While flight plan calculations are necessary for safety and regulatory compliance, they also provide airlines with an opportunity for cost optimization.
Effective Flight Plans Can Help Airlines Economize

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Every commercial airline flight begins with a flight plan. Over time, small adjustments to each flight plan can add up to substantial savings across a fleet. Optimal overall performance is influenced by many factors, including dynamic route optimization, accurate flight plans, optimal use of redispacht, and dynamic airborne replanning. While all airlines use computerized flight planning systems, investing in a higher-end system — and in the effort to use it to its full capability — has significant impact on both profitability and the environment.

An operational flight plan is required to ensure an airplane meets all of the operational regulations for a specific flight, to give the flight crew information to help them conduct the flight safely, and to coordinate with air traffic control (ATC). Computerized systems for calculating flight plans have been widely used for decades, but not all systems are the same. There are advantages to selecting a more capable system and using all of its analytical and optimization capabilities. Using the flight planning process to reduce fuel not only saves money but also helps the environment: carbon dioxide (CO₂) emissions are directly proportional to fuel burn, with more than 20 pounds of CO₂ emitted per U.S. gallon of fuel burned.

This article provides a brief overview of flight planning and discusses ways that flight planning systems can be used to reduce operational costs and help the environment.

### FLIGHT PLANNING FUNDAMENTALS

A flight plan includes the route the crew will fly and specifies altitudes and speeds. It also provides calculations for how much fuel the airplane will use and the additional fuel it will need to carry to meet various requirements for safety (see fig. 1).

By varying the route (i.e., ground track), altitudes, speeds, and amount of departure fuel, an effective flight plan can reduce fuel costs, time-based costs, overflight costs, and lost revenue from payload that can’t be carried. These variations are subject to airplane performance, weather, allowed route and altitude structure, schedule constraints, and operational constraints.

### OPTIMIZING FLIGHT PLANS

While flight plan calculations are necessary for safety and regulatory compliance, they also provide airlines with an opportunity for cost optimization by enabling them to determine the optimal route, altitudes, speeds, and amount of fuel to load on an airplane. Optimization can be challenging because it involves a number of different elements. An optimized flight plan must not
By varying the parameters in a flight plan, flight planning systems can improve the efficiency of an airline’s operations.

**Computer Flight Plan**

<table>
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<th>Flight Number</th>
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**Figure 1: Minimum information on an operational flight plan**

**ROUTE OPTIMIZATION**

The best route to fly depends on the actual conditions for each flight. These include the forecast upper air winds and temperatures, the amount of payload, and the time-based costs that day. The time-based costs are especially dynamic, driven by the value of the payload and the schedule and operational constraints for the crew and the airplane. Winds can have a significant impact on the optimal route: it can be very far from the great circle “direct” route (see fig. 3). Flight planning systems use wind forecasts from the U.S. National Weather Service and U.K. Meteorological Office, updated every one to six hours, to include the winds in every flight plan calculation.

While nearly all computer flight planning systems can optimize routes, many airlines still use fixed “company routes” most of the time. One reason adoption of dynamic route optimization has been limited is that ATC organizations, flight operations managers, and company policies place restrictions on routing in certain areas. An effective flight planning system contains models of all these restrictions, which are then applied as constraints in the numerical optimization process. This allows the flight plan to be optimized with the dynamic data on winds, temperatures, and costs while still complying with all restrictions.

One recent study by Boeing subsidiary Jeppesen considered the benefit of dynamic route optimization on an airline that used fixed company routes in its computer flight planning system. This airline, which had 60 single-aisle airplanes, used fixed routes developed with historical winds and experience about ATC requirements. The study determined that using routes optimized with the most recent forecast winds, with numerical constraints modeling ATC requirements, would save about 1 million U.S. gallons of fuel per year. This, in turn, would reduce annual CO2 emissions by about 20 million pounds.

**THE IMPORTANCE OF ACCURACY**

Airlines can reduce fuel consumption and costs by improving the accuracy of their flight plans. The flight crew and dispatcher can elect to add fuel they think might be needed to complete the flight as planned. But the heavier the airplane, the more fuel it will burn, so adding extra fuel — which adds weight — burns more fuel, increasing both operating costs and emissions.

Accurate flight plan calculations can minimize the additional fuel the flight crew adds. Accurate calculations are the result of several factors that combine engineering and information management. Some of the relevant factors require integration with other systems and data sources, both within and outside an airline.

