Reducing fuel consumption requires an effort across several departments in an airline. There are many operational procedures that can be employed to produce consistent results. It is generally accepted that some carriers can reduce fuel use by up to 5% if all methods & techniques are employed.

Proven techniques to reduce fuel burn

Efforts by airlines to reduce fuel consumption will take years to achieve results, since new procedures must be fully understood, developed and implemented across several departments, while large volumes of data must be collected and analysed to determine progress and trending. Airlines are now implementing proven techniques, however, to reduce fuel consumption.

Crude oil prices have steadily risen from $20 to more than $80 per barrel over the past 10 years. The price of jet fuel per US Gallon (USG) is related approximately to the price of crude oil plus $20 per barrel for refining, divided by 42 USG per barrel. Current jet fuel prices are therefore about $2.50 per USG.

Several fuel-saving programmes have concluded that some airlines' annual fuel consumption can be reduced by up to 5%. An airline with a modern fleet and good flight-planning system already in place may achieve reductions of 1-2%. Other benefits are reduced CO2 and other gaseous emissions, and increased payloads on some flights.

Savings targets

Several aircraft types are used to illustrate the possible financial savings from reducing fuel burn and lowering CO2 emissions.

Common narrowbody types like the A320 and 737-800 typically operate on 90-minute flights, and generate 3,000 flight hours (FH) and 2,000 flight cycles (FC) per year. An A320 typically burns 1,200-1,300 US Gallons (USG) of fuel on this mission length. A 737-800 will possibly slightly more, 1,300-1,400USG.

An average saving of 3% for the year's operation will save 75,000USG and $190,000 per aircraft. The reduction in CO2 emissions will also be about 700 tonnes per aircraft per year.

A large type, like the A330-200, will burn 9,000USG on a 2,400-2,500nm trip, and accumulate 3,500FH and 650FC per year. An average saving of 3% per trip will deliver an annual fuel burn reduction of 176,000USG and $440,000, and lower CO2 emissions by 1,700 tonnes.

A larger type, like the 747-400, burns 24,800-25,500USG on a 4,000nm trip, so an average 3% saving will save 360,000USG per year, equal to $900,000. CO2 emissions will also be lowered by about 3,400 tons per aircraft annually.

The current global commercial aircraft fleet consumes 67-70 billion USG per year. A 3% saving would therefore save the industry 2 billion USG annually, equal to saving about $5.2 billion, and lower CO2 emissions by 20 million tons.

Airline departments

"There are several main departments where airlines can make savings in fuel consumption," explains Captain Chris Schroeder, head of corporate social, environment & fuel projects at Qatar Airways. "These are flight dispatch, ground operations, flight operations, the commercial department, and maintenance & engineering. Airline departments are interlinked, and each has to play its part.

"Airlines are data-rich, but will be information-poor unless they have a fuel management information system in place to gauge their achievements," continues Schroeder. "Each route, pilot and aircraft must be analysed, together with flight phases, flight planning, and aircraft configuration."

Aircraft weight

The first main area where fuel can be reduced is aircraft weight, or more specifically operating empty weight (OEW) or aircraft prepared for service (APS) weight. This is partly the remit of an airline's commercial department, since interior seating and other cabin installations, in-flight entertainment equipment (IFE), catering and on-board service items like magazines and newspapers are determined by the quality of cabin service. Removing used cabin service items will reduce APS weight.

Large and complex seats, sometimes of a lie-flat design, and bar equipment are heavy, raising OEW and APS weight. Their position at the front section of the cabin also brings the aircraft's centre of gravity forward. This is an issue that the commercial and flight operations need to discuss and address.

Seating and aircraft interior equipment manufacturers are developing lighter seats, mainly for economy class.

There is also the issue of potable water. Water consumption is high during daytime flights, so all water loaded is normally used, while it is lower on night flights because passengers are sleeping. "Airlines should monitor potable water consumption on day and night flights, and build a statistical database to determine the amount of water usually needed for night flights. A lower amount will effect a weight saving," says Marcel Martineau, president at TFM Aviation.

Other areas for potential weight saving are crew bags and equipment, or aircraft manuals. It is not unusual to have up to 80kg of manuals and paper logs on the flightdeck, so replacing these with 3kg of electronic flight bags (EFBs) and electronic technical logs (ETLs) will achieve a substantial weight reduction.

