CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Transportation Sciences

Department of Air Transport

Relevantnost evropské výkonnostní politiky v době krize

Currency of the European performance policy in the times of crisis

Bachelor's Thesis

Study programme: Technology in Transportation and Telecommunications

Study field: Air Traffic Control and Management

Supervisor: Ing. Terézia Pilmannová, MBA

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BACHELOR'S THESIS ASSIGNMENT

(PROJECT, WORK OF ART)

Student's name and surname (including degrees):

Fanglin Wang

Study programme (field/specialization) of the student:

bachelor's degree – LED – Air Transport

Theme title (in Czech): **Relevantnost evropské výkonnostní politiky v době krize**

Theme title (in English): Currency of the European performance policy in the times of crisis

Guidelines for elaboration

During the elaboration of the bachelor's thesis follow the outline below:

- The goal of the bachelor thesis is to analyze the currency of the European performance policy set for the Air Navigation Services Providers with regards to the crisis the aviation sector is currently experiencing. Further goal of the thesis is to propose performace indicators that would be more suitable in the context of the crisis as well as in the context of the European Green Deal and the technological advancement Air Navigation Services are experiencing
- Further requirements on the bachelor thesis are as follows:
- Analysis of the issues, description of impact of the crisis on aviation stakeholders
- Limitations indentification of the current European performance policy
- Proposal of future performace areas more suitable fot the assessments
- Proposal of the assessment process

Graphical work range: according to the instructions of thesis supervisor

Accompanying report length: minimum of 35 text pages (including figures, graphs and sheets which are part of the main text)

Bibliography: Single European Sky 2+, https://ec.europa.eu/transport/modes/air/ses_en

Commssion IR (EU) No 390/2013, http://data.europa.eu

https://ansperformance.eu

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L.S.

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dean of the faculty

I confirm assumption of bachelor's thesis assignment.

Fanglin Wang

Fanglin Wang
Student's name and signature

Prague .....August 17, 2021

Abstrakt

Hlavním cílem této práce je navrhnout nové výkonnostní indikátory založené na analýze vlivu krize na poskytovatele služeb řízení letového provozu a s tím související limitace hodnocení výkonnosti. V úvodu této práce se autor zabývá návrhem metodiky, na základě, které je možné stávající situaci analyzovat a následně navrhnout nové klíčové ukazatele výkonnosti. Dále, autor v rámci práce popisuje současný vývoj v evropském letectví a dopad krize na všechny zúčastněné strany, zejména na poskytovatele letových navigačních služeb. Poté autor představí současnou evropskou politiku pro hodnocení výkonnosti. Na základě analýzy stávajících výkonnostních indikátorů jsou dále stanoveny limitace současného hodnocení výkonnosti. Nakonec jsou na základě analýzy navrženy nové klíčové indikátory pro měření výkonnosti poskytovatelů služeb řízení letového provozu. Tato práce navrhuje 10 nových klíčových ukazatelů výkonnosti pokrývajících 4 klíčové oblasti výkonu a navrhuje způsob jejich vyhodnocování. V poslední kapitole autor diskutuje možnosti jejich aplikace v souvislosti se zavedením iniciativy Single European Sky 2+.

Klíčová slova: klíčový ukazatel výkonu, klíčová oblast výkonu, poskytovatel letových navigačních služeb, hodnocení výkonu, politika

Abstract

The main purpose of this thesis is to propose new Key Performance Indicators (KPIs) based on the research of current European policies and the limitations of performance assessment. This thesis will first introduce the methodology that is a way how to propose new KPIs based on analysis. Then, it will describe the current development in European aviation and its impact on all stakeholders, especially Air Navigation Service Providers (ANSPs). After that, the current European policy and performance assessment will be described. Then it will enumerate the limitations of current performance assessment. Finally, new KPIs are proposed according to analysis. This thesis proposes 10 new KPIs covering 4 Key Performance Areas (KPAs) and describes how to evaluate them. Also, in the last chapter there will be a discussion on their application with regards to the introduction of the Single European Sky 2+ initiative.

Keywords: Key Performance Indicator, Key Performance Area, Air Navigation Service Provider, performance assessment, policy

Poděkování

Především bych chtěl poděkovat vedoucí práce, Ing. Terézia Pilmannová, MBA. Její hluboké odborné znalosti, seriózní vědecký přístup, přísný akademický duch a neúnavná pedagogická etika na mě měly hluboký dopad. Od výběru tématu až po konečné dokončení práce mě vždy vedla a dávala mi mnoho podnětů a zpětné vazby.

Dále bych také rád poděkoval dalším učitelům, kteří mi pomohli. Jejich asistence mi poskytla mnoho osvícení během procesu učení.

Nakonec bych také rád poděkoval svým rodičům, kteří mě kultivovali, a spolužákům, kteří mi pomáhali.

Čestné prohlášení

Prohlašuji, že v práci, kterou jsem napsal, není žádný plagiát. Použité zdroje a citace jsou uvedeny v seznamu přiloženém k práci.

Nemám závažný důvod proti užití tohoto školního díla ve smyslu §60 Zákona č.121/2000 Sb., o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon).

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List of Abbreviations

ACC	Area Control Center
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
ATM	Air Traffic Management
ATFM	Air Traffic Flow Management
ATCO	Air Traffic Controller
CNS	Communication, Navigation and Surveillance
EU	European Union
FAB	Functional Airspace Block
GHG	Greenhouse Gas
KEA	Key performance Environment indicator based on Actual trajectory
KEP	Key performance Environment indicator based on last filed flight Plan
KPA	Key Performance Area
KPI	Key Performance Indicator
NM	Network Manager
NSA	National Supervisory Authority
PRB	Performance Review Body
RP1	First reference period
RP2	Second reference period
RP3	Third reference period
SES	Single European Sky

Introduction

The aviation industry as such is very sensitive to any type of disruption, such as economic downturn, war in some parts of the world, terrorism, or pandemic. Due to the dependency on many external factors, the impact of any disruption may be substantial or even fatal for the aviation sector. The past 20 years have seen many crises. For example, the 9/11 terrorist attacks, SARS, the Iraq war, the global economic crisis of 2008 and now Covid-19, all of which have had to varying degrees an impact on the aviation industry. Except for Covid-19, the impact of other crises on the aviation industry has not been fatal and has only been limited, as the impact has been largely regional. Covid-19, on the other hand, has been fatal for whole the aviation industry.