For example, the basic airplane performance characteristics come directly from manufacturer data, but must be modified...
by active master minimum equipment list/configuration deviation list data (available in an operator's maintenance tracking system) and by measured deviations from baseline data, available from Boeing Airplane Performance Monitoring software. Up-to-the-minute payload predictions require integration with the reservation system, and time-based cost prediction is most accurate when it is integrated with operational control and crew tracking systems. Integration with convective weather and air traffic delay predictions helps to accurately predict possible airborne delays or deviations, rather than using rough guesses. Because an integrated, properly tuned flight planning system increases the accuracy of calculations used to develop flight plans, flight crews and dispatchers will feel confident reducing the amount of extra fuel they request.

Further study of the airline described in the “route optimization” section found that it carried an average of 300 U.S. gallons of extra fuel per flight. Analysis showed that the airline could save an additional million U.S. gallons of fuel per year by cutting that amount in half.

**Figure 2: Optimal flight planning using multiple routes for each flight**

A user interface allows management of multiple possible scenarios for a single flight.

An advanced flight planning system can reoptimize the flight plan while the airplane is in flight. The airline's operations center has more information about weather and traffic far ahead of the airplane, as well as the dynamic costs associated with other flights (related to crew, airplane, and passenger connections), so the flight planning system can find better solutions than the flight crew working with the flight management computer (FMC) alone. The new route and latest forecast winds can be uplinked directly to the FMC, minimizing crew workload.

**TRENDS IN FLIGHT PLANNING**

Airspace design and regulations are changing all the time, sometimes quite rapidly. Some recent innovations include continuous descent approaches, high-altitude redesign in the western United States, and new U.S. Federal Aviation Administration (FAA) extended-range twin-engine operational performance standards (ETOPS) rules. (Boeing can help operators make sure they're defining all of their ETOPS parameters and fuel analyses correctly.) These are in addition to less recent changes, such as the introduction of a reduced vertical separation minimum in different parts of the world.

However, not all operators can take advantage of the improvements right away because their flight planning software cannot be updated quickly enough. Those whose
Figure 4: Determining the optimal redispatch decision point
On this flight from Denver to Tokyo, the optimal decision point to redispatch changes based on the relative location of all the airports. In this first instance, the decision to turn back to Anchorage is made after the airplane is over Russia. In the second instance, the redispatch decision point occurs as the airplane approaches the coast of Japan. The diversion city is Sapporo.

Diversion Path
Diversion Cities

Figure 3: Forecast winds must be considered to find the optimal route
This flight from Jakarta to Honolulu illustrates that a wind-optimal flight path may be far from the great circle. This route is 11 percent longer than a great circle route, but is 2 percent faster and uses 3 percent less fuel.

Software is ready could take full advantage of the innovations, immediately reducing their fuel consumption and operating costs. Further route, altitude, and speed optimization will be made possible by 4D trajectory-based approaches, such as the Next Generation Air Transportation System, which is the FAA’s plan to modernize the national airspace system through 2025, and the Single European Sky Air Traffic Management Research Programme (SESAR). Ongoing research goes beyond compliance with new approaches, identifying opportunities for improved optimization that build on the changes to the global traffic management system.

Companies such as Jeppesen are also working on improved optimization scenarios designed to minimize fuel consumption, operational cost, and emissions. For instance, Jeppesen is developing a new optimization objective function for its flight planning system that is based on an atmospheric impact metric developed by airplane design researchers at Stanford University, taking many emission products into account, rather than just minimizing fuel as a means to minimize CO₂.

Another future trend in flight planning optimization is a close integration with other airplane operations efforts, such as disruption recovery, integrated operations control, and collaborative air traffic management. Current systems can already pick optimal cost index speeds if the cost of arriving at different times is available. This cost, however, is not independent for a single flight, but related to the decisions made for all an airline’s flights because the cost for passengers, crew, and the airplane itself to arrive at a specific time depends on when their next flights will depart — which, in turn, depends on when all other flights arrive. By combining the different operational decisions and optimizing them together, better solutions that factor in all of the different costs and constraints can be attained.

SUMMARY
Accurate, optimized flight plans can save airlines millions of gallons of fuel every year — without forcing the airlines to compromise their schedules or service. Airlines can realize their benefits by investing in a higher-end flight planning system with advanced optimization capabilities and then ensuring accuracy by comparing flight plan values to actual flight data, identifying the cause of discrepancies, and using this information to update the parameters used in the flight plan calculation.

Current research in flight planning system development ensures that flight planning systems take full advantage of airspace and air traffic management liberalization and work together with other airline operations systems to produce the best overall solutions.

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