# IT-ASSISTED OPTIMISATION OF FUEL CONSUMPTION IN AIR TRANSPORT

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**KEYWORDS**

Fuel Costs, Aviation Emission, Data Analytics, Big Data

**ABSTRACT**

Aviation continues to be an essential means of transport for passengers and cargo. In recent years, the COVID-19 pandemic led to a collapse. In 2022 Europe was back up to around 85% of 2019 levels (EASA, 2022). In 2021 van der Sman et al. predicted an recovery to 2019 levels in 2024 (van der Sman et al., 2021). However, fuel savings and emissions reduction have become increasingly important in recent years.

As part of a PhD thesis, possibilities for reducing fuel consumption by reducing the final reserve fuel were investigated. A smaller amount of tanked fuel required leads to a reduction in the transported (fuel) weight and, thus, a reduction in overall fuel consumption. This is because fuel consumption for a given route depends, among other factors, on the aircraft's weight. The more an aircraft weighs, the higher the fuel consumption. To keep fuel consumption as low as possible, carrying only the minimum weight required for the route in question is the most economical. Carrying more or even unnecessary weight increases the amount of fuel required and consumed in flight.

The overarching research aims to explore and evaluate how to reduce the fuel carried by aircraft and, thus, the total fuel required for a given flight. The main focus of this paper is on the opportunities and challenges that have arisen with introducing new fuel regulations in European aviation regulations. Operators with appropriate safety levels can apply more tailored provisions. This requires the demonstration of the safety level. This is achieved by defining specific safety performance indicators (SPIs), compliance with which is then continuously monitored and evaluated during operation. This requires the collection and evaluation of correspondingly large amounts of data. This is only possible using appropriate IT applications. Example below shows the amount of data that accumulates during flight operations. Recording, processing and saving pose a challenge in this respect. On the other hand, performance-based regulations allow for a more individualised implementation on and by the respective companies via the demonstration of a corresponding level of safety. Safety indicators are used for this purpose, which must be obtained and evaluated from various existing data. A large amount of data, which can only be collected and processed with the help of various IT applications, represents a challenge. However, companies can benefit from the corresponding advantages if they can cope with this.

The following is an excerpt of the requirements and possible implementation, focusing on the amount of data and the associated challenges and opportunities.

**INTRODUCTION**

In 2015, around 3.5 billion passengers already used air transport for business and tourism purposes. Despite a downturn in 2020 and 2021, aviation is expected to recover to pre-pandemic levels. The high aviation traffic volume is associated with an enormous demand for aviation fuel and associated high emissions. Lee et al. provide an overview of $CO_2$ and other related emissions and impacts of aviation on the climate (Lee et al., 2009), likewise Fleming and Ziegler (Fleming and Ziegler) and Filippone (Filippone, 2008) - to name just a few examples.

Over the past 30 years, damages resulting from climate-related weather events increased by a factor of twenty. In 2017 the weather-related damages amounted to $ 330 billion 2017, making it the most costly year on record (van der Sman et al., 2021). Some observed effects of climate change, which also affect the aviation sector (van der Sman et al., 2021), are Temperature changes, changes in precipitation and humidity, different wind patterns, different storm patterns, and sea level rise. This is an increase of around 6.4 % compared to 2014 (ICAO, 2016).

For 2037, an IATA forecast predicts the number of air travellers reaching 8.2 billion (IATA, 2018). The industry is facing significant challenges at the same time. Emissions from aviation, domestically and internationally, account for about 2% of total global $CO_2$ emissions (ICAO, 2014). The UK Civil Aviation Authority’s Airspace Change Masterplan states that "without significant changes to the system, increased congestion, vectoring and arrival holding will lead to a further degradation in environmental efficiency as traffic levels grow, with average per flight $CO_2$ emissions expected to rise by between 8% and 12% by 2030 compared to current levels" (Beevor and Alexander, 2022).

Reducing the effects of global warming due to emissions has become a goal. As a result, reducing emissions has become an important issue. Commercial aviation has already developed and implemented many techniques to reduce fuel consumption for economy and efficiency. On the operator side, these are primarily operational improvements, such as reducing the weight of onboard equipment or using a fixed ground power supply instead of the aircraft's auxiliary power unit on the ground. Airlines are searching for fuel-efficient routes or flight profiles most of the time. Airlines, airports and air navigation service providers take measures to reduce noise and pollution in their daily operations (IATA, 2019a). Effects on new aircraft generations introduced in recent years can be seen in Table 1 by IATA (IATA, 2019b).