The additional advantage of EFBs is that it is expensive for airline operations departments to update paper manuals. This has to be set against the high cost of installing the equipment on the aircraft.

Lowering aircraft OEWs or APS weights delivers a clear benefit in reduced fuel burn. The general rule is that for additional weight carried, fuel burn increases by 2.5-4.5% per hour depending on the aircraft type and mission profile. An extra 100kg carried

The benefits of reducing fuel consumption are clear. The large volumes airlines use, and the high price of crude oil and jet fuel, mean reductions in consumption of just a few percent have the potential to save the industry hundreds of millions of dollars per year.

on a short-haul aircraft flying average FCs of 90 minutes will therefore burn an extra 3.75-6.75kg of fuel per flight, and 7.5-13.5 tonnes of fuel per year.

A weight reduction of 300-400kg on an A320 or 737-800 will save 5.2-6.9USG on a 90-minute flight trip, equal to 10,400-13,800USG and $26,000-35,000 per year.

In the case of one of the largest types, a 2.0-tonne reduction in weight may be possible in the case of a 747-400. This would result in a fuel burn reduction of about 24USG per hour, or 190-215USG for a typical eight- or nine-hour flight. This is equal to an annual saving of $230,000-300,000 in fuel costs.

Flight dispatch

Flight dispatch is one area where large savings are possible.

"The flight dispatch department is responsible for preparing and planning flights, and calculating fuel needs," says Schroeder. "Large savings can be realised because most flight plans are still not optimised. An optimised flight plan will have the optimum flight track in terms of distance and time, the optimum speed, the optimum altitude for the aircraft's all up weight (AUW) at every stage of the flight, and the optimum amount of fuel for the flight, and take into account the strength and direction of winds at all stages of the flight, and so pick routeings that take advantage of tailwinds, thereby minimising the impact of headwinds.

"An optimised flight plan will also take into account overflight and air traffic control charges for each route, and combine this with the flight time and fuel burn and cost of each one to provide a list of routeings, and the flight times and cost of each one," continues Schroeder. "There is also the issue of the optimum speed and flight time. Aircraft will clearly use the lowest fuel when cruising at the aircraft's long-range cruise speed (LRC), but all other time-related operating costs must be considered, like compensating passengers who miss onward flight connections in the event of late arrival."

The first stage in optimising flight plans is to use 4-D (four-dimensional) flight planning systems.

The original 2-D flight planning systems simply planned routes by picking the lateral track and the optimum or preferred altitude.

Later 3-D flight planning systems integrated forecast winds throughout a flight's path at various altitudes, in order to deviate the aircraft's track so as to avoid the strongest headwinds, and make use of the strongest tailwinds.

The most recent flight planning systems are 4-D, which take time-related issues into account to provide a more optimum flight plan. These include airport operating restrictions, open and closed airspace, and overflight charges.

4-D flight planning systems include the LIDO system provided by Lufthansa Systems, as well as systems provided by Sabre and Austrian-based FWZ.

FWZ's Flywize uses a real 4-D flight optimisation that considers optimum speed at optimum altitude simultaneously at route creation time. The consideration of all known airspace constraint is one of the most complex tasks in 4-D flight optimisation. Finding a compliant and optimum route in areas of dense air traffic, like Europe, is almost impossible without advanced tools.

Besides air traffic control (ATC) restrictions and overflight charges, one of the biggest issues in airline operations is delay cost management. Flywize offers a completely automated solution to speed up or even slow down flights individually to achieve the minimum total cost.

Lateral track

The first stage of optimum flight planning is selecting the best lateral route, or track for the flight. The use of airways and trans-ocean tracks means that there are several lateral tracks that can be used between two airports. The lateral distance between tracks can vary by several hundred miles on long-distance flights, so different tracks will traverse different countries and airspace.

A good 4-D flight planning system will take into account, for example, no-go areas of airspace, or those that have limited capacity or are temporarily closed, as well as all winds throughout a flight to avoid severe weather en route, in order to select optimal tracks on the day,.

The choice of optimal tracks also has to take into consideration overflight and navigation charges. These vary between countries and in the way they are calculated. A modern 4-D flight planning system will take these into account.

Although dispatchers can provide flight crews with several optimum routeings, the route the aircraft ultimately takes is subject to limits placed by ATC. On trans-ocean operations, flights follow pre-determined tracks which are adjusted daily to accommodate the maximum flow of traffic, such as between New York and London, and to take advantage of the wind conditions on the day. The need to maintain lateral separation between aircraft, equal to a certain number of minutes on these tracks, means that pilots are not always able to use the optimum routes picked by dispatchers.

Optimum altitude

The optimum altitude clearly depends on the aircraft's AUW at every stage of the flight. A 4-D flight planning system and a well-trained dispatcher can create a flight plan that indicates when step climbs

The role that flight dispatch and flight dispatchers play in reducing fuel burn is overlooked by many carriers. Through use of 4-D flight planning systems, flight dispatch can optimise flight plans and consistently reduce fuel consumption by several percent.

should be made to a higher altitude as the AUW allows, taking into consideration flight-level separation requirements and the higher rate of fuel burn during each step climb and the rest of the flight if the climb is at a point close to destination.

While it is possible to plan for the optimum altitude, these plans can be pushed aside by ATC restrictions, due to congestion by other aircraft. Also, step climbs to higher altitudes to save fuel are not permitted on trans-ocean operations because there is no radar monitoring, so they are only possible when the aircraft makes landfall and is visible by radar.

Optimum cruise speed

The optimum cruise speed is the aircraft's LRC. Mach number speeds that are slower or faster than LRC result in higher fuel burn, while a particular Mach speed is equal to a faster true airspeed as altitude decreases. An aircraft cruising at a particular Mach number will therefore save time-related costs at a lower altitude. The optimum speed therefore has to be considered together with the expected cruise altitude by the flight dispatchers.

Again, ATC can limit the cruise speed that can be used. As with lateral tracks, trans-ocean routeings require constant lateral separation between aircraft on a particular track at the same altitude. The slower cruise speeds of some aircraft, in particular the 767, will limit the cruise speed of other aircraft behind, usually to Mach 0.80-0.82, on the same track. Optimum cruise speed is therefore not always possible. Taking these situations into account, well-trained dispatchers will provide flightcrews with two or three trans-ocean track and altitude options so that an alternative routeing can be used if the preferred one is not available.

Experienced dispatchers know the density of traffic on the oceanic tracks. A dispatcher will request a certain track and the positive control airspace (PCA) controllers will provide a slot time, which often will accommodate a flight. As the heaviest traffic is between the eastern US and London/Paris, flights often have to adjust their tracks so that all traffic can be accommodated. The introduction of reduced vertical separation minima (RVSM) over the ocean opened up the availability of tracks. Twins like the 767 and A330 will fly higher than faster aircraft such as the 747 and 777.

Most flights will be planned at the best speed for each aircraft type. The 767 may be planned at Mach 0.82, instead of Mach 0.80, to increase the chances of being accommodated on the requested track. The dispatcher will often provide the crew with options so that they can decide whether it is better to fly faster or accept another track. Being moved to an adjacent track, if advised early enough, will not have a significant impact on the fuel burn and flight time, and the additional fuel burn increase can be catered for by using some of the normal contingency fuel planned on these flights.

"Airlines often under-estimate the importance of flight dispatchers, yet they can save several thousand dollars on one long-haul flight by optimising a flight plan," says Martineau. "Optimisation also means that additional passenger or freight payload can be carried. Training dispatchers is a very important, but often neglected, issue."

Cost index

Modern flight planning systems have a built-in cost-index capability to take into consideration other time-related costs such as those caused by delays, as well as revenue-related issues. The computed cost index is inserted into the aircraft's flight management system (FMS), which allows the aircraft to fly at the optimum cost-index speeds as computed by the flight-planning system.

The main time-related operating costs are maintenance, flight- and cabin crew, and lease charges or aircraft depreciation. Time-related costs are important in that faster speeds will reduce them, but at the expense of increased fuel consumption.

The first issue relating to speed is aircraft utilisation. While faster speed may save time on that flight, the aircraft is still unlikely to achieve higher rates of annual utilisation as a result. Careful consideration should therefore be given before including the aircraft financing costs in the cost index as these are not normally related to aircraft utilisation.

