The New Flight Efficiency Performance Approach: Partitioned Efficiency Indicator

Antonio Lazarovski
ATOS
Brussels, Belgium
antonio.lazarovski@atos.net

***Abstract*— The consequences of the air traffic growth on the environment have been recognized by the Report of The Wise Persons Group on the Future of the Single European Sky as a key challenge in the aviation sector today. Limited capacity of the ATC sectors leads to an increased flight trajectory length and results in increased CO2 emissions. The invention of performance indicators to promote the identification, data-driven decision-making and measurement of strategic goals in different areas is necessary in order to provide ATM solutions. Inventing new approaches to measuring efficiency is important to identify abnormal behaviour and concealed influences. The Partitioned Efficiency Indicator (PEI) has been developed to construct a robust metric for efficiency analysis and to provide the opportunity to isolate inefficiency spillage between multiple areas. This indicator introduces an approach that can be used for combining the horizontal and vertical component of efficiency while taking into account user preferred baseline for comparison. To demonstrate this capability, flight trajectories from an open source in the period of three days have been chosen for analysis.**

Keywords-efficiency, indicator, area, spillage, performance.

I. Introduction

Enhancing the performance of Air Navigation Services (ANS) relies heavily on measuring it accurately. This was established by the International Civil Aviation Organization (ICAO) by defining a performance-based approach built on three principles: focus on desired results, performance-based decision making and reliance on facts and data for decision making [1]. This approach emphasizes on understanding performance as a key factor to move forward by: assessing current state, then identifying and addressing found gaps, and finally developing options and objectives for operational improvements [1].

The European Parliament and Council of the European Union (EU) adopted Regulation no. 549/2004 defining the framework for Single European Sky (SES), with a goal to enhance Air Traffic Management (ATM) performance related to safety, efficiency and capacity in the EU [2]. With Regulation no. 691/2010, the scope was extended to the ICAO European (EUR) and African (AFI) regions where necessary measures, defined as performance and key performance indicators (KPI), were established to improve performance [3]. Regulation no. 390/2013 has further developed the established measures, specifically in the environment area, allowing for local performance monitoring [4]. Additional performance measures for monitoring network performance have been defined in the latest Regulation no. 317/2019 [5]. A performance scheme was established to set targets in the key performance areas (KPA) through the adoption of European Union-wide performance targets and approval of consistent National or Functional Airspace Blocks [4].

The ICAO EUR region Performance Framework Document (ICAO EUR Doc 030) was issued to support the future developments of the EU Performance Scheme by defining: scope, roles, metrics and monitoring processes [6]. According to ICAO's manual on global ANS performance, a performance indicator should present current/past performance, expected future performance and actual progress in achieving performance, while considering a performance objective. It can be measured directly or from supporting metrics through clearly defined formulas [1].

The environment and efficiency, as key challenges in aviation today, are being measured through CO2 emissions and Horizontal Flight Efficiency (HFE), as described within the performance framework document in 2019 and the SES Performance Scheme regulation. Several other indicators (such as 3Di [7]) based on the HFE methodology have been established by Air Navigation Service Providers (ANSP) used to assess performance with a different setting.

The need for inventing an approach of measuring efficiency of multiple aspects at once, per area, applicable to dynamic baseline has emerged. A concept like this would allow assessment considering different user requirements, while making it possible to understand how efficiency is transferred from one area to another.

The objective of this research is to propose a new approach of measuring efficiency of the ANS performance. This is by defining an indicator that can be used to address both the currently measurable (e.g. HFE) and overlooked parts of the current ANS performance framework in the environment/efficiency KPA. This study examines partitioned efficiency, by decomposing the flight path and reconstructing an indicator to reflect the unbiased performance and the potential spillages between areas. The procedure involves the methodology for the calculation of the Network Partitioned Efficiency Index (NPEI), Local Partitioned Efficiency Indicator (LPEI), Absorbed Deviation (ADEV), Transferred Deviation (TDEV) and Given Deviation (GDEV). The analysed use-case describes the application of the indicators on operational flight data within the ECAC[1] area.

II. Background

Defining flight efficiency can be considered as challenging as defining an optimal flight path which in many cases is different depending on users or their specific goals in a given time. The optimal flight path often involves different trade-offs in different scenarios: fuel cost vs. time cost, distance flown vs. time flown and/or noise vs. emissions, thus making it complex to define one single value that will reflect all and everyone's requirement [8].

The struggle of defining a baseline means that whichever is considered, a 100% efficiency is often impossible or undesirable to achieve due to trade-offs with other KPAs such as safety [9].

A. *Overview of the HFE indicator*

Within ICAO and the EU the proposed KPI for measuring environmental performance in the horizontal plane is the En-route HFE, measured using the flight plan or the actual flight path [4][6] and it is defined as follows: "comparison between the length of a trajectory and the shortest distance between its endpoints" [10].

One of the great advantages of the HFE over old methodologies is that it offers the possibility of calculation per area, meaning that parts of the trajectory of a flight can be evaluated separately [10]. Another big advantage of this methodology is that it considers the network component as much as the local inefficiencies [10]. The algorithm behind it uses multiple measures and combines them into a single value showing the area efficiency individually [10][9]. It is based on the achieved distance metric (H), which is the average of two values: achieved remoteness (r) - showing how much a flight is getting further from its origin (O) and achieved approach (a) - showing how much a flight is getting closer to its destination (D) [10].

For a specific example as shown on the Figure 1, where the origin is denoted by "O", destination by "D", achieved remoteness by "r", achieved approach by "a", and the flight path of interest by "NX": the ratio between the flown distance and achieved distance gives the HFE value using (1) and (2) as shown below:

$$H = \frac{1}{2} * (a + r) \quad (1)$$

$$HFE = \left(1 - \left(\frac{NX}{H} - 1\right)\right) * 100\% \quad (2)$$

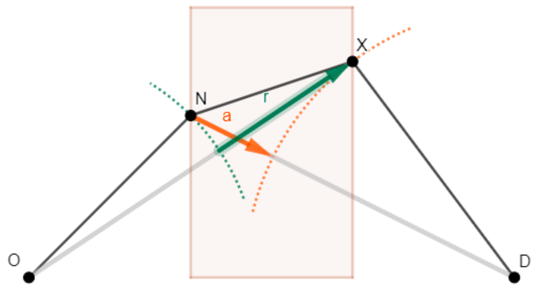

Figure 1. HFE methodology

Even though in many cases in aircraft flight management the optimum route is defined as a compromise between the shortest, cheapest and fastest, depending on airline preference and considering the variety of inputs, the baseline component for HFE is chosen to be the great circle distance between the origin and destination, due to it giving a constant baseline throughout the years [11].

This indicator considers only the horizontal plane and does not show the vertical profile performance.

B. *Vertical flight efficiency*

A separate metric to address the vertical aspect of flight efficiency has been developed by the Performance Review Commission (PRC) [12]. This Vertical Flight Efficiency (VFE) assesses the impact of procedures like Continuous Climb Operations (CCO) and Continuous Descent Operations (CDO), without taking levelled/cruise flight phase into account [12]. The indicator shows time and distance flown level within 200NM in climb and descent operations of the destination airport [12].

C. *3Di NATS flight efficiency indicator*

The United Kingdom service provider has developed the "3Di" indicator to show the three-dimensional flight efficiency. The 3Di Score combines measures of track extension with vertical efficiency to predict fuel efficiency, as shown in (3) where φ is 3D score, H is HFE, V_{CL} is vertical inefficiency of climb, V_{CR} is vertical inefficiency of cruise, V_D is vertical inefficiency of descent, and β_1, β_2, β_3 and β_4 are weights [7].

$$\varphi = \beta_1 H + \beta_2 V_{CL} + \beta_3 V_{CR} + \beta_4 V_D \quad (3)$$

The HFE is calculated using the HFE algorithm, and the VFE is calculated for: climb, cruise and descent separately [7]. These four measures give one value that shows fuel efficiency. To determine the fuel efficiency, the fuel used in a modelled optimal trajectory is used as a reference for comparison [7].

Since HFE methodology is used for the calculation of 3Di, it can be assumed that both indicators share the same core properties.

[1] An intergovernmental organisation (44 Members States in 2010) active since 1955 in promoting the co-ordination, better utilisation and orderly development of European civil aviation in the economic, technical, security and safety fields

III. Partitioned Efficiency Indicator

A. *Inspiration*

Several areas for improvement of the current efficiency indicators have been identified. The most common are the ability to measure against a dynamic baseline and to identify inefficiency spillage between neighbouring areas, which are to be discussed further in the paper. The goals of this research are to create a new flight efficiency indicator that will:

- show an isolated quantity per area;
- consider the network component;
- show inefficiency spillage between neighbouring area;
- allow for an optimal dynamic user preferred reference trajectory;
- establish an architecture for combining horizontal and vertical flight efficiency.

B. *Approach*

To simplify the initial description of the concept, the optimal trajectory of a flight involves the distance-based optimal flight trajectory, taking the great circle connecting the origin and destination as a reference for comparison. Even though it is acknowledged that the optimal trajectory varies based on user preferences, the distance-based approach offers a static reference for the comparison throughout different regions and time periods. This concept allows to apply a user defined reference, such as the Cost Index (CI), in which case the calculated efficiency could show the deviation from the flight path defined by the optimal CI.

As visible on Figure 2, the instant optimal path (IOP) for a flight is dynamic and its direction changes continuously throughout a flight path, while the IOP at its origin is equal to the absolute optimal path (AOP). The PEI approach considers a static reference system (SRS) based in the flights origin, to decompose the flight path into two components: “approach” - x component and “deviate” - y component. It considers the ratio of deviate and approach to show, how much, for a given segment, the aircraft got away from its destination versus how much closer it got at the same time. In terms of the SRS, it shows efficiency as a ratio of two quantities, the projection of the travelled distance on the x axis which contributed to the flight getting closer to its destination, and the projection on the y axis that didn’t contribute to getting closer to the destination (perpendicular to AOP).