Air Navigation Service Providers (ANSPs) are important an counterpart of European aviation. For the future development of European aviation, eliminating the inefficiencies in the European Air Traffic Management (ATM) is one of the crucial tasks. Basis of this initiative, formulated in Single European Sky is performance assessment of ANSPs.

Due to the crisis as well as with regards the expected development of the aviation industry there are many limitations in the existing performance assessment, which in many cases have opposing targets and do not reflect deficiencies of European ATM properly. Therefore, within the scope of this thesis, it is necessary to analyze current policy with regards to performance assessment, identify its major limitations, and propose new performance indicators reflecting actual conditions as well as future drivers of the airline industry.

For the purposes of the new performance indicators proposal, the author has develop a method defining current and future needs, as well demonstrating the limitations of current indicators.

Therefore, within the scope of this thesis, firstly, the current development in European aviation and its impact on all stakeholders, especially ANSPs will be described. After

that, the current performance assessment will be analyzed. Then, the limitations of current performance assessment will be identified. Finally, based on the recent developments and future needs of the ATM, the new Key Performance Indicators will be proposed.

1 Methodology

As already described in the introduction, the current performance assessment policy does not reflect the needs that emerged from the recent development in the aviation industry. Also, in some cases, the potential of the current indicators has already been exhausted and for the future definition of the Single European Sky 2+ package a discussion about reasonable assessment process has to be conducted.

In order to solve the limitations of current performance assessment and propose reasonable indicators for future reference periods, there has been a methodology concept elaborated within the scope of this thesis, as shown in Figure 1.

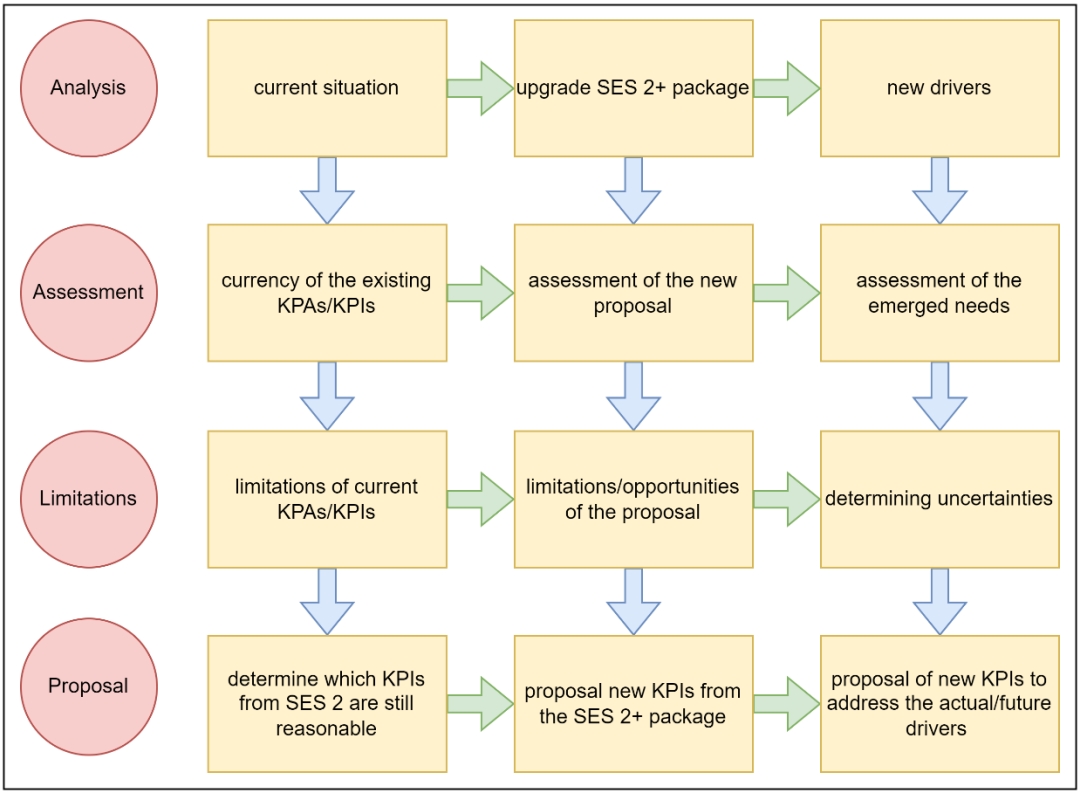

Figure 1: Methodology concept

Methodology consists of four parts, including (1) analysis, (2) assessment, (3) limitations and (4) proposal.

(1) Analysis

Firstly, the current situation is described. The SES 2+ package as a guidance should be considered. Then, the new drivers should be found based on analysis of current situation, SES 2+ package proposal, that has not formulated any indicators yet, as well as the future industry drivers.

(2) Assessment

Assessment includes three subparts. The first is the assessment of current KPAs and KPIs. The second is the assessment of new proposal of SES 2+. The last one is the assessment of current and future needs.

(3) Limitations

Limitations can be considered as an extension of analysis and assessment. Find the limitations of current KPAs and KPIs, the limitations of new proposal of SES 2+ and the uncertainties drivers based on analysis and assessment.

(4) Proposal

For the proposal of performance indicators for the upcoming reference periods, firstly, it was crucial to determine which KPIs from SES 2 can be retained based on their validity for future assessment. Then, on this basis, it is determined which new KPIs to propose by combining the analysis of the SES 2+ package and other industry drivers that have emerged in recent years and are not considered for assessment within the SES 2+ period.

The scope of this methodology is to identify current and new performance indicators that target the areas suffering from inefficiencies and still are realistic in terms of realizability and feasible with regards to the situation within the industry.