*Table 1: Aircraft technology effects*

| Reference | New generation | Fuel saving |
|---|---|---|
| ATR/CRJ | MRJ | 20% |
| A320 | A320neo | 15% – 20% |
| B767 | B787 | 20% – 25% |
| A330 | A330 - 800neo | 14% – 20% |
| A330 | A330 - 900neo | 14% – 20% |

Corresponding developments are also taking place on the legislator's side. With amendments to Annex 6, ICAO has adopted a less prescriptive approach in the design of regulations. As a result, national regulators may work with air operators on new standards and adopt operational variations based on the individual ability to demonstrate an (equal) level of safety. Statistical data methods and safety risk management (SRM) are necessary. They enable a performance-based approach in the area of flight planning; this would improve fuel efficiency and therefore reduce emissions.

With the Executive Director's Decision 2022/005/R, the European Union Aviation Safety Agency (EASA) introduced new rules. Entry into force was on October 30th, 2022. These rules effectively adopt ICAO standards and recommended practices (SARPs) and integrate them into the current requirements of Air OPS Regulation (EU) No 965/2012, as well as the associated Guidance Material (GM) and Acceptable Means of Compliance (AMC). The new rules offer three different fuel schemes: basic fuel scheme, fuel scheme with variations and individual fuel scheme—the individual fuel scheme, in particular, offers excellent potential for fuel savings.

## SAFETY MANAGEMENT

Rules and regulations in aviation are drawn up for safety. Figure 1 (Shappell and Wiegmann, 2000) illustrates how the Swiss Cheese model helps to understand the interplay of different factors in accident causation. Several layers of defence are built into the aviation system to protect against variations, e.g. in human performance or decision-making, at all levels. But each layer typically has vulnerabilities, represented by the holes in the slices of "Swiss cheese" (ICAO, 2018).

Regulations, training and technology are some barriers (or slices) to preventing accidents. Safety management seeks to proactively mitigate safety risks before they result in aviation accidents and incidents (ICAO, 2018).

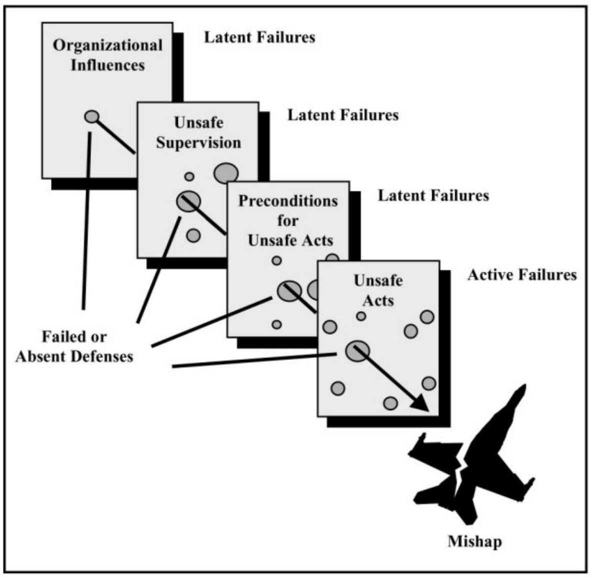


*Figure 1: "Swiss cheese" model of human error causation*

Safety management is one of the pillars to enable aviation safety and is subject to change and development. Namely, the performance-based approach to safety offers improvements as it focuses on achieving the desired outcome and not just on whether or not the regulation is complied with (ICAO, 2018). However, the theoretically possible level of safety is not always achieved. Scott A. Snook's theory, see Figure 2 (ICAO, 2018), is used to understand how the performance of a system deviates from its original design.

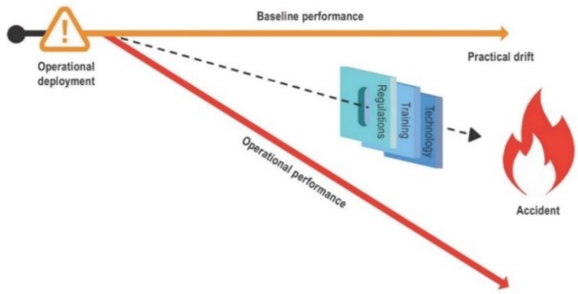


*Figure 2: Concept of practical drift*

The drift is a consequence of daily practice and is referred to as practical drift. Audits, observations and safety performance indicator (SPI) monitoring, as safety assurance activities, can help uncover activities that practically drift (ICAO, 2018). As Figure 3 (ICAO, 2018) shows, aviation is moving within a field of tension. Too little action in safety can lead to accidents, while too much can lead to financial bankruptcy. The relationship between the costs of a safety measure and the benefits can be examined, for example, with the "Total Judgement-value" method (Dietrich, 2016). Here, it can be determined how the costs are in relation to the increase in safety for the respective reference group.