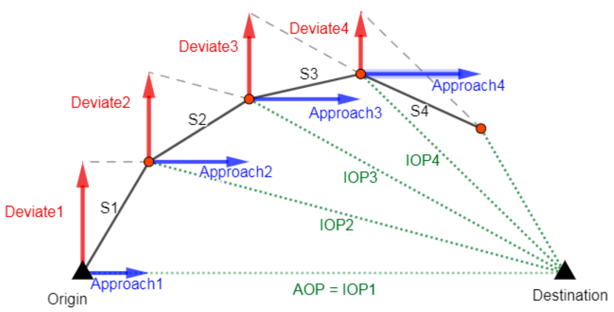

Figure 2. Representation of the IOP

The PEI approach can be applied to calculate the Network Partitioned Efficiency Indicator (NPEI) indicator which analyses performance of an area by considering only entry and exit points, and the Local Partitioned Efficiency Indicator (LPEI) which focuses on local performance within an area, both of them discussed further on in the paper.

C. *Conceptual design of NPEI*

One flight path crossing three neighbouring areas is considered to exemplify the conceptual design of this indicator. In all examples the flight’s current position is at the entrance of the middle area that is referred as “current” area, the first area in the sequence is referred as “previous” area, while the third area in the sequence is referred as “next” area. The word area refers to a 2-dimensional polygon. The great circle line connecting the origin and destination of the flight will be referred as absolute optimal path (AOP). The great circle line from the current position of the flight towards its destination will be referred as instant optimal path (IOP). The flight origin point is denoted by O, destination point by D, entry and exit point from current area as E and L, current area as A, intersection points between the IOP and the current area as IL, intersection points between the AOP and the current area as GE and GL for the entry and exit respectively. The flight path is decomposed using static reference system with its centre based in the O point, where its X axis is aligned with the AOP and its Y axis is perpendicular to the AOP. Three scenarios are described to fully show the interdependencies between the measures. The following measures will be considered:

a) *Px – produced approach;*
b) *Py – produced deviation;*
c) *Gy – given deviation;*
d) *Ty – transferred deviation;*
e) *Ay – absorbed deviation;*
f) *Cy – complete deviation;*
g) *Iy – inherited deviation.*

As shown on Figure 3, Figure 5 and Figure 4, when a flight enters the current area at a certain distance from the AOP, it can be deduced that a certain amount of inherited deviation Iy comes from previous area. Using the same logic if a flight exits the current area at a certain distance from the AOP, it can be deduced that a certain amount of deviation will be transferred

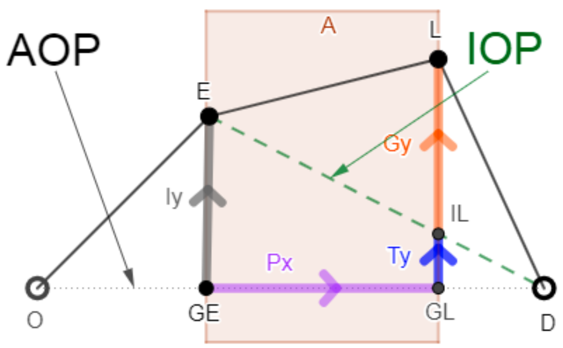

Figure 3. Scenario 1

founding members
EUROPEAN UNION
EUROCONTROL
9th SESAR Innovation Days
2nd – 5th December 2019
ISSN 0770-1268

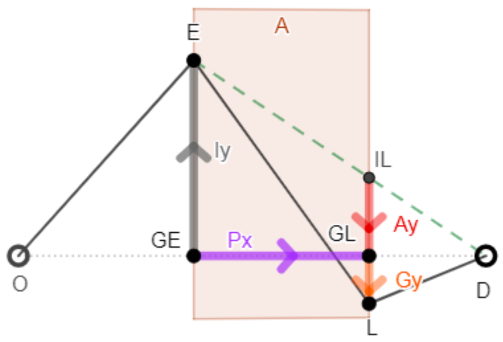

Figure 5. Scenario 2

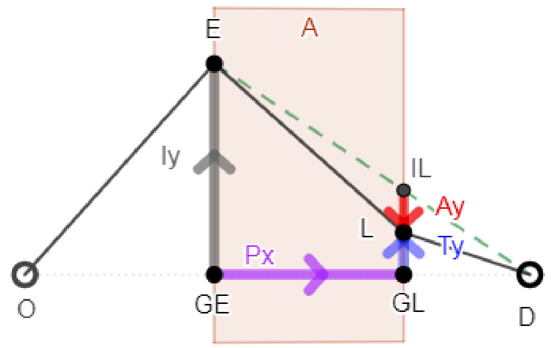

Figure 4. Scenario 3

to the next area. Depending on the geometry of the path within A, the inherited deviation can increase or decrease by approaching the destination.

In scenario 1 this inherited deviation is completely transferred to the next area by a certain amount Ty, since the current area did not absorb it. There is a contribution to the complete deviation Cy by the current area denoted by Gy. This is a measure of the contribution of the current area on the complete deviation Cy that is accepted by the next area in the sequence. Whenever an area doesn't bring the flight aligned with its IOP it creates deviation Gy that goes to the next area in the sequence. In this case, the complete deviation Cy from the current to the next area in this case is equal to the sum of given and transferred deviation of the current area.

In scenario 2, the current area managed to bring the flight across the AOP, and by making so completely absorbing the inherited deviation by the amount Ay. In this scenario there is no transferred Ty deviation, although by moving away from the AOP after crossing it, a contribution from current area is created, denoted by Gy. Here part of the produced deviation Py of current area is used to absorb the transferred deviation Ty and add the Gy, which is the only exported to the next area in line. The complete deviation Cy in this case is equal to the Gy since all of the inherited deviation was absorbed by the current area.

In the third scenario, the current area manages to get the flight to exit between the AOP and IOP, making it partially absorb the inherited deviation by a certain amount Ay, and transfer some deviation Ty to the next area. In this case there is no given Gy deviation from area A to the next area since the produced deviation is towards the AOP and did not absorb the transferred deviation. In this case the complete deviation Cy is equal to the transferred deviation from the previous area Ty.

In a scenario when an area manages to bring the flight to exit on a point that lays on the AOP, the transferred deviation drops to zero since the current area manages to absorb everything, meaning there is no exported deviation to the next area.

In all three scenarios the NPEI indicator is always the ratio of two measures, approach Px and deviation Py. The Px is always oriented from the GE toward GL and is always aligned with the AOP, while the Py is always calculated from the IOP toward the exit point of the area L and aligned with the perpendicular line of the AOP. These two values are used to define a quantity by dividing the deviation with the approach component giving an understanding of how performant the flight path is. The NPEI indicator emphasizes on expressing the state within the area of interest without external influences, but by taking into consideration how well this area performs considering the origin and destination.

The final form of the proposed indicators is shown with (4), (5), (6) and (7).

$$NPEI = \frac{\sum P_y}{\sum P_x} * 100\% \tag{4}$$

$$ADEV = \frac{\sum Ay}{\sum Cy} * 100\% \tag{5}$$

$$GDEV = \frac{\sum G_y}{\sum Cy} * 100\% \tag{6}$$

$$TDEV = \frac{\sum T_y}{\sum Cy} * 100\% \tag{7}$$

The NPEI indicator shows the efficiency within a certain area while isolating all influences from previous areas. It describes the ratio of how much closer versus how much further away, flights within a certain area have progressed.

The ADEV indicator shows the amount of absorbed versus complete deviation of an airspace. It is a measure that is independent from NPEI, but together both can indicate the combinations of whether an area is efficient or absorbent.

The indicators GDEV and TDEV show the percentage of given and transferred deviation relative to the complete exported deviation from an area and can be used in combination with NPEI and ADEV to provide a deeper understanding of efficiency performance.

D. Local efficiency concept

The local efficiency within an area can also be calculated using the LPEI methodology, shown on Figure 6.

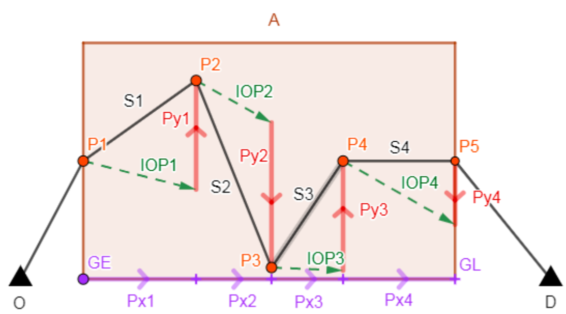

Figure 6. LPEI methodology

If there is an area of interest A, the LPEI showing the inner efficiency can be calculated by considering all approach and deviation components of every individual segment of the flight path. The end value can be calculated using the same approach as the NPEI, using (8), where A indicates the name of the area of interest.

$$LPEI = \frac{\sum Py_A}{\sum Px_A} * 100\% \qquad (8)$$

E. Obtainable potential

The possibilities of this approach allow for measuring efficiency using a manually calculated optimal path that does not necessarily need to follow the absolute optimal path. In many cases a custom path optimizing time or CI can be used as a baseline, like shown on Figure 7.

The optimal trajectory is shown by the segments O1, O2 and O3, while the flown trajectory is shown with S1, S2 and S3. Considering the "current" area, the IOP is not the line connecting the entry point E with the destination but the line connecting the current entry point E with the exit optimal point OL. Considering this, the distance between the optimal exit point OL and the actual exit point L is the produced deviate, while the produced approach is equal to the distance between the GE and GL. The IOP of the "previous" area is equal to the O1 segment while the IOP of the next area is equal to the S3.

Another possibility to consider is the application of the proposed approach to calculate vertical flight efficiency. A necessary requirement would be definition of the optimal vertical profile using a defined set of constraints. Any deviation from the optimum can afterwards be calculated using the decomposition technique and via the ratio of the y and x component, a final percentage defining the efficiency can be computed. Although the possibility of combining horizontal and vertical efficiency is possible using this approach, there comes the question of assigning the correct weights of whether horizontal or vertical efficiency is more important for the final metric. If this is to be defined than a single value for the complete flight efficiency can be calculated.

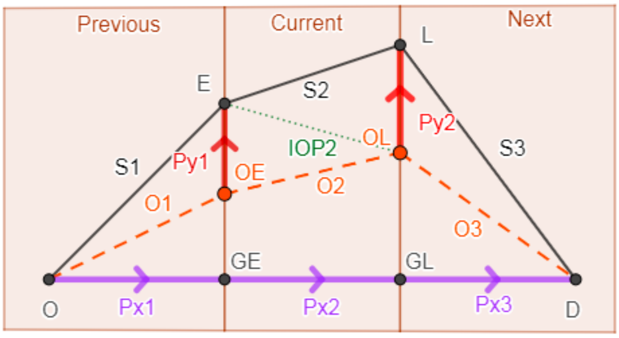

Figure 7. PEI methodology on custom optimal path

F. Comparison to the current HFE approach

To show the potential for improvement, both PEI and HFE methodologies have been used in the example shown on Figure 8 to compare the output and display the corrections. The efficiency scores are shown on TABLE 1.

A flight from O to D has chosen three alternative paths: case 1, case 2 and case 3 denoted by segments S21, S22 and S23. The focus here is to examine the performance of current area for all three cases using both HFE and PEI approach. Intentionally, segment S22 was made to follow the direct distance from E to D, S23 exits current area on the AOP and proceeds to D aligned with it, S21 proceeds parallel to the AOP until the exiting current are and then follows the direct to D. The segments S21 and S23 have the same length.

Using the en-route HFE methodology the efficiency of the segments S21, S22 and S23 has been calculated and is approximately: 78%, 73% and 45% respectively. The HFE indicator for this specific example shows misleading results since all segments start at a certain distance from the IOP, which is the baseline for the indicator. The HFE optimal path is not the one leading towards the destination but the one leading away, parallel to the IOP. In this case, the current area has the highest efficiency when it directs the flight away from the destination, through L1, parallel to the AOP. Obviously the optimal and most efficient flight path should have been through L2 leading directly towards the destination, however this scenario shows an efficiency decrease of 5 percentage points compared to S21. The 3rd option given by segment S23 has the lowest efficiency and almost half than the one of S21.

TABLE 1. EFFICIENCY SCORES

	HFE[%]	PEI[%]	GDEV[%]	ADEV[%]	TDEV[%]
1	78,32	50	50	0	50
2	73,34	100	0	0	50
3	44,75	50	0	50	0

Using the newly proposed indicator it can be seen that S22 is the best option giving 100% efficiency since it offers the most direct path, giving the overall shortest to fly distance, out of all options. The other two segments S21 and S23, overall, offer the same distance to fly to D, and considering only CA they both have the same "deviation" and "approach". These two cases produced deviate which is half the amount of the approach resulting in a 50% efficiency within the current area.

Another benefit of the new approach is that indicators GDEV, ADEV and TDEV can be used to assess the transfer of deviation from one to another area. This can show whether an area had low efficiency due to absorbing deviation or due to adding deviation on top of the deviation received from the previous area.

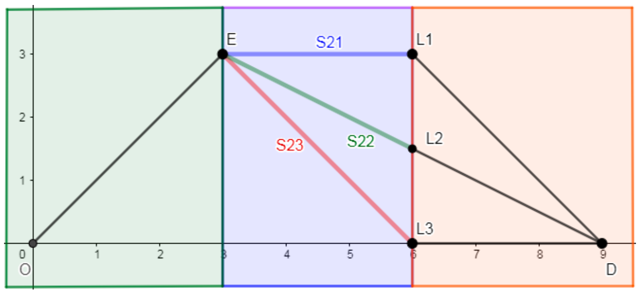

Figure 8. HFE vs PEI, GDEV, TDEV and ADEV comparison

In case 2, the current area is the most efficient but cannot remove the transferred deviation from the previous area, so it sends it to the next area. This shows that the current area can have high efficiency and still transfer deviation to the next area. This is due to inheriting deviation from another area that the flight crossed before this one. When an area receives deviation from the previous area and is sending the flight along its IOP it will never be able to remove the transferred deviation. Case 1 and case 3 produce the same PEI efficiency, but for the next area, the case 3 seems as a better option seeing that it exports 0 deviation. In this case the current area had low efficiency, but this was because it was used to absorb the transferred deviation from previous airspace towards the next. This clearly shows that even though an area might be well performing it could still send a flight highly deviating from its AOP towards its destination.