2 Current development in aviation

In recent years, the global aviation industry has developed rapidly and has become an important industry in the world. The aviation industry has also become an indispensable industry in people's daily lives. Such as tourism, official business and air transportation. The booming development of the aviation industry has not only brought convenience to people's lives, but also brought huge profits to the stakeholders in the aviation industry. But it is volatile to many types of disruptions. The Covid-19 has deviated the aviation industry from its normal development trajectory.

This chapter will introduce the current crisis in European aviation, the consequences of the crisis on aviation industry stakeholders and the crisis faced by ANSPs.

2.1 Current crisis in European aviation

Covid-19 has caused an unprecedented blow to the global aviation industry. The outbreak of Covid-19 in China in early 2020, followed by an uncontrolled global spread and a surge in the number of infections. As a result, many countries have adopted varying degrees of control measures to curb the spread of the epidemic, for example, travel restrictions and border management measures. Covid-19 has affected different countries to varying degrees, as the epidemic situation varies from country to country in Europe, and so do policies. In countries where the epidemic is more severe, governments restrict the free movement of people and require mandatory closure of shops. The control measures have led to a sharp reduction in the number of flights. The impact on the airline industry is obvious.

In the EUROCONTROL area, the number of flights decreased on average by -55.2% in 2020 compared to 2019, dropping as low as -88% in April 2020. This corresponded to 6.1 million fewer flights in 2020 with grave consequences on the aviation industry’s income and employment levels.[1] The number of controlled flights in the period January to August 2021 is 3,509,000, which is 2.6% higher compared to the same

period in 2020. But in August 2021, the growth rate of controlled flights is 45% compared to August 2020, which means the huge improvement compared to previous period.[2] It also should be noted that the Covid-19 did not break out in full force between January and March 2020. Therefore, from these two aspects, the traffic flow has an improvement in 2021.

From Figure 2, it shows that the number of flights in 2020 has dropped significantly compared to 2019 . Especially during from April to June, there is a decrease of more than 80% compared to 2019. The reason is that the first peak of the Covid-19 outbreak in Europe in this period. The number of flights decreased after a slow increase, because Europe ushered in the second outbreak of Covid-19 in October.

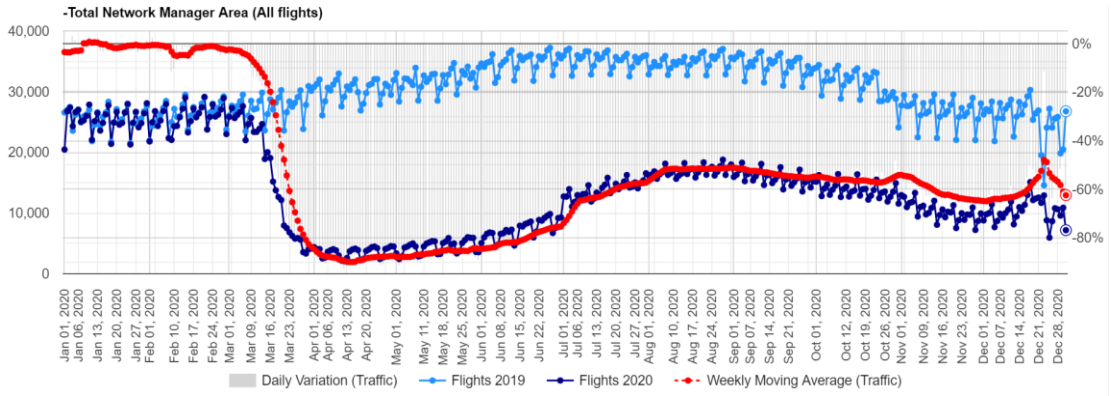

Figure 2: All flights in Network Manager Area from Jan.01, 2020 to Dec.28, 2020 (source: [3])

Figure 3 is a continuation of Figure 2, showing all flights in the Network Manager Area from January 01, 2021 to October 01, 2021. It shows that the number of flights was also low between January and April, but it took a turn for the better from May, especially from July.

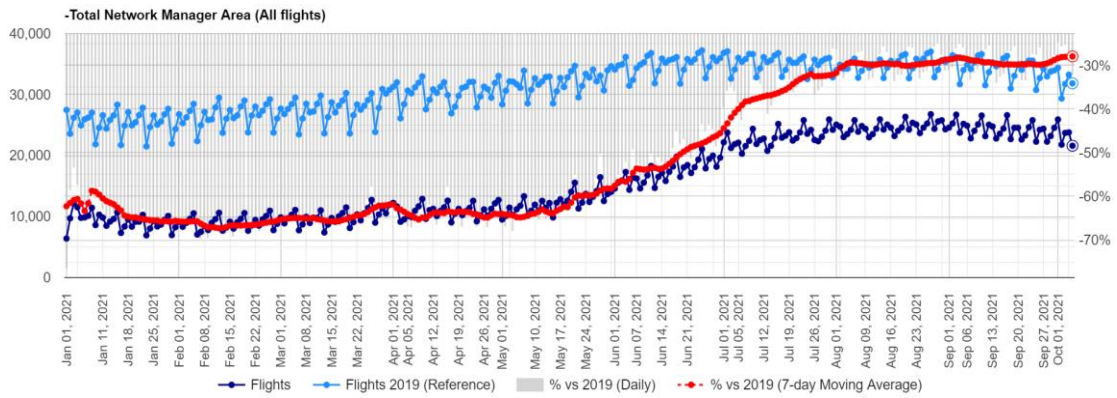

Figure 3: All flights in Network Manager Area from Jan.01, 2021 to Oct.01, 2021 (source: [4])

Figure 4 shows EUROCONTROL's traffic forecasts for the period January 2021 to December 2021 and the actual traffic situation. From the figure, we can see that the actual situation is not much different from the predicted situation. This is mainly due to vaccines are widely applied all around the world.

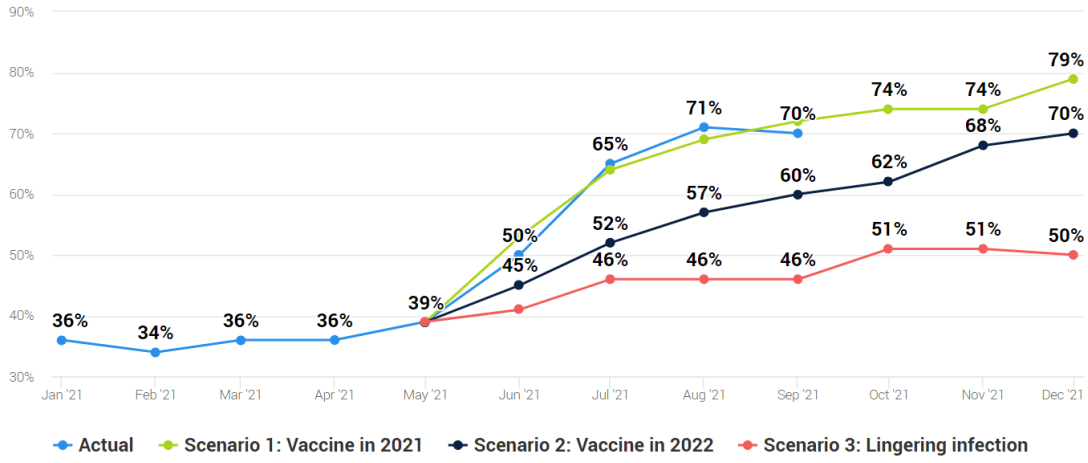

Figure 4: EUROCONTROL Draft Traffic Scenarios (source: [5])

In addition to forecasting the recent air traffic flow, the European Union (EU) can also forecast the number of European flights in the next four years. Figure 5 shows the EU's predictions from 2020 to 2024 when the vaccine is available in 2021, when the vaccine is available in 2022, and no vaccine. Although we can't make sure whether the

predicted result is accurate or not, there is no doubt that the vaccine is the most effective way to solve the pandemic of Covid-19. Although the vaccine was developed and applied all around since December 2020, which means the vaccine was available in 2021, European aviation will not be able to return to the number of flights in 2019 until around 2024. It can be seen from the forecast that even if the vaccine was available, the recovery of European aviation will still take 3 years according to the best-case scenario. It once again shows the difficulty of recovery road.

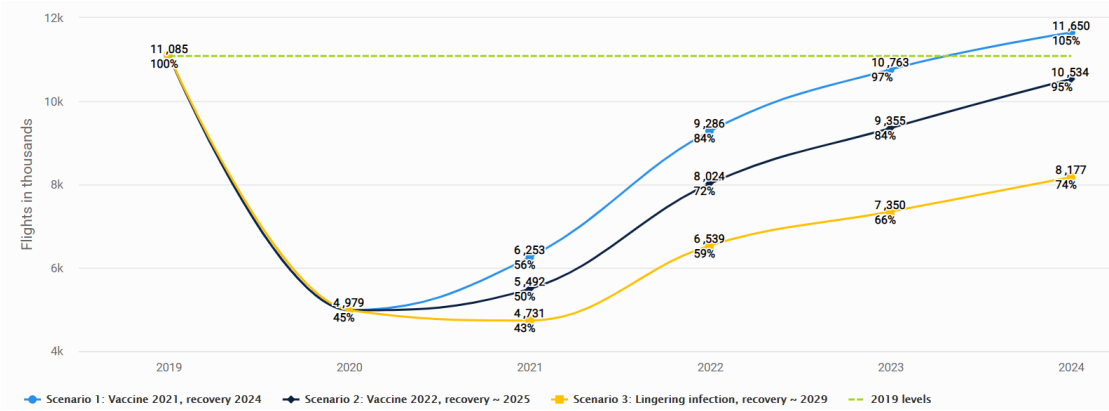

Figure 5: Forecast flights for 2020-2024 (source: [6])

The aviation industry includes many stakeholders, such as airlines, airports and government and so on. When the European aviation industry experiences a downturn, all stakeholders are greatly affected.

2.2 Consequences on aviation stakeholders

All stakeholders in the aviation industry have been hit to varying degrees. The impact on airlines is obvious. As a result of the massive reduction in the number of flights, airlines have had to ground a large number of aircraft and maintain only a small number of aircraft in operation. More than 6,000 aircraft were grounded in Europe in 2020 April and 2020 May.[7] Employees were undoubtedly the most innocent victims. The airline has reduced many staff to survive. Some airlines can survive by receiving financial assistance, but some airlines have to declare bankruptcy.

Airport operators and aircraft manufacturers are also directly affected. As airlines grounded a large number of aircraft, the number of aircraft operating at the airport dropped dramatically. In addition to this, airport operators offer fewer services to passengers as fewer passengers fly through the airport. This has led to a reduction in revenue for airport operators. This reduction in revenue is coupled with the need to maintain airport equipment to ensure that it is functioning properly. The reduction in demand for aircraft has resulted in fewer orders being received by aircraft manufacturers, thus reducing revenue.

ANSPs were also hit hard. ANSPs' main source of income is the income generated from the provision of Air Navigation Service (ANS). However, the drastic reduction in flights has led to a significant reduction in ANSPs' financial resources, and although Covid-19 has not had a significant impact on air cargo transport, the money earned from providing services to cargo flights alone is not sufficient. Table 1 shows the number of flight hours, controlled flights, and en-route service units. From the data, it is obvious that in 2020 there is a 56.4% decrease in flight hours compared to 2019 and a 54.7% decrease in controlled flights, which leads to a 57.4% decrease in En-route service provided by ANSPs. Although the situation has improved in 2021, it is only a small increase and still cannot be compared with 2019.

Table 1: Flight hour, controlled flights and en-route service units in EUROCONTROL area (source: [8])

	Year to date		Jan-Aug	
	2020	vs 2019	2021	vs 2020
Flight hours	7,498,000	-56.4.%	5,772,000	+3.6%
Controlled flights	4,624,000	-54.7%	3,509,000	+2.6%
En-route Service Units	66,035,000	-57.4%	50,209,000	+1.3%

While Covid-19 caused a crisis for the ANSPs' economy, Covid-19 also presented an opportunity for the ANSPs to adapt itself. Prior to the outbreak, European airspace was arguably the busiest airspace in the world. During the period 2015-2019, the volume

of air traffic in the European Control Area kept increasing. The limited airspace was accompanied by an increase in traffic, so Air Traffic Flow Management (ATFM) delays gradually increased, with a peak in 2018 and some relief in 2019. Although there were some measures to reduce the delay of single flight, the overall delays were still increasing due to the rising number of flight.

In 2017, aviation accounted for approximately 3.8% of total Greenhouse Gas (GHG) emissions in 28 EU countries.[9] Aviation is one of the fastest growing sources of GHG emissions in Europe. ANSP can further improve the Air Traffic Management (ATM) system during this period of global aviation downturn and strengthen the management capacity of Air Traffic Controllers (ATCOs) to prepare for a future busy aviation industry once it has recovered. This will not only improve flight efficiency and reduce delays in European aviation, but will also contribute to the environment by reducing aviation emissions. This is because inefficient flights lead to increased flight times and thus increased emissions.

The road to recovery for European aviation depends on the efforts of all of stakeholders. The EU's financial support for European aviation is particularly important in this crisis, is essential for European aviation to survive the epidemic. All stakeholders in the aviation industry should also help themselves and seize every opportunity according to their policies. The vulnerability of the aviation industry in the face of Covid-19 is a wake-up call for the European aviation industry. The European aviation industry should further improve the scalability of its own internal systems to cope with the current and possible future crisis.

2.3 The challenges for ANSPs to face crisis

The challenges for ANSPs resulting from the pandemic are enormous. The first challenge is to ensure that ANSPs can continue to provide high quality and safe services. ANSPs need to keep ATCOs' work ability as the traffic volumes are low and ATCOs are lacking the daily workload.

The second challenge is to finance technological investments at times when them is no demand for their services. ANSPs need to carry out the necessary technological innovations to face the future recovery of European aviation. Technical equipment needs to be maintained, regardless of whether they are used or not. When ANSPs need to use equipment, ANSPs need to ensure that they can be used normally, otherwise it may bring greater economic losses.

The cost structure of ANSPs, consists of staff costs, non-staff operating costs, depreciation costs, cost of capital and exceptional costs (Figure 6). Staff costs are the main cost, which includes gross remuneration, overtime payments and insurance payments etc. Non-staff operating costs are the secondary costs, which includes energy costs, communication costs and so on. ANSPs can reduce costs by control each part costs. It's obvious that controlling staff costs is the most functional way to reduce costs. The most direct way is to reduce the number of staff. However, the ANSPs invest substantial amount of money to the ATCO training, therefor the staff cost reduction should concern predominantly the administrative staff. To replace the operational staff once the demand for air travel returns to the 2019 numbers would be more difficult and cost intensive, than it is the case of administrative staff.

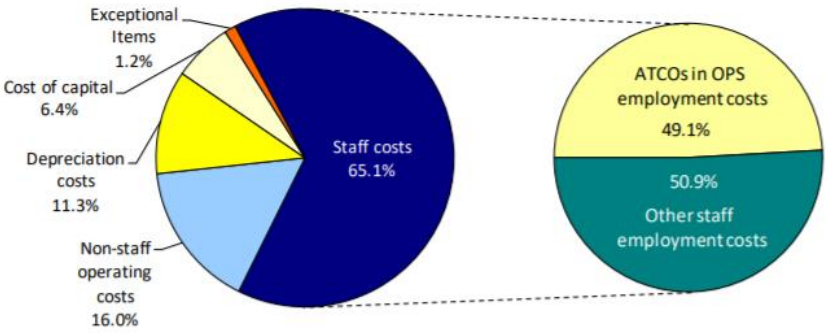

Figure 6: Cost structure of ANSPs (source: [10])

Even with a significant reduction in traffic, ANSPs need to be able to continue to provide safe ANS to airspace users, which requires ANSPs to maintain their own internal staff structure and to continuously improve the capacity of ATCOs to cope with future traffic

increases. In 2020, the loss in Pan-Europe's en-route revenues is estimated at €48 million. While the majority of these lost revenues are expected to be recovered from airspace users in the coming years under the current ANS cost recovery methodology. The timing of the recovery of these losses from airspace users may present significant challenges for ANSPs in the short term, particularly in terms of their ability to meet various payment obligations. These potential cash shortfalls will be already apparent in 2021 and even more in 2022.[11]

All in all, the crisis facing the ANSPs is mainly of an economic nature. ANSPs revenues are in their vast majority made of en-route and terminal charges (respectively 74% and 16% of the gate-to-gate ANS revenues). Other ANS revenues include income from airport operators (around 4%) which correspond to situations where terminal charges are charged to airspace users by the airports before transferring revenues to the ANSP. The last 6% of gate-to-gate ANS revenues are made of financial income and other revenues (mostly from the government).[12] However, the drastic reduction of flights has led to a significant reduction in ANSP's financial resources. Therefore, ANSPs need financial assistance in the current crisis, and it need funds to maintain the company's basic operations.

3 Performance assessment

Performance assessment is an important instrument to measure ANSPs' behaviors. Organizational policies are carried out based on the results of performance assessment. It can be said that the performance assessment will directly affect the operation of ANSPs.

This chapter will introduce the current European policy on performance assessment of ANSPs including SES 2+ initiative and the main elements of performance assessment.

3.1 Current European policy on performance assessment of ANSPs

Prior to the outbreak of Covid-19, European air traffic grew solidly year to year in recent years, peaking in 2019. In 2019, the number of flights controlled by the ANS system increased by 1.5 million (+15.4%).[13] The demand for air navigation services provided by the ANSPs is growing as traffic continues to grow and the number of flights increases. The ANSPs have shown shortcomings in the face of the increasing demand for its services.

Most notable is the issue of ATFM delays. As traffic continues to grow, ATFM delays gradually increased, peaking in 2018. This has led directly to an increase in the cost of the service. The economic unit cost in 2018 was €509, 6.2% higher than in 2017.[14] This significant increase is mainly due to a significant increase in ATFM delays compared to 2017 (+64.5%).[15]

Single European Sky (SES) is a key European Commission policy aimed at reforming Europe's air traffic management system through a series of actions at four different levels, with a view to meeting the capacity, safety, efficiency and economic needs of Europe's airspace and reducing its impact on the environment. The European

Commission proposed SES in 1999, SES 1 in 2004, SES 2 in 2009 and SES 2+ in 2014, a revised version of SES 2.

It is currently in the negotiation stage for the implementation of the SES 2+ package. The process of acceptance of SES 2+ package is shown in Figure 7. The green part represents the completed stage, including Commission proposal, opinions of Parliament and Council, draft report and Committee vote. Red represents the unfinished stage, including the trilogue, the voting process of the plenary, and the final adoption. The process of SES2+ approval is currently in the trilogue stage, which means that no particular KPIs have been formulated by now. Once the package is approved the SES Committee will be the one to determine the KPIs.

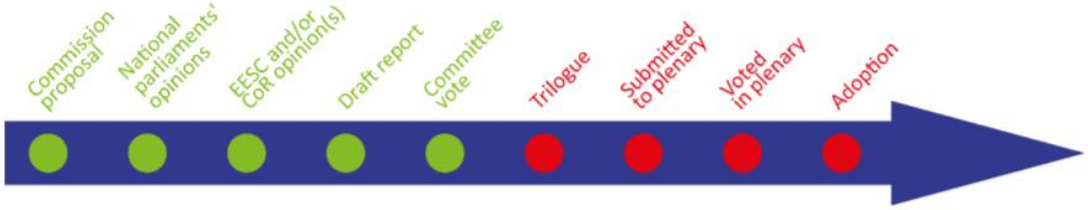

Figure 7: The process of acceptance of SES 2+ package (source: [16])

3.2 SES 2+ initiative

Delays and congestion in 2018 and 2019 have brought renewed attention. Therefore, on 22 September 2020, the Commission presented a new proposal. The objective of the new SES 2+ proposal is to improve the European airspace management and air navigation service system to increase airspace capacity, improve the cost-effectiveness of air navigation services and enhance the capacity of the air navigation service system to adapt to changes in traffic, while also attempting to reduce aviation CO_2 emissions. These initiative does not solely regulate the ANSPs but formulates recommendations throughout the industry.

With regards to the authorities carrying out oversight functions, the committee recommends strengthening the independence and professionalism of National

Supervisory Authority (NSA), and requires that conflicts of interest be avoided as much as possible[17]. For this reason, the proposal provides for the separation of economic and safety supervision tasks. The SES2+ initiative requires member states to establish an institution that is functionally, organizationally, and legally independent of ANSPs and independent of other organizations. According to the separation of economic and safety supervision, the current single certificate will be divided into safety certificates and separate economic certificates of ANSPs.

The new proposal also provides recommendations for ANSPs. The committee recommends that ANSPs can outsource support services, such as communications, navigation and surveillance services, aviation flight information services, flight weather services, and new ATM data services under market conditions, which can improve the financial cost-effectiveness.[18]

In order to better solve the problems of traffic congestion and routes, the proposal strengthens the network-centric approach.[19] The committee proposes to add new network functions and expand the roles and tasks of Network Manager in the areas of space management, capacity management, and infrastructure management.

The committee also recommends institutionalizing the Performance Review Body (PRB).[20] The proposal provides for the separation of en-route and terminal air navigation services planning and goal setting processes. The NSA should be responsible for terminal services, while the proposed new PRB should be responsible for en-route services. Member states will not participate in evaluating performance scheme.

The charging plan requires that the unit charges will be determined by the NSA after verification by the PRB.[21] The charging scheme should be based on the following principle: airspace users should pay for the costs incurred in providing the services provided. Fees should encourage the safe, efficient, effective and sustainable provision of air navigation services. In order to encourage airspace users to fly the shortest route, especially when traffic is congested, a common unit charge should be

established for route services in the entire SES airspace.

Unfortunately, the proposal does not take into account the great impact that Covid-19 will have on aviation. However, there is no doubt that the proposal will further optimise European aviation to better suit traffic development. As an integral part of the SES programme, the new proposal for SES 2+ will have a considerable impact on ANSPs, which should consider how to optimise itself under this policy.

ANSPs could outsource services to support ANS. Although this may make its structure more complex, it significantly increases the efficiency of the service, improves cost effectiveness. It also increases flexibility of system and promotes technological innovation. These possible improvements can be achieved through the provision of services which by their nature are favourable to market conditions.

The network-centric approach has a positive impact on the amount of ATFM delays,so ANSPs should strengthen own capacity to work in this area. Achieving this goal requires ANSPs to be more cohesive, such as strengthening cooperation and sharing information between each other. In addition, ANSPs can improve the capacity and knowledge of Network Manager (NM) to ensure that they can deal with peak traffic.

The performance scheme has been changed. It will separate the en-route services from the terminal services. This means that performance scheme will become more detailed and the assessment process will be fairer and more rigorous, and that ANSPs should also separate services in their statistics to better achieve performance targets.

ANSPs agree with the general direction of the new proposal. They believe that the core of the new proposal, the digitisation and decarbonisation of European ATM, will indeed optimise European aviation. However, they also think that in the absence of an assessment of impact, risks, costs and benefits, it is difficult to draw conclusions on the advantages and disadvantages. It is also argued that the proposal lacked a recommendation for Covid-19. In addition, it is considered that the environmental benefits are too optimistic, and that ATM's contribution is limited in terms of its ability

to reduce emissions.[22] Many factors outside the ANSPs' capability will affect flight efficiency, such as bad weather, collision avoidance areas, aircraft operational constraints, etc. Therefore, the environmental benefits should be focused on fuel efficiency and technology.

Some ANSPs suggested that the current SES 2+ regulatory scheme is too prescriptive and involves micromanagement for a large number of ANSPs. They strongly believe that providing a holistic and systematic approach to alignment with all stakeholders working in concert is an effective way to reach the ultimate goal of SES. Proposals should focus on a minimum level of service delivery and provide economic incentives for ANSPs to provide capacity at a reasonable price.[23] In other words, they think regulators should pay maximum extent possible.

They also refer to the price settings. An EU-wide single route fee could devalue a competitive and cost-effective service.[24] Furthermore, the development of SES 2+ should not add an additional economic burden to ANSPs.

Other ANSPs have suggested that the new ATM data service provision could lead to an industry monopoly by leading providers, which is contrary to the principle of fair competition.[24] Data is a vital part of the ANS and it is a matter of aviation safety. In any case, attention should be paid to the market conditions in the ANS.

Although there is no clear legislation for ANSPs on how to deal with Covid-19, ANSPs must not sit idly by and take action to save themselves; ANSPs must first ensure the health and the professional ability of their own staff, especially essential staff. ANSPs can also seek financial assistance from the government to maintain their operations, and they should take advantage of every opportunity to provide services to airspace users to increase their revenue.

Performance assessment is very important for policy formulation, and the main department responsible for performance assessment is PRB.

3.3 Performance Review Body

The performance assessment is an important tool for testing whether ANSPs have achieved their performance target. The performance assessment process in ATM system is carried out by PRB in Europe. The assistance provided by the PRB is essential to achieve the objectives of a complete SES. The work of the PRB has contributed positively to the improvement of the European ATM network, in particular by providing the Commission with impartial advice on the performance of ANS and on performance schemes.

The PRB consists of nine members, including a Chairman. The members shall be appointed by the Director-General of the Commission's Directorate-General for Mobility and Transport. The Chairman shall be elected from among the members after consultation. The Chairman shall be the representative of the PRB and shall be responsible for the day-to-day conduct of its meetings. The term of office of the Chairman and other members is two years, renewable for two terms.[25]

The tasks of PRB include (Table 2):

Table 2: The task of PRB (source: [27])

Data collection	• Collecting and confirming relevant data from ANSPs • Receiving data from NSA
Evaluation	• Evaluation of the achievement of performance indicators
Monitoring	• Monitoring the performance of European ATM networks • Monitoring the performance of ANS
Others	• Adjustment of Key Performance Areas (KPAs) and Key Performance Indicators (KPIs) • Confirming the draft of performance scheme • Setting EU-wide performance targets • Coordination of stakeholders related to the performance scheme

The PRB conducts an annual evaluation to see how the ATM has performed during the year, so that problems can be identified and recommendations for improvement made. In addition, the PRB conducts a summative evaluation at the end of the reference

period, every five years, and provides the Board with recommendations for the establishment of a performance scheme for the next reference period.

The final result of performance assessment is the performance assessment report, published by PRB.

3.4 Performance assessment report

The performance assessment report is issued by special performance assessment bodies, which contains the performance of various aspects of European aviation during the year. It can help the European Commission find out the current aviation crisis in time and formulate relevant laws for it. At the same time, the aviation stakeholders can discover their shortage in order to make improvements.

The performance evaluation report mainly includes two annual reports, one is Performance Review Report, and the other is ATM Cost-Effectiveness (ACE) Benchmarking Report. The former evaluates the performance of the entire aviation industry, while the latter focuses on the performance evaluation of ANSPs.

The Performance Review Report issued by the PRB is based on the analysis of the European Air Traffic Management System by four Key Performance Areas: safety, capacity, environment and cost-efficiency.

Another report issued by PRB is ATM Cost-Effectiveness (ACE) Benchmarking Report. This report contains data and analysis on cost-effectiveness and productivity of European ANSPs. The report covers en-route and terminal navigation services (gate-to-gate). The main concern is the cost of ATM and Communication, Navigation and Surveillance (CNS), which are directly controlled by ANSPs. The report also introduces a cost-benefit implementation framework that emphasizes three key performance drivers including productivity, employment cost, and support cost.

For performance assessment, KPAs and KPIs are crucial assessment benchmark. They can reflect more specific problems of each part.

3.5 KPAs and KPIs assessed by performance scheme

The performance scheme aims to improve the performance of ATM systems by adopting EU-wide performance targets for a fixed reference period, requiring countries to adopt binding performance schemes aligned to the EU-wide targets before each reference period and to monitor the performance achieved against the agreed targets and to take corrective measures as needed. The first reference period (RP1) was from 2012 to 2014. The second reference period (RP2) was from 2015 to 2019. It is currently in the third reference period (RP3).[28]

The KPAs and the KPIs are important parts of the performance scheme. The KPAs divide the overall ATM system into four key areas to facilitate the Commission's management of the entire ATM system and the establishment of the performance scheme. Each KPA has its own KPIs, and the PRB and NSA assess the performance by evaluating whether the indicators are being met, which also helps in the monitoring of the ATM system.

The performance scheme consists of four KPAs: safety area, capacity area, environment area and cost-efficiency area, each of which has its own objectives:

- **Safety area**

The objective is to confirm that all NSAs and ANSPs providing airline services meet an agreed minimum level of safety management and regulatory maturity. The incidence of flight accidents is reduced through a range of measures.

- **Capacity area**

The objective is to reduce airspace congestion through effective measures and to reduce ATFM delays and improve flight efficiency.

- **Environment area**

The goal is to reduce CO_2 emissions from the aviation industry and to meet the objectives of the European Green Deal.

- **Cost-efficiency area**

The objective is to reduce the unit cost efficiency of air navigation services.[29]

Table 3 shows all KPIs included in the four KPAs. KPIs are important to determine whether performance targets are being met in each KPA.

Table 3: Performance Scheme KPI (source: [30])

KPA	KPI
Safety	• Effectiveness of safety management • Application of severity classification based on risk analysis tools • Level of presence or absence of just culture • Application of automated safety data recording for separation minima infringement monitoring • Application of automated safety data recording for runway incursion monitoring • Level of occurrence reported • Number of separation minima infringements, runway incursions, airspace infringements
Capacity	• En-route ATFM delay per flight attributable to ANS • Arrival ATFM delay per flight attributable to terminal and airport ANS • ATFM slot adherence • ATC predeparture delay
Environment	• Average horizontal en-route flight efficiency of the last filled flight plan trajectory (KEP) • Average horizontal en-route flight efficiency of the actual trajectory (KEA) • Additional time in the taxi-out phase • Additional time in terminal airspace • Effectiveness of booking procedures for flexible use of airspace • Effective use of conditional routes • Rate of planning of conditional routes
Cost-efficiency	• Determined Unit cost for en-route ANS • Determined Unit cost for terminal ANS • Terminal ANS costs • Terminal ANS unit rate • EUROCONTROL costs

Figure 8-10 show the results of some KPIs in RP2. PRB can judge whether it meets the target by assessing the relative data. If not, EU can make a discussion with all stakeholders to find the best resolution.

Figure 8 shows the effectiveness of safety management score of ANSPs. The scoring area is from 0 to 100 points. The higher the score, the better the safety management. All most of ANSPs had a good performance on it, whose score were over 75 points. Only PANSA's score was lower than 25 points that means its safety management was

so bad. Many factors can influence safety management performance, including the limited resources within the ANSPs.[31]

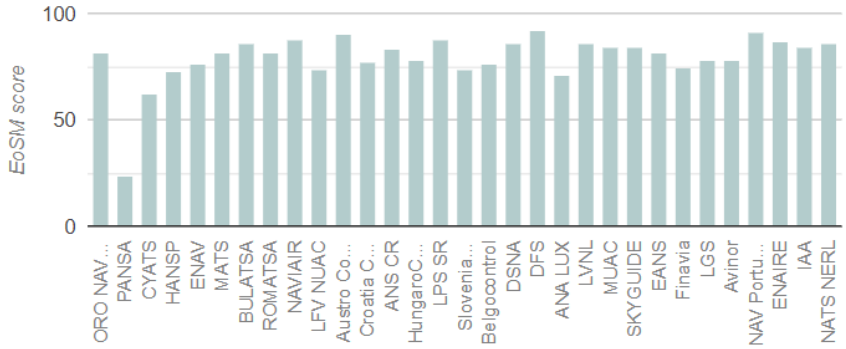

Figure 8: Effectiveness of safety management score (source: [32])

Horizontal en-route flight efficiency is an important KPI of environment KPA. The performance of environmental performance did not meet expectations. In 2015, the KEA was approximately 3.0%, which was much lower than KEP (approximately 5.0%) (Figure 9).

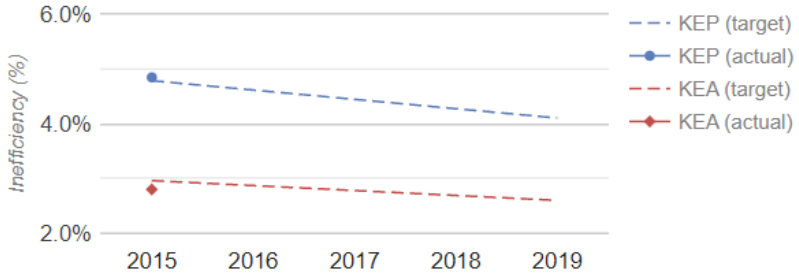

Figure 9: Horizontal en-route flight efficiency (source: [33])

Figure 10 shows the en-route ATFM delays indicator. The actual performance of en-route ATFM delay was 0.75 minutes per flight, but the target was 0.5 minutes per flight. It maybe duo to the increased traffic volume.

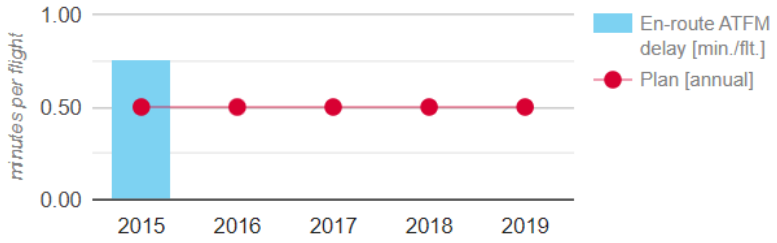

Figure 10: En-route ATFM delays (source: [34])

4 Limitation of performance assessment

The performance assessment is based on the current situation on the market and assumptions on the future development. However, due to the volatile nature of the European aviation industry, these assumptions might be obsolete in couple years. The reason is a cause-and -effect relationships between performance drivers and indicator. The results of performance indicators will influence the formulation of future strategic goals and policies. Some of the limitations are derived from the nature of the KPA itself. The way the KPAs are formulated create conflicting targets. For example, the conflict between capacity area and cost-efficiency area. The improvement of the KPIs in current environment area has done well, there is not much room to improve them. In order to achieve the goals of the European Green Deal, the environmental area needs to be adjusted.

4.1 Conflict between capacity and cost- efficiency area

The different KPAs formulated in the performance scheme are interdependent, and there are trade-offs between them. For example, the environment is impacted because of sub-optimal flight profiles, which can generate additional emission. When the traffic is on its capacity limits, the profiles will worsen. The capacity area and cost-efficiency area also influence each other and have a conflicting relationship. The capacity area focuses on ATFM delay. The cost-efficiency area focuses on the total cost of ANS, the unit cost of ANS and EUROCONTROL costs. The conflict is reflected in the reduction of ATFM delay will lead to an increase in the total cost of ANS and the EUROCONTROL cost. It is also reflected in the decrease in unit cost of ANS as the traffic volume increases.

Before the outbreak of Covid-19, the continuous increase in traffic volume posed a lot of challenges to the operation of the ATM system. The airspace capacity is not unlimited, it has been well utilized at present, so it is very difficult and expensive to

further improve the airspace. When the traffic volume increases further, it will inevitably lead to congestion in the airspace and to further increase in the ATFM delay. