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Effective Flight Plans Can Help Airlines Economize

By Steve Altus, Ph.D., Senior Scientist, Airline Operations Product Development, Jeppesen

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 redispatch, 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 (CO_2) emissions are directly proportional to fuel burn, with more than 20 pounds of CO_2 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

Figure 1: Minimum information on an operational flight plan

By varying the parameters in a flight plan, flight planning systems can improve the efficiency of an airline's operations.

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                              COMPUTER FLIGHT PLAN
SPEED SKD      CLB-250/340/.84      CRZ-CI40 (1)  DSC-.84/320/250

                  FUEL     TIME
POA ZBAA   (2)   224000    10/31
ALT ZBTJ         006100    00/15
RESV             008500    00/30
CONT             011200    00/40
REQ              249800    11/56
XTR              000000    00/00
TOT        (3)   249800    11/56

KSEA..YVR J528 TRENA J488 UAB..YYD NCA34 YXY J515 FAI J502 OTZ B244
FRENK G902 ASBAT B337 URABI G212 DABMA W74 SABEM G332 GITUM GIT01A ZBAA (4)

FL  300/YVR   320/YYD   340/FRENK 348/BUMAT 381 (5)
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1 What speed to fly (possibly varying along the route)

2 How much fuel the airplane will burn ("trip fuel")

3 Total departure fuel, and how it is allocated – fuel to alternate, contingency fuel, and other allocations that vary between airlines and regulatory rules

4 What route (ground track) to fly

5 What profile (altitudes along the route) to fly

only take into account the correct physics (i.e., airplane performance and weather) but also route restrictions from ATC and all relevant regulatory restrictions. The mathematical nature of these constraints and the overall size of the calculation combine to make it a challenging problem, even by modern optimization standards. Some of the equations that describe the behavior are nonlinear and noncontinuous, and the airplane state is dynamic (i.e., it depends on how the airplane has gotten to a specific point, not just where it is). As a result, tens to hundreds of thousands of individual calculations are required for a single flight.

An optimal flight planning scenario for saving fuel and emissions involves calculating multiple routes or operating approaches for each flight, ranking these scenarios by total cost, choosing the scenario that best accomplishes the airline's cost objectives, and providing summaries of the other scenarios for operational flexibility (see fig. 2). While the scenario chosen by the system might be used most of the time, dispatchers and operations managers at an airline's control center may choose another scenario to meet the airline's operational goals, such as routing of airplanes, crews, and passengers. Because they are often making these decisions shortly before departure time, a user-friendly presentation of the relevant information is vital.

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, overflight permissions, 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 CO_2 emissions by about 20 million pounds.

THE IMPORTANCE OF ACCURACY

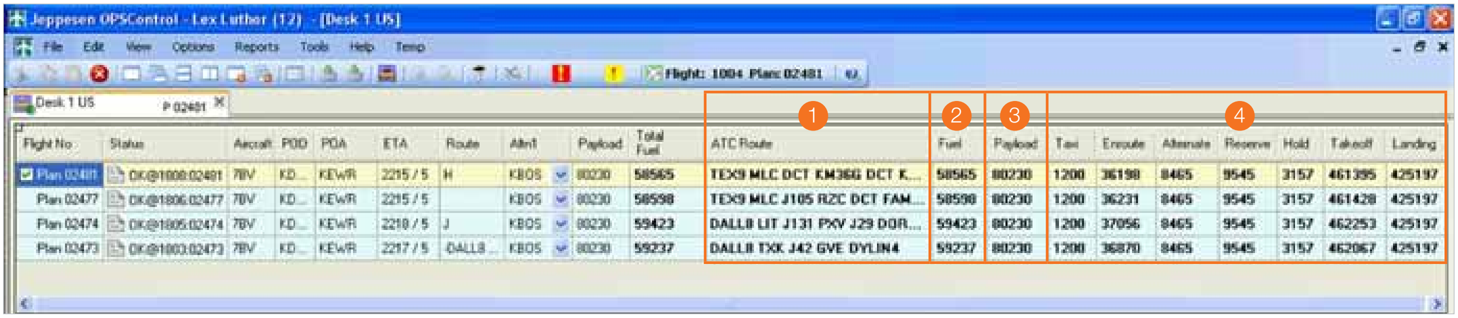
Airlines can reduce fuel consumption and costs by improving the accuracy of their flight plans. The flight crew and dispatcher can elect to add fuel they think might be needed to complete the flight as planned. But the heavier the airplane, the more fuel it will burn, so adding extra fuel — which adds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

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

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



1 Multiple routing scenarios displayed simultaneously 2 Scenario sort by fuel 3 Scenario sort by payload 4 Scenario sort by any computed field

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.

OPTIMAL REDISPATCH DECISION POINT

Another way to decrease total fuel carried is to reduce international contingency fuel required by using a redispatch technique. Contingency fuel (called "international reserve fuel" in the United States), which is defined by a percentage of flight time or planned fuel burn (varying by different regulators), can be reduced by splitting a flight plan into two different calculations: one from the departure airport to an airport that is closer than the intended destination, and another from a decision point on the route of flight to the planned destination. Each calculation requires contingency fuel over its entire distance, but each is less than the total that would be required for the entire flight to the planned destination. The actual flight must carry the greater of the contingency fuels for the two scenarios.

The optimal flight plan places the decision point in a location where the contingency fuels for the two scenarios are exactly equal; moving it in either direction increases the fuel required for one scenario or the other. While some general guidelines exist for a good location of the decision point, a flight planning system can calculate the optimal location automatically — and it can vary dramatically based on the relative locations of all the airports (see fig. 4).

DYNAMIC AIRBORNE REPLANNING

Winds, temperature, convective weather, and ATC congestion have a sizeable impact on the optimal 4D path for an airplane. Over the course of a long flight, this information can change significantly, and the predeparture flight plan may no longer be optimal.

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

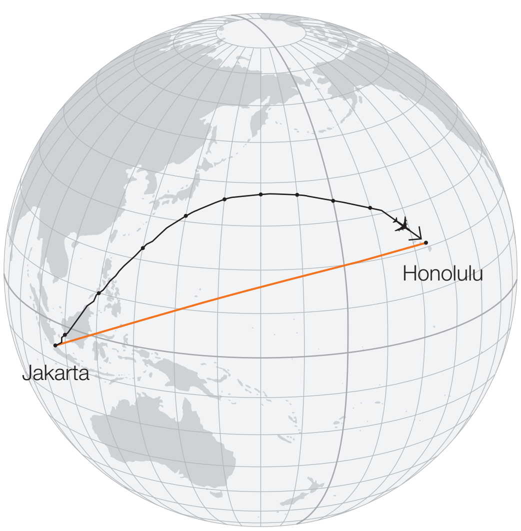
On this flight from Denver to Tokyo, the optimal decision point to redispatch changes based on the relative location of all the airports. In this first instance, the decision to turn back to Anchorage is made after the airplane is over Russia. In the second instance, the redispatch decision point occurs 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.



Optimized Route

Great Circle

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 CO_2.

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.

For more information, please contact Steve Altus at steve.altus@jeppesen.com.