IV. Experiment And Results

A. Data inputs

In order to compute indicators, data on airports, flight trajectories, and airspace areas were needed. For this use case, data has been downloaded from ICAO's API[2] service, which is freely available. The airport dataset includes 1485 airports while the area definitions contain data for 258 countries. Out of the full set, 148 airports and 33 states within ECAC have been used.

The reference trajectory data has been extracted from EUROCONTROL PRUs Github portal [13]. This trajectory data is produced by the PRU[3] to allow different stakeholders to compute performance indicators or reproduce already established ones published by the PRU [13]. Reference trajectory data takes as input the following sources of data: ADS-B[4], CPR[5], APDF[6] and NM[7] environment data, in order to produce a merged dataset with higher accuracy than any of the individual sets alone [13]. The available set of 3 days of data was used, including the period from 2017-08-01 to 2017-08-03, inclusive.

B. Data processing

The overall process of computing the indicators included interpolation of the reference trajectory point profiles on a 1-second interval. The points with the earliest time in each area were kept. This created a single point per area profiles containing only entry points. The exit points referring to the IOP and the AOP were calculated as intersections of great circle lines. The full processing of the data was done in R/RStudio, and the library Geosphere was used for spatial calculations.

Filter was introduced on the reference trajectory data to ensure that the scope of this study remains within the ECAC area. For this purpose, only flights departing and arriving within the ECAC area were analysed. To remove the TMA[8] flight portions from the analysis, trajectory data within the departing and arrival countries were removed. This was done to reduce the impact of arrival and departure operations on the flight efficiency indicators. Another filter on the reference trajectory data was that only flights crossing at least 10 countries within the ECAC were considered for the analysis. This was done to ensure good coverage of the area of interest and exclude short/in-country flights. The total set of flights contains 2846 trajectories. The HFE, NPEI, GDEV, ADEV and TDEV were calculated for the given trajectories.

C. Results

The purpose of this use case is to highlight the improved areas of the current methodology. A better assessment of the performance using NPEI and HFE would require a representative sample, or a significantly bigger data sample that wouldn't be influenced by special occurrences such as adverse weather or traffic complexity.

Noticeable difference between the NPEI and HFE distribution can be seen on Figure 9. The current HFE methodology ranks Sweden with lowest performance, while using the improved NPEI approach the country with lowest efficiency is Switzerland.

Focusing on Sweden on Figure 10, it can be seen that by comparing the approach, deviation and HFE values per flight, in most cases when the approach and deviation component are relatively small, HFE underestimates efficiency.

Considering Figure 12, by implementing the new indicator, states like Cyprus, Latvia and France will experience the most benefits in terms of precisely defining their performance in terms of efficiency. According to previously discussed

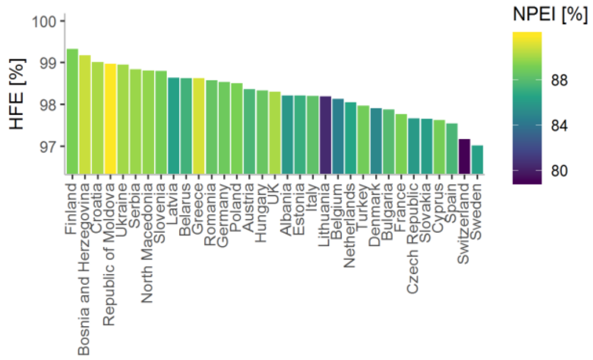

Figure 9. HFE vs NPEI

---

[2] Application Programming Interface (API) is a set of functions and procedures allowing the creation of applications that access the features or data of an operating system, application, or other service.

[3] Performance Review Unit (PRU) is part of the EUROCONTROL Agency responsible for monitoring and reviewing the performance of the Pan-European ANS system across a number of key performance areas

[4] Automatic Dependent Surveillance – Broadcast (ADS–B) is a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it

[5] Correlated Position Report (CPR) is a radar position report from Air Traffic Control which contains information about the flight it is associated to.

[6] Airport Operator Data Flow (APDF) provides departure and arrival data on a per airport basis

[7] Network Manager means the body entrusted with the tasks necessary for the execution of the functions referred to in Article 6 of Regulation (EC) No 551/2004 **Error! Reference source not found.**

[8] Terminal Airspace (TMA) is Control Area normally established at the confluence of ATS Routes in the vicinity of one or more major aerodromes

ISSN 0770-1268

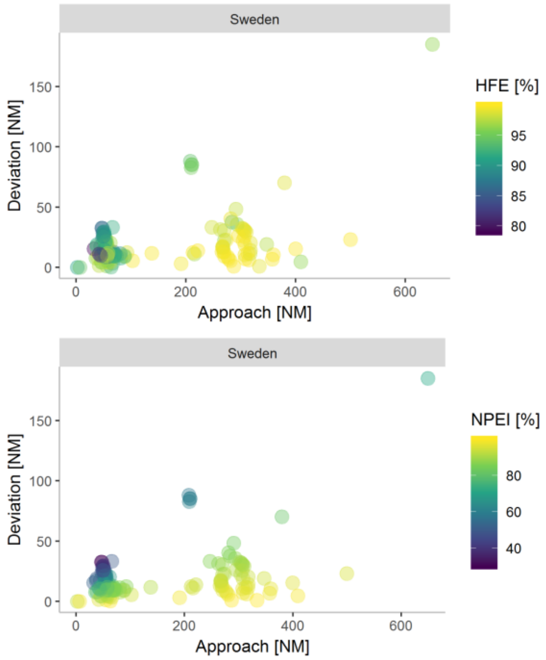

Figure 10. Sweden comparison approach/deviate vs HFE

scenarios, the cases with most improvement will occur when the flight approaches the AOP rather than following the IOP.

This can be calculated using the ADEV and TDEV indicator shown on Figure 11 and Figure 13. It shows that Sweden has relatively high absorption meaning that flights are directed more towards AOP than towards IOP, for which a simplified example was shown on Figure 8 via segment S23.

It can be seen that the assessment of these cases was optimized using the NPEI indicator.

As shown, the efficiency should only depend on the ratio between the approach towards the destination point and the deviation from this optimal path, ranking Moldova as the best performing.

Figure 12 shows average values of efficiencies calculated using both methodologies. It shows which countries have been repositioned after optimization. Turkey is absorbing the maximum amount of deviation but is still better than average performing according to NPEI. This same country, using HFE, was ranked among the countries with lowest efficiency scores due to the effect described on Figure 8 as segment S23. Lithuania, as well, absorbs most of the deviation, but in exchange performs low. This same country, using HFE, had an almost average score.

Switzerland transfers high amounts of deviation to next areas and has relatively low NPEI value, having a similar rank as when compared to the HFE value.

Overall, few states kept their rank, while many states shifted ranks noticeably when using the new efficiency approach.

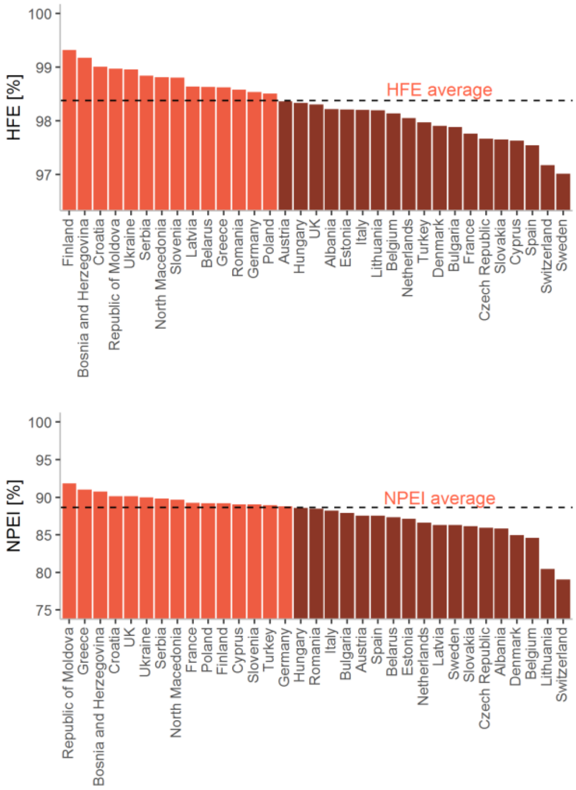

Figure 12. Average HFE and NPEI

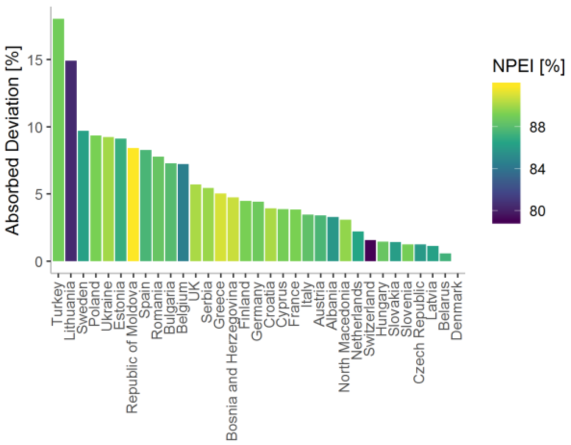

Figure 11. Absorbed deviation by country

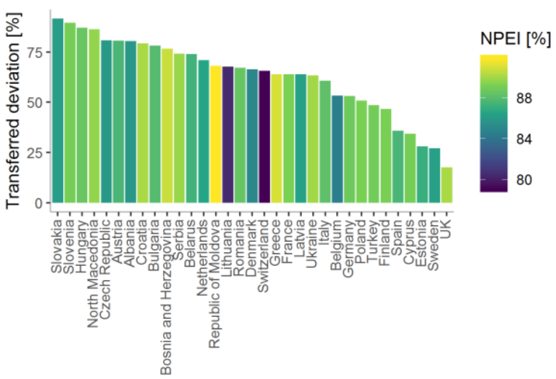

Figure 13. Transferred deviation by country

V. Further Steps

Initially, the use case on which the current methodology could be tested could involve post operations analysis to assess the effects of implementation of ATM solutions such as Free Route Airspace, Flexible Use of Airspace FUA and other.

One possible upgrade to the proposed PEI approach could be the development of a universal indicator which would consider all vertical, horizontal and local flight efficiency. In addition, the integration of the complementary deviation indicators demonstrating efficiency spillage could be also considered as potential improvement.

Moreover, the application of the PEI approach for calculation of emissions in both the approach and deviation directions could be investigated in the future. This could potentially result in a final measure which will include the ratio of emissions during the deviation and the emissions during the approach, which is expected to show harmful effects on the environment.

Further assessment and ultimate acceptance by the ATM stakeholder community could potentially lead to inclusion of the new PEI methodology into the ICAO's performance indicator catalogue.

Conclusions

The need for invention of indicators to support the identification, decision-making and performance review has emerged with the increase in complexity and environment effects of aviation. A number of existing efficiency indicators have been analysed to address overlooked areas with potential for improvement. Such points of interest were discovered in cases where the trajectory is parallel to the great circle connecting the origin and the destination, or generally when trajectory is misaligned with the instant optimal path to the destination. This paper introduces a new PEI approach of breaking down flight segments into approach and deviation components. Considering that an ideal optimal path to destination changes its direction at every new flight point, it has to be calculated at every reported position of the aircraft. The two measures are always expressed in a reference system based in the flights origin with an x axis pointing towards the flights destination. This allows for calculation of the distance flown along the great circle and distance flown along the perpendicular line to the great circle starting from its instant optimal path to its actual flown path.

Another benefit of the new approach is that different parameters (indicators GDEV, ADEV and TDEV) can be used to assess the transfer of deviation from one to another area. This can show whether an area had low efficiency due to absorbing deviation or due to adding deviation on top of what it already has received from the previous area.

The provided use case shows that the NPEI indicator calculates efficiency by taking into account many influencing factors such as efficiency spillage between neighbouring areas and absorption of deviation. As such, it can be said that the indicator expresses the intention of the associated performance objective.

Other design advantages of PEI allow for measuring efficiency considering user requirements as opposed to the single possibility of the current methodology to measure relative to the great circle connecting an origin and destination. The architecture to combine horizontal and vertical flight efficiency was successfully established using PEI. The further development to combine horizontal and vertical flight efficiency into approach and deviation components resulting in a single metric will ultimately bring possibility to express methodology benefits in 3D. The calculation of emissions as a ratio between approach and deviation will open opportunities for comparison between areas of different sizes and properties, as an improvement to current possibilities.

Disclaimer

The views expressed herein are the authors based on the research that lead to this paper and shall not be confused with the official views or policy of ATOS.

References

[1] ICAO, 2009, Manual on Global Performance of the Air Navigation. 1-th edition. Montreal, Canada

[2] The European Parliament and the Council of the EU, 2004. Regulation (EC) No 549/2004 Of The European Parliament And Of The Council of 10 March 2004. Official Journal of the EU.

[3] European Commission, 2010. Commission Regulation (EU) No 691/2010 of 29 July 2010. Official Journal of the EU.

[4] European Commission, 2015. Commission Implementing Regulatin (EU) No 290/2013 of 3 May 2013. Official Journal of the EU.

[5] European Commission, 2020. Commission Implementing Regulation (EU) No 317/2019 of 11 February 2019. Official Journal of the EU.

[6] ICAO, 2017, Implementation of ICAO EUR Performance Framework, ICAO EUR Regional Performance Framework Workshop, Brussels (Belgium).

[7] NATS, 2015 (January), Flight Effciency Metric Calculation and Annual Review Protocol

[8] Dalmau R., Melgosa M., Vilardaga S., Prats X., 2018, A Fast and Flexible Aircraft Trajectory Predictor and Optimiser for ATM Research Applications, ICRAT 2018 Barcelona (Spain).

[9] PRC, 2019 (June), Performance Review Report 2018, EUROCONTROL. Brussels (Belgium).

[10] Guastalla G., 2014 (July) Performance Indicator – Horizontal Flight Efficiency, EUROCONTROL Performance Monitoring and Reporting.

[11] Kettunen T., Hustache J., Fuller I., Howell D., Bonn J., Knorr D. 2005 (June) Flight Efficiency Studies in Europe and the United States, Baltimor (USA).

[12] Guastalla G., Peeters S., 2017 (January), Analysis of En-Route Vertical Flight Efficiency, EUROCONTROL Performance Monitoring and Reporting.

[13] Spinelli, E., Koelle, R., Zanin, M. and Belkoura, S. 2017 (November). Initial Implementation of Reference Trajectories for Performance Review. Proceedings of the 7th SESAR innovation days. Belgrade (Serbia).

[14] European Commission, 2019, Commission Implementing Regulation (EU) No 123/2019 of 24 January 2019. Official Journal of the EU

[15] DG MOVE, 2019 (April), The Report of the Wise Persons Group on the Future of the Single European Sky. Official Journal of the EU