If you're a charter operator in the market for a transcontinental U.S. range aircraft with rock-bottom operating costs that accommodates a dozen-plus passengers and virtually all the baggage they can bring along, the Legacy 600 is a strong contender. **B&CA**



**DOWNLOAD** Operators Survey on the Embraer 135/Legacy 600 from the June 2009 **B&CA** or go to [www.bcadigital.com/legacy600opsreport](http://www.bcadigital.com/legacy600opsreport)