Due to changes in Regulation (EU) No. 965/2012, which has been applied since the fall of 2022, there was an adjustment in the fuel requirements. These were previously regulated in CAT.OP.MPA.150, among others, will be referred to in CAT.OP in the future.MPA.180 and the following sections (EASA, 2020b). Operators demonstrating specific capabilities can use a basic scheme with variations or an individual fuel scheme.

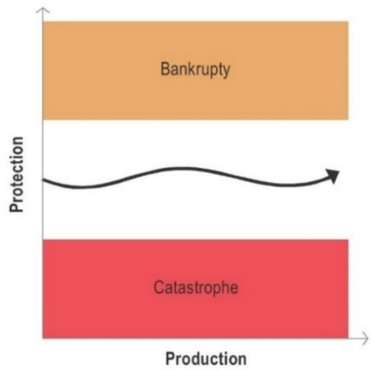


*Figure 3: Concept of a safety space*

This is intended for operators who can demonstrate a defined safety level, thus reflecting the move towards performance-based regulations (EASA, 2020b). Data supporting the intended deviation is required to implement the individual fuel scheme. The Annex to Opinion No. 02/2020 already contains preliminary information on the draft Acceptable Means of Compliance (AMC) and Guidance Manual (GM) and information to be considered for the performance-based deviation. A non-exhaustive list of safety performance indicators (SPI) that can be used to measure safety performance are:

- flights with 100 % consumption of the contingency fuel;
- flights with a percentage consumption of the contingency fuel (e.g. 85 %), as agreed by the operator and the competent authority;
- difference between planned and actual trip fuel;
- landings with less than the final reserve fuel (FRF) remaining;
- flights landing with less than minutes of fuel remaining (e.g. 45 minutes), as agreed by the operator and the competent authority;
- 'MINIMUM FUEL' declarations;
- 'MAYDAY MAYDAY MAYDAY FUEL' declarations;
- in-flight replanning to the planned destination due to fuel shortage, including committing to land at the destination by cancelling the planned destination alternate;
- diversion to an en-route alternate (ERA) aerodrome to protect the FRF;
- diversion to the destination alternate aerodrome; and
- any other indicator with the potential to demonstrate the suitability or unsuitability of the alternate aerodrome and fuel planning policy (EASA, 2020a).

As can be seen from these indicators, airlines wishing to have an individual fuel scheme approved by a competent authority are required to gather a significant amount of data and information on fuel consumption. The collection, monitoring and storage of these indicators is a challenge An example of a practical implementation follows below.

## FUEL REDUCTION OPTIONS

Airbus has recently launched an initiative regarding sustainability, which can be found on its Worldwide Instructor News homepage (Airbus S.A.S., 2023). Part 1 of the series published there deals with flight planning and again emphasises the possibilities of saving fuel by reducing weight.

*Table 2: Savings through 100 kg weight reduction*

| Aircraft | Fuel [kg] | $CO_2$ [kg] |
|---|---|---|
| A220/A320 | 20 | 63 |
| A330/A350 | 36 | 113 |

Table 2 shows the potential savings if the weight for a flight segment is reduced by 100 kg. Assumed were a loading of 80 per cent and a maximum range sector.

This paper focus researching and evaluating how to reduce the fuel carried by aircraft and, therefore, the total fuel requirement for a given flight under consideration of the necessary IT Data for the performance-based approach. This research aims to demonstrate, based on today's regulations in the field of aircraft certification and operation, that such a high level of safety has been achieved that it is possible, using a performance-based approach, to define a set of measures and circumstances that make it possible to reduce some of the fuel carried, and thus the weight and resulting emissions, almost immediately. Therefore, tracking, recording and evaluating vast amounts of Information is required - mainly to fulfil safety performance indicators.

The potential therein will be highlighted below using examples. The planning for two flights is adjusted so fuel is planned for five minutes less flight time. This is done using current flight, weather and aircraft data. Two flights are considered to highlight the potential for fuel savings: Hong Kong to Cincinnati and Hong Kong to Leipzig. Figure 4 and Figure 5 show these flights, planned with actual data and information as if they were carried out - but were not carried out.

Table 3 and Table 4 present an excerpt from the operational flight plan, fuel planning, and mass and loading. Table 3 shows the comparison of fuel planning for a flight from Hong Kong to Leipzig.

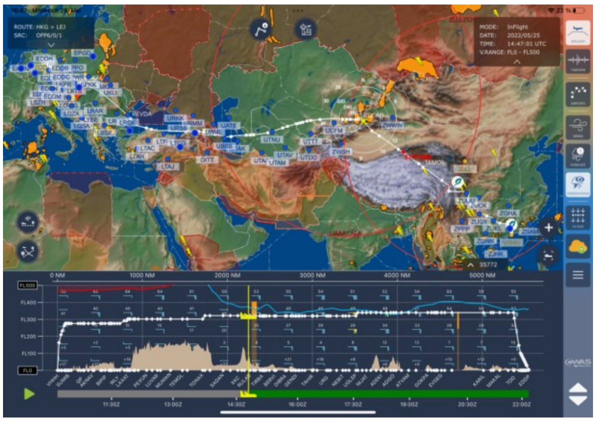

*Figure 4: Flight information Hong Kong – Leipzig*

Since the current approved planning is used, a value of 5 minutes of extra fuel was included as additional fuel for comparison. The alternate and final reserve values shown in Table 3 do not correspond to those that would result from an actual reduction. The 700 kg / 5 minutes in the right column only affects trip and contingency fuel, but not alternate and final reserve fuel. With an absolute fuel reduction, these values would also be lower, leading to a more significant reduction in trip and contingency fuel. Therefore, the resulting delta, in this case, an additional consumption of 257 kg, is lower than an actual saving in the reduction case. But the trend and thus a rough figure for evaluation is evident. The average additional consumption for this route is 21.34 kg/flight hour, i.e. this would be the savings potential.

*Table 3: Route comparison Hong Kong - Leipzig*

| | Origin | 700 kg extra | Δ |
|---|---|---|---|
| TRIP | 102090 | 102342 | 252 |
| CONT 3% | 3063 | 3070 | 7 |
| ALTN | 3832 | 3832 | |
| FINRES | 3136 | 3136 | |
| REQTOF | 112200 | 112400 | |
| ADDFU | | 700 | |
| TAXI | 767 | 767 | |

Table 4 shows the same considerations for the route from Hong Kong to Cincinnati. Here, the difference in fuel, i.e. the savings potential, is 364 kilograms. The average additional consumption for this route is 25.1 kg per flight hour, i.e. this would be the saving potential in this case.
Both examples show savings opportunities. An aircraft with an average flight time of 15 hours would consume around 300 kg less fuel per day. Even if these savings seem small, with a relatively small fleet of only twenty aircraft, the total value is correspondingly high. A conservative projection of 20 kg fuel saved per flight hour and fifteen flight hours per aircraft per day results in a daily fuel saving opportunity of 6 000 kg - this applies to a fleet of twenty Boeing B777-200F aircraft. The associated savings in emissions are, for carbon dioxide ~18 900 kg, water ~7 500 kg and 30 to 150 kg of nitrogen oxides per day.

*Table 4: Route comparison Hong Kong – Cincinnati*

| | Origin | 700 kg extra | Δ |
|---|---|---|---|
| TRIP | 117295 | 117649 | 354 |
| CONT 3% | 3519 | 3529 | 10 |
| ALTN | 3326 | 3326 | |
| FINRES | 2968 | 2968 | |
| REQTOF | 127200 | 127500 | |
| ADDFU | | 700 | |
| TAXI | 767 | 767 | |

These considerations are conservative and do not reflect other further advantages or that of a fighter aircraft. The values of 21 - 25 kg of additional fuel consumption determined above correspond to a fuel penalty factor of approx.—3%. Further considering the savings effects, the savings of the 5-minute fuel weight (here 700 kg for 5 minutes) and the additional consumption added up per flight hour must also be considered cumulatively.

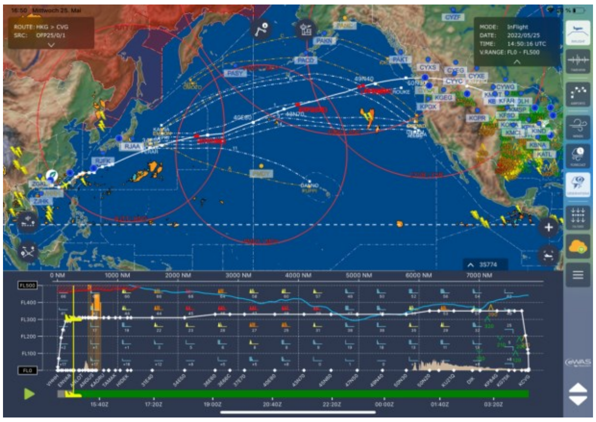

*Figure 5: Flight information Hong Kong – Cincinnati*

The two flights examined above result in approximately 1 000 kg difference at the take-off.

Figure 5 shows route optimisation options. These are presented to the crew during the planning process. As can be seen, the route already contains potential for shortcuts. These possibilities are statistically recorded and are considered in flight planning - by providing them as information to the crew in the IT application.

## DATA COLLECTION - REPORTING SYSTEM

One significant change within the European airline operational rules through Regulation (EU) 2021/1296 was the introduction of fuel schemes. Operators who can demonstrate an equivalent level of safety may be approved to use a basic with variations or individual fuel scheme, as regulated in AMC1 CAT.OP.MPA.180. This reflects the move towards performance-based regulations (EASA, 2020b). Data supporting the intended application is required to support the implementation of such advanced fuel schemes. An Annex to Opinion No. 02/2020 already contained preliminary information on AMC and GM to be considered for the performance-based approach. GM2 CAT.OP.MPA.180 now shows a non-exhaustive list of safety performance indicators (SPI) that can be used to measure safety performance.

To shed light on the number of data and the challenges, examine real flight data of a worldwide operating European airline where chosen. Therefore, data from a roughly 5-year (4 years and ten months) period, from March 2016 to the end of December 2020, of a cargo airline was provided. The utilized aircraft are Boeing B777-200 in a freighter version. It has a maximum take-off mass of around 347 800 kg, a maximum landing mass of 260 800 kg and a dry operating weight of around 141 600 kg. That explains a maximum resultant revenue payload capability of roughly 103 metric tons. Maximum fuel capacity for that version ~ 144 000 kg.

The operated network contains large airports, together with regional airports. The network destinations are a mix of short, medium and long-haul flights.

The data was provided in different reports. The following standard components of data analysis were done:

- Pre-processing - accounting for outliers, missing values and smoothing data,
- Summary - calculating basic statistics to describe the general position, scale and shape of the data,
- Visualisation - plotting data to identify patterns and trends.

The data were analysed to obtain information for other evaluation purposes—two ways of analysing fuel information. In the first step, available and valuable data and information from the airline reporting system are evaluated, together with background information on limitations. In the second step, a detailed evaluation is done for some unique routings based on information gathered in the first step. The evaluation was conducted with the help of Excel and MATLAB. For advantages and possibilities of MATLAB, compare, e.g. Saivenkatesh et al. (Saivenkatesh et al., 2020).

The evaluation and the consequences are not the focus of this paper, but the focus is on the amount of data and the processing of the information to meet the performance-based approach.

A starting point for possible relevant information can be found in ICAO Doc 9976, the Flight Planning and Fuel Management (FPFM) Manual. It provides a non-exhaustive list of data required to demonstrate performance-based compliance.

- *Actual versus planned taxi times;*
- *Taxi and ground delays;*
- *En-route speed restrictions (ATC, turbulence, etc.);*
- *En-route deviations (route and altitude for ATC, Wx, etc.);*
- *Air traffic delays experienced;*
- *ATC flow management and aerodrome capacity/congestion and demand;*
- *Runway closures or reductions in aerodrome capacity;*
- *Any ATC or aerodrome factors that could contribute to the planned fuel consumption being exceeded;*
- *100 per cent consumption of contingency fuel;*
- *100 per cent consumption of holding fuel;*
- *Low fuel state (as defined by operator or Authority);*
- *Minimum fuel state (as defined by operator or Authority);*
- *Emergency fuel state (as defined by operator or Authority);*

*• Less than final reserve fuel remaining;*
*• Actual versus planned time spent holding;*
*• Actual versus planned SID/STAR ground track flown (including portion of Point Merge STAR actually flown, if applicable);*
*• Missed approaches;*
*• Additional approaches;*
*• Proceeding to destination alternate aerodrome or diversions prior to destination;*
*• Proceeding to en-route alternate aerodrome (e.g. due to in-flight re-dispatch or re-planning);*
*• Ground-based approach facilities malfunctions;*
*• Destination or alternate aerodrome meteorological conditions below forecast conditions;*
*• Other factors or occurrences identified by the Authority or the operator as having caused delays, diversions, additional fuel consumption or other undesirable outcomes (ICAO, 2015).*

As shown above, GM2 CAT.OP.MPA.180 of Regulation (EU) No 965/2012 also contains similar parameters. ICAO Doc 9976 emphasises the special evaluation for respective city pairs. As seen from this SPI list, various information must be collected and stored for each flight. As mentioned, various reports are used for this purpose, two of which are presented by example.
As shown below, a large amount of information and data is simultaneously created, collected and stored during each flight. Filtering the necessary information while making data efficiently available for future flights is a challenge that can only be met with the support of appropriate software.

**Fuel Analyzer App Data**

The Fuel Analyzer App Data report contains data represented to the flight crews on the electronic flight back (EFB) application for fuel planning information. It is possible to choose a Flight number / City-Pair and get multiple information (e.g. Minimum, Maximum, Average, 25% Quantile, Median and 75% Quantile) for relevant factors like trip time deviation, PIC extra fuel uplift, company extra fuel uplift, fuel amount above legal reserve at touch down, fuel amount at touch down (actual, corrected only for tankering), tankering information, taxi out time, taxi out fuel, trip fuel deviation, extra fuel consumed, zero fuel weight (ZFW) fuel correction and taxi out fuel deviation. An overview is shown below.

The crew gets a recommendation for extra fuel, the share of flights that needed extra fuel, the number of flights considered and a general overview about the fuel status of the considered flights at the destination. It is possible to choose between 100% of all flights, 90% of all flights or to exclude invalidated flights. When compiling the information, it is possible to select equal or similar flight conditions and to consider or ignore the Cost Index.

The following information is provided in the Fuel Analyzer App. Data in the report is distinguished between original, general, and ZFW corrected values.

*Original*:
*Trip fuel deviation: planned trip fuel versus actual trip fuel*
*Company extra fuel uplift: extra fuel ordered by company (except tankering)*
*PIC extra fuel uplift: extra fuel ordered, calculated as actual off block fuel minus planned off block fuel*
*Extra fuel consumed: PIC extra fuel (ordered) minus extra fuel remaining (fuel above legal reserve at touch down)*
*Fuel at touch down (actual, corrected only for tankering): ACARS fuel message minus tankering*
*Above legal reserve at touch down: touch down fuel above legal reserve*

*ZFW corrected:*
*Trip Fuel deviation corrected: planned trip fuel* versus actual trip fuel* (ZFW corrected)*
*ZFW fuel correction kg*
*PIC extra fuel uplift corrected: corrected for ZFW deviation, displayed only if more than 200 kg or less than -200 kg*
*Extra fuel consumed corrected*
*Fuel at touch down corrected*
*Above legal reserve at touch down corrected*
*General:*
*Trip time deviation: taxi out time + flight time (planned vs actual)*
*Taxi out time: times from ACARS*
*Taxi out fuel: fuel consumption during taxi out from ACARS*
*Taxi out fuel deviation*
*Tankering: fuel ordered for economic reasons*

For a flight from Leipzig (LEJ) to East Midlands (EMA) on the 09th of May 2021, the crew would have been provided with the following general information:

*Without PIC extra fuel and without tankering an AVG: 10 370 kg [MIN: 6 800 kg, MAX: 30 294 kg kg] would have been available on touchdown at destination*
*Is PIC extra fuel recommended: False*
*Extra fuel needed percentage: 0*
*Number of flights considered: 83*

As described above, the Fuel Analyzer App is an application that is available to the crews and obtains the data from a system behind it. This data basis is presented in the next step.

**Excerpt of the Fuel Analyzer App Data**

During the flight planning, the crew used the collected and provided information, for example, for a flight from Hong Kong to Leipzig. Table 4 contains excerpts of the information; the following list contains the information for the crew. The information in Tables 4 and 5 is cut off behind the data contained in the original table, such as median, quantile 75, Bar Value1, Bar Value2, Bar Value3, Bar Value4, Bar Value5, Bar Value6, Bar Value7, Bar Value, for better presentation.

<u>Similar flight conditions</u>

> *Without PIC Extra Fuel and without tankering an AVG: 9 678 kg [MIN: 3 803 kg, MAX: 78 364 kg] would have been available on touchdown at destination*
> *Is PIC Extra Fuel Recommended: WAHR*
> *Extra Fuel Needed Percentage: 10*
> *Amount Of Flights Considered: 725*

*Table 4: Excerpt, HKG-LEJ, 06th May 2021*

| Measure | Min | Max | AVG |
|---|---|---|---|
| Trip Time deviation | -40 | 76 | -7.19 |
| PIC Extra Fuel Uplift corr | -96 665 | 8 133 | 1 058.8 |
| Company Extra Fuel Uplift | 0 | 4 000 | 53.86 |
| Above Legal Reserve @TD | -601 | 23 279 | 3 841.34 |
| actual Fuel @TD | 5 600 | 30 100 | 10 490.48 |
| Summary | 3 803 | 78 364 | 9 678.25 |
| Tankering | 0 | 20 000 | 259.78 |
| Taxi Out Time | 10 | 116 | 21.18 |
| Taxi Out Fuel | -98 700 | 2 600 | 706.62 |
| Trip Fuel Deviation | -99 201 | 6 108 | -469.85 |
| PIC Extra Fuel Uplift | -97 400 | 7 400 | 781.10 |
| Extra Fuel consumed | 0 | 2 990 | 51.20 |
| Trip Fuel Deviation corr | -99 200 | 6 108 | -469.85 |
| ZFW Fuel Correction kg | -2 994 | 2 737 | -934.42 |
| Extra Fuel consumed corr | 0 | 3 160 | 69.32 |
| Above Legal Reserve @TD corr | -993 | 23 959 | 3.559.24 |
| Fuel @TD corr | 5 687 | 30 042 | 10 208.37 |
| Taxi Out Fuel Deviation | -1 833 | 99 467 | 60.61 |

As can be seen, the crew can choose between the similar and the equal conditions. Table 5 shows the evaluation for the equal conditions; the information to the crew is listed below.

<u>Equal flight conditions</u>

> *Without PIC Extra Fuel and without tankering an AVG: 9.031 kg [MIN: 4.501 kg, MAX: 13.674 kg] would have been available on touchdown at destination*
> *Is PIC Extra Fuel Recommended: WAHR*
> *Extra Fuel Needed Percentage: 19*
> *Amount Of Flights Considered: 81*

*Table 5: Excerpt, HKG-LEJ, 06th May 2021*

| Measure | Min | Max | AVG |
|---|---|---|---|
| Trip Time deviation | -32 | 26 | -4.70 |
| PIC Extra Fuel Uplift corr | -269 | 5 834 | 1 467.58 |
| Company Extra Fuel Uplift | 0 | 1 225 | 15.12 |
| Above Legal Reserve @TD | -14 | 22 378 | 3 499.53 |
| actual Fuel @TD | 6 600 | 28 700 | 10 244.44 |
| Summary | 4 501 | 13.674 | 9 031.56 |
| Tankering | 0 | 20 000 | 246.91 |
| Taxi Out Time | 11 | 48 | 21.78 |
| Taxi Out Fuel | 400 | 2 100 | 944.44 |
| Trip Fuel Deviation | -3 412 | 2 891 | -78.09 |
| PIC Extra Fuel Uplift | -400 | 5 600 | 1 196.30 |
| Extra Fuel consumed | 0 | 1 549 | 95.81 |
| Trip Fuel Deviation corr | -3 412 | 2 891 | -78.09 |
| ZFW Fuel Correction kg | -2 961 | 2 498 | -860.89 |
| Extra Fuel consumed corr | 0 | 1 690 | 98.17 |
| Above Legal Reserve @TD corr | -480 | 21 661 | 3 226.14 |
| Fuel @TD corr | 6 133 | 27 983 | 9 971.04 |
| Taxi Out Fuel Deviation | -1 333 | 367 | -177.44 |

In total, an 18 by 15 matrix entry is created for each flight analysis. This relates to the connection for a city pair which shows the amount of information. With 20 aircraft flying between 2 and four sectors a day, you can see the large amount of data that is being collected.

**Fuel Analyzer App Reference List**

In another report, additional information is stored for each flight. The Fuel Analyzer App References List Report contains information for 31 315 flights, period 1st March 2016 to the end of December 2020. This report is, amongst other things, fed by planning information and return information sent from the aircraft. It contains planned (p), actual (a) and corrected (c) information. As planned figures are self-explanatory, e. g. scheduled departure time, actual figures are accurate figures, like actual departure time. Actual figures describe the figures as sent from the aircraft. The report contains corrected figures. Corrected figures describe the difference between planned and feedback figures based on the actual fuel decision and the flight payload. The Fuel Analyzer App References List comprises the data used to feed the Fuel Analyzer App. It contains: Flight Leg Event ID, Flight Designator, STD, ATD, STA, ATA, Month, Zero Fuel Weight (ZFW) Deviation Fuel, Off Block Fuel Deviation, Final Reserve Fuel, Min Alternate Fuel, Company Extra Fuel (p, c), Needed Extra Fuel (p, c), PIC Extra Fuel (p, c), Additional consumption for PIC Extra Fuel (c),
Is Extra Fuel Needed (p, c), Touchdown Fuel (a, c) Company Eco Tankering Fuel, Trip
Fuel (p, a, c), Taxi Out Time, Taxi Out Fuel (a, p), Above Legal Reserve At Touchdown
Fuel (a, c), Trip Time Deviation, Cost Index - this means a large amount of data.

Thirty-eight single entries are stored for every flight in the Fuel Analyser Analyzer References List. The number of entries adds up with the associated number of aircraft movements. In the area of long-haul flights in the investigated cargo flight sector, there were 20 aircraft with 2 to 3 flight segments per day. Therefore, an average of 40 new data sets were added per day. For example, 36 flights with respective entries were recorded on 13th December 2022. If the type of flight operation varies, e.g. short- to medium-haul passenger operations where each aircraft flies 4 to 8 sectors per day and the fleet is correspondingly more extensive, the number of data records generated will be more significant.

A lot of data is collected, stored and analysed for a flight. Fast and manageable evaluation is only possible with IT support. This can also be used to provide evidence of the requirements for SPI by Regulation (EU) No 965/2012.

IT systems such as eWAS Dispatch and eWAS pilot collect and process the amount of information per flight. For example, eWAS Dispatch provides continuously EFB Weather Awareness (Aircraft IT, 2022).

Position messages are reported every 20 seconds, with information such as altitude, speed, deviations from the flight plan or fuel situation.
In addition, information is exchanged between the operations centre on the ground and the aircraft. For a company with 20 aircraft in the air for between 15 and 16 hours, this amounts to approximately 8000 messages per day.

For the airline under consideration, this means for one year:

- 4 087 038 messages processed
- 58 213 electronic flight plans generated
- 638 963 eWAS (Positions, Progress and OOOI) messages processed
- 1 758 727 Aircraft Status Reports generated

The manual evaluation and monitoring of this data, 24 hours a day throughout the year, is no longer possible.

In the meantime, commercial providers offer the possibility of using off-the-shelf software to give crews in the air and dispatchers on the ground the comprehensive possibility of planning and executing flights with a uniform programme. In particular, the possibility of almost immediate communication between the crew on board and the ground crew makes it possible to react to unforeseen events.

The connection between aircraft in-flight and dispatch personnel on the ground becomes increasingly important (SITA, 2023b).

*During the coming three years, airlines will continue to drive investments in emerging technologies. The top four priorities remain the same, as airlines focus on data management to enhance their business models and operational efficiencies through technologies such as business intelligence software (74%), data exchange technologies (82%), artificial intelligence (76%), and Radio Frequency Identification (RFID) tracking (80%). Two areas look set for significant growth in the future, despite showing low implementation at the present moment. Airlines have doubled R&D plans for Near Field Communications (57%) and 'augmented/virtual reality tech'(42%) suggesting they have the potential to become areas of focus in years to come (SITA, 2023a).*

**CONCLUSION**

Operational regulations in aviation are adapted to take account of the reliability of aircraft, better avionics and possibilities out of it, and technical developments in-flight monitoring and communication with the crews on board. The collection and processing of large amounts of data, using appropriate IT hardware and software, allow the definition and control of safety performance indicators and move away from prescriptive regulations towards performance-based approaches.

Operators with appropriate safety levels can apply more tailored provisions. This requires the demonstration of the safety level. This is achieved by defining specific safety performance indicators (SPIs), compliance with which is then continuously monitored and evaluated during operation. This requires the collection and evaluation of correspondingly large amounts of data. This is only possible using appropriate IT applications. The example above shows the amount of data that accumulates during flight operations. Recording, processing and saving pose a challenge in this respect.

Implementing the latest technologies for flight planning operations offers advantages. Improved process management, decision-making and profitability are possible through modern IT systems. This can reduce the amount of fuel used, thus reducing emissions and costs. At the same time, flight availability can be increased and regulatory compliance granted.

If the operator makes the necessary effort, he can apply a basic with a variation or individual fuel scheme. This, in turn, enables operational advantages, plus saves fuel and thus emissions.

The use of artificial intelligence is one of the challenges but also one of the options that can help companies meet the numerous regulatory requirements. In some cases, companies are taking the first steps in this area (Travelnews, 2023), but further research is necessary.

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