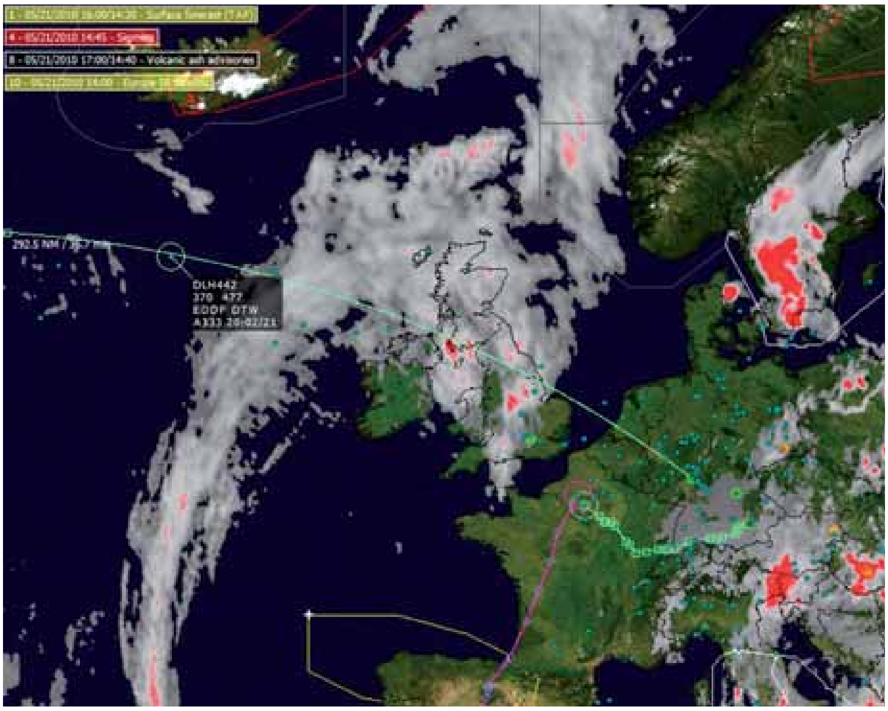
Crew costs are another issue. Faster cruise speeds would theoretically mean that crews could be rostered on more trips, lowering the cost per trip, but only if trips are consistently flown at faster speeds, and several hours are consistently saved over a sustained period.

Crews do receive duty pay on a per day basis, so faster flying times will not reduce these crew costs. They should not be included in the cost index. Ignoring crew cost completely, however, in calculating the cost index would result in a very low cost index number and can seriously extend the flight times. No one can say that when a pilot is sitting in his seat, he is not costing the airline anything.

Taking a 747-400 as an example, total direct maintenance costs are $1,900-2,000 per FH, or even higher for aircraft that are past their mature maintenance phase. This amount includes all elements of maintenance, including labour hours. The portion of maintenance costs that are directly related to the hours flown should be factored into the cost index.

The other side of the cost equation is the impact of late arrivals on revenues. While faster cruise speeds can make up for some of the delay, more fuel will be consumed as a result, while missed flight connections can lead to tens of thousands of dollars being spent on placing

Flight dispatch can also consistently reduce fuel consumption by monitoring the progress of flights through use of an aircraft situation display. These are used by flight dispatchers to optimise flights as they operate.



passengers in hotels or re-booking them on new flights. The cost of delays and missed calculations should also be factored into the cost index. This varies between each route and individual flight.

Flight dispatchers can also save fuel during flight operation by using a flight tracking system. "In the US, flight dispatchers have joint responsibility with captains for monitoring flights, which they do via an aircraft situation display (ASD)," says Steve Caisse, supervisors standard and training flight control at Delta Airlines. "ASD systems give dispatchers the tools potentially to save large amounts of fuel, by optimising flights as they operate. The ASD is like an ATC screen, which dispatchers use to monitor flights in terms of weather and large traffic volumes. The ASD follows the position of the aircraft, and monitors the altitude, speed, intended route and destination. The weather, airways and navaids can all be overlaid on the screen.

"Savings can be realised by getting more direct, and therefore more economic, routeings for flights. Reducing the time by just a few minutes per flight can save a lot of fuel across the entire operation," explains Caisse. "This can, however, be disrupted by the weather. A dispatcher plans flights three hours prior to departure, so if a group of thunderstorms are forecast he will plan a long routeing around them. As the flight progresses and the weather situation unfolds, however, the dispatcher may see that it is possible to take a shorter route.

"Another example is that dispatchers can monitor flights in holding patterns close to busy airports," continues Caisse. "Captains will be concerned about remaining fuel, and will often divert, thereby significantly affecting costs. Dispatchers can inform them how many aircraft are holding and how much longer they are likely to have to hold before being able to land, which avoids a large number of flight diversions. Overall, dispatchers can potentially save airlines several hundred thousand dollars per year by monitoring flights in real time."

The savings from enhanced and optimised flight dispatch are considerable at some carriers. "We are half-way through implementing a three-year programme to improve our flight dispatch," explains Schroeder, "and expect to reduce fuel burn by up to 4%."

Flight operations

Flight operations cover all phases of the flight, planning and determining the fuel required for the trip, and preparing and configuring the aircraft for departure, and deal with chief pilots, operating standards, technical fleet pilots, pilot training, safety, rostering and scheduling. Flightcrews are therefore able to effect a saving in fuel consumption here.

Flight preparation

Preparing the aircraft for service includes planning the aircraft load and determining where the load freight is distributed on the lower deck. This will determine the tailplane trim setting.

This can commence once the flight dispatcher has completed the flight plan, after acquiring the number and seating positions of the passengers, and the amount of freight being carried, with the weight of individual pallets and containers. The fuel requirement for the flight is then calculated. This information is also required to determine the taxi and take-off weight of the aircraft for performance calculations.

One important aspect of load sheet preparation is that the aircraft's centre of gravity needs to be in an aft position to minimise drag caused by the tailplane.

"In a steady flight situation, the tailplane has to be trimmed to hold the nose up, which causes drag," explains Martineau. "If the centre of gravity is moved aft then less trimming of the tailplane is required, and the overall aircraft drag is reduced. It has been shown that if the aircraft's load is placed at its maximum rearward limit then the aircraft will burn about 1% less than the baseline. If the load is placed towards the front then fuel burn can be 2.5% higher than baseline. The problem is that heavy premium-class seats in the front of the cabin move the centre of gravity forward."

One way to achieve an aft centre of gravity is to load freight containers and pallets in specific positions in the belly. Key Codes of The Netherlands has developed an algorithm with KLM to automatically determine the positioning of pallets and containers on the main and belly decks of freighters to optimise the aircraft's centre of gravity. "The system is the autoload function for an existing weight and balance system," says Eric van Gend, commercial director at Key Codes. "The system went live in December 2009, and we have already proved that by optimising weight and balance on freighter aircraft, the centre of gravity, and the tailplane trim setting can result in a 1% saving in fuel burn.

"The loader using the system clicks the autoload button, which then displays all the pallets and containers to be loaded," continues van Gend. "There are details on each one, including its dimensions, shape and gross weight. The system also shows the positions available for each container and pallet on both decks. There are 10 to the power of 30 different loading permutations possible, and the system calculates the optimal one in about one minute. It then provides an overview of the flight, including all the main weights, and the weight of the containers on each side of the aircraft in case it is imbalanced and needs trimming. The system optimises by placing the centre of gravity as far within limits as possible, and provides the trim setting."

Key Codes' system is currently only available for use with freighter aircraft.

Careful analysis has to be made of all phases of flight in the planning stage to see where fuel consumption can be reduced. One technique that can be employed is re-dispatch during flight to effect a reduction in contingency fuel. This is only permitted if several conditions are met. One is for the airline to have a system to track and monitor the fuel consumption of every flight and aircraft.

Fuel planning

Dispatchers determine the amount of fuel for the trip. The final figure is reviewed by the flightcrew, and accepted by the captain, who can change it. Up to 10 different elements, many of which are legal requirements, determine the final quantity of fuel that is required. Some of these can be optimised, however, to result in a lower fuel figure. This is important, since reducing weight will save 2.5-4.5% of fuel required per hour.

The typical quantities of fuel required for each element are illustrated with the fuel used for a 747-400 on a mission of 5,500nm with a flight time of 10.5 hours. The maximum fuel capacity of a 747-400 is 57,065USG, 382,336lbs, or 170.6 tons.

APU, engine start & taxi

The first element is for running the auxiliary power unit (APU), taxiing out at the departure airport and taxiing in after landing. The amount required for each flight therefore depends on the anticipated turn time and historical taxi times, which can all be loaded into the flight-planning system. There are some possibilities here for reductions.

In the case of the 747-400 with a three-hour turn time between flights, a 20-minute taxi-out and 10-minute taxi-in, up to 7.05 tons of fuel can be used.

The APU consumes about 900lbs or 134USG of fuel per hour, so more than a ton of fuel can be consumed in a three-hour turnaround if the APU is left running. Taking into account the APU's maintenance costs of $50-60 per FH, the cost of running the APU is therefore equal to $385-395 per APU hour.

Provided ground power at the airport is cheaper, using the APU can be limited to 30-45 minutes, thereby saving 2,025-2,250lbs of fuel, equal to $750-840.

The first flight phase is pushback, engine start and taxi-out. Single engine-out taxiing is possible, with the engine starting closer to the holding point. This will mean a longer taxi-out time. In some cases, the weight of the aircraft or ramp congestion can prevent this procedure.

The final flight phase is taxi-in, where engine-out taxiing is possible. This will not cause any delays. Each engine may burn about 110lbs per minute on a type like the 747, so it may be possible to save up to 1,000lbs when taxiing in with one engine out.

Trip fuel

The largest element of the fuel load is for the trip fuel, or flight from take-off to landing at destination. The quantity is calculated by the flight-planning system with the known or predicted payload and forecast en-route winds, provided the flight operates according to plan. This assumes there are no delays, technical problems, or re-routing, level or speed constraints. A 747-400 operating a 5,500nm and 10.5-hour mission may need 100 tons or 33,400USG of fuel.

This amount can be optimised by using 4-D flight planning systems and dispatchers following an optimised flight profile, as well as through savings in the aircraft's zero fuel weight, although not reduced below that legally required. "Modern flight planning systems are extremely accurate in forecasting en-route winds, so they accurately assess the required fuel," says Linney.

There are other considerations. For example, flights into any one of New York's three airports invariably experience early descents initiated by ATC, as well as convoluted flight paths round the area, which increase fuel burn. Some airlines will account for this in the trip fuel amount.

Reductions are possible during all phases of flight. At take-off, utilising a lower flap setting reduces drag. This must take into consideration the noise abatement profile, the requirements for obstacle clearance and airport elevation. This is a performance decision, but airlines like to use standard procedures, and the practice only saves a small amount of fuel.

Martineau says that reduced take-off flap settings also reduce the drag once the aircraft is airborne, which improves the second-segment climb performance. Reduced flaps can save up to 450lbs of fuel for a large aircraft, noise abatement and noise procedures permitting.

The second trip phase is the transition from the initial climb at take-off power to the lowering of the aircraft nose to accelerate the aircraft and reduction to climb power. Flaps can then be retracted in stages as the aircraft accelerates. There are some suggestions that at some airports with special procedures, this height could be lowered from 3,000 feet to 1,500 to allow earlier flap retraction, a reduction in drag, and so effect a lower fuel burn. Retracting flaps at 1,500 feet is standard procedure at most airports, so there will be no fuel burn reduction in most cases. There is also the issue of noise abatement procedures to consider.

The climb phase of the flight following flap retraction is a trade-off between forward speed and climb angle. While a faster speed will reduce overall flight time, it will take longer to reach the cruise altitude, which is where the aircraft is most fuel-efficient. "The FMS therefore determines the best climb profile. This will not only calculate the best rate of climb and airspeed, but will also take into consideration tail- and headwinds. The optimum climb can be spoilt, however, by interference from ATC," says Linney.

Martineau points out that being able to accelerate up to 300-320 knots below 10,000 feet in a large aircraft can save as much as 220lbs per flight.

The next flight phase is the cruise, and concerns the lateral track selected by the flight dispatcher, the cruise altitude and

Optimising climb, cruise and descent segments of a flight involves optimised flight planning and a 4-D flight planning system. For long-distance flights in particular, there are several tracks a flight can follow. Cruising altitude and speed can also be optimised.

the speed flown. "This can be optimised by using a cost index, and is partly down to the flight dispatch department in the planning phase. It can then be modified by reference to the FMS when the flight is actually operating. There are times, however, when a less than optimum fixed Mach number must be flown, for example on North Atlantic tracks, or when other route, altitude or speed constraints are imposed by ATC. The planning system will not necessarily know about these constraints and therefore cannot always account for these restrictions in the plan," says Linney.

Martineau estimates that it is possible to save from 450lbs to one ton of fuel on some long-distance flights with medium and large widebodies using cost-index-optimised speeds. "Cost-index optimisation also gives positive results for aircraft not operating at optimum altitudes in congested areas," says Martineau. "Operators of smaller regional jets have reduced fuel consumption by 4% by adopting cost-index-optimisation techniques."

During descent, which follows cruise, a continuous approach profile computed by the FMS allows the aircraft to descend in a steady profile, with engine throttles at idle, without the use of speed brakes. This saves fuel compared to a traditional stepped descent.

ATC controllers are recognising the value of continuous descent approaches, and are improving procedures. "Continuous descent approaches are now recommended at some airports, although this is a relatively new development. This requires good ATC and established procedures. It can save 900lbs of fuel for a 747-400, but is not always possible because of ATC restrictions in the vicinity of large airports," says Linney. There is then the final approach phase of the flight. "The concept of a decelerated approach is to keep the aircraft speed as high as possible to delay extending flaps," says Martineau. "Extending flaps and lowering the landing gear should be left until the aircraft is at a specified altitude above the landing runway to minimise drag and save fuel."

Fuel burn during the landing phase is reduced by using a lower flap setting and idle reverse, rather than full power reverse thrust. As with the take-off phase, lower flap settings will reduce drag and so fuel burn, but could also increase the landing length slightly. "Reverse thrust increases engine wear and fuel burn, while the use of idle-reverse reduced fuel consumption will also increase the wear of brakes, increasing their maintenance costs," says Linney. "Using lower flaps and idle reverse is a performance consideration, and not always possible. Although most airlines try to use idle reverse, ATC requires aircraft to leave runways as quickly as possible after landing at busy airports, so reverse thrust is used. There is also the trade between brake wear and maintenance costs, and thrust reverser wear and maintenance costs. The potential for fuel saving in this case is therefore limited."

Contingency fuel

The third element is contingency fuel. This has traditionally been 5% of trip fuel, so it is 5.0 tons in the example used. This is legally required for several eventualities, including en-route ATC delays, stronger-than-forecast headwinds, and a need to hold prior to landing at the destination. Notices to airmen (NOTAMs) state that crews should have enough fuel for a specified time when flying to particular airports. The NOTAM for operations to London Heathrow (LHR), for example, tells crew to anticipate holding for 20 minutes and to have the necessary contingency fuel.

There is scope to reduce the amount of contingency fuel, however. "The penalty of 3.5% per hour to carry these five tons to destination for 10 hours means an additional 3,920lbs or 1.75 tons of fuel will have to be added, taking the contingency fuel loaded at departure up to 6.75 tons," explains Martineau.

Some airlines designate an en-route alternate or a re-dispatch procedure to reduce the contingency fuel carried. This is permitted under European operating regulations (EU-OPS), Canadian regulations (CARs) and US regulations (FARs).

Airlines that use re-dispatch have to meet several conditions, like tracking the accuracy of their flight-planning system with respect to fuel, and the fuel consumption of each aircraft in the fleet. Re-dispatch requires an assessment to be made three-quarters of the way through the flight. Using this technique, contingency fuel is only required for the distance from the re-dispatch point to the destination. The regulations also require a suitable airport en route at which the aircraft can land. This must be within a radius from the re-dispatch point that is equal to 20% of the total flight length. There also has to be a suitable alternate.

"For an aircraft flying from LHR to Chicago (ORD), the system works by assessing the fuel situation abeam a suitable diversion airport that is 90-120 minutes' flying time from the destination, which in this case is Montreal," says Martineau. "At this point, if there is sufficient fuel to continue to Chicago, then the contingency fuel that is required is equal to 5% from abeam Montreal, which would be 1.0 ton. If there is insufficient fuel to continue, then the aircraft can land at Montreal."

Linney explains that the minimum amount of fuel in the tanks when arriving at destination must be equal to the fuel needed to fly to a suitable alternate plus the final reserve, known as company minimum reserve (CMR). This determines if there is enough fuel to continue to the scheduled destination.

Aircraft weight and maintenance condition are often overlooked in their effect on fuel consumption. Engines that have accumulated a high time on-wing can burn up to 12% more fuel than engines fresh from a shop visit, for example.

Alternate fuel

An aircraft may have to fly to a suitable alternate airport if it cannot land at the destination. The alternate will have a usable runway and forecast weather above specific alternate minimum requirements. The amount of fuel will therefore vary according to how far it is from the destination. Using Detroit (DTW) in the example of LHR-ORD, the amount of alternate fuel will be 6.0 tons.

The final reserve is equal to the amount of fuel used when holding for 30 minutes at 1,500 feet above the airport in International Standard Atmosphere (ISA) conditions at the estimated landing weight. The final reserve for the 747-400 is equal to 5.0 tons.

The FMS should therefore forecast that there will be a CMR of at least 11.0 tons in the tanks when the aircraft touches down at ORD for it to continue to ORD. There will therefore be some fuel available for holding at ORD prior to landing, and enough for the aircraft to land with the CMR in the tanks.

Using re-dispatch reduces the contingency from 5.0 tons to 1.0 ton, so the aircraft can carry 4.0 more tons of payload instead.

There is also the weight-related factor of carrying the contingency fuel. In the case of 5.0 tons, another 1.75 tons will have to be carried for the 10-hour flight.

If using just 1.0 ton of contingency fuel, an additional 79lbs per hour will have to be carried, totalling 790lbs or 0.35 tons. The saving in this weight-related fuel for carrying the contingency fuel will therefore be 1.4 tons.

Additional & extra fuel

The two final elements are referred to as ‘additional’ fuel and ‘extra’ fuel. “Carrying additional fuel is a legal requirement because technical faults with the aircraft may cause some drag,” says Martineau. “Other examples are where there is a particular requirement for holding fuel. There is a NOTAM that specifically requires all flights to carry 20 minutes’ holding fuel when going to LHR, although this could be part of the contingency fuel. If the total of alternate and final reserve is below that required as airline policy, the balance is added.”

The ‘extra’ fuel is added at the captain’s discretion, for example in poor forecast weather conditions, if the pilot has never flown to a particular airport before, if traffic is busy and it looks as if the flight will get stuck behind another aircraft and have its speed limited, or if the aircraft has to fly faster than planned because of late take-off or crew running to the limits of their duty times.

These final two elements could therefore vary from zero to several tons in the case of a 747-400. Minimising these two is clearly a priority.

Summary

Linney says the best opportunities for fuel burn reduction are: optimising the flight profile, both in terms of dispatch and via the use of the FMS; using continuous descent approaches; the use of engine-out taxiing in; and using lower flap settings in a few circumstances.

“These techniques can all save fuel, depending on how often they are used and by how many crews,” says Schroeder. “Crews will only use them if they are convinced they work, and are aware of the savings to be made. This requires a system to accurately track the data.”

Martineau estimates it is possible to save 450lbs or 5% on a typical 90-minute flight from a typical fuel burn of 4.0 tons for a type like the A320 or 737-800, but only when a good fuel management system is in place, and pilots and flights are tracked over many trips to establish trends. “Efforts are required from pilots, dispatchers, flight operations and the commercial department to reduce fuel consumption,” says Martineau.

Maintenance condition

Some appreciable fuel burn savings can be made by closely monitoring the aircraft’s maintenance condition.

The condition of aircraft engines is key. Engine blade tips wear with operation, and impair engine efficiency. Engines are kept on-wing until exhaust gas temperature margin has eroded, life limited parts are close to expiry, or the engine displays some other deterioration which requires a removal for a shop visit. Engines that have accumulated a long time on-wing can burn 6-7% more fuel compared to new ones. “The rate of increased fuel burn in extreme cases has been as high as 12-13% on some older aircraft before removal from the fleet,” says Martineau. “The engine removal intervals, overall cost of engine maintenance, and higher fuel burn due to engine wear should be considered together, so communication is necessary between maintenance & engineering and flight operations. It is also important to have the higher rates of fuel burn in an airline’s flight-planning system, which should be re-calibrated after an engine shop visit. Water-washing the engines every 500FC will recover 0.75% of fuel burn efficiency loss. Using de-rated engines at take-off reduces engine wear.”

The aircraft’s cleanliness and the condition of its paintwork also matter. Chipped paint and a dirty aircraft reduce fuel burn efficiency by 1.0-1.5%, so the cost of cleaning and repainting should be assessed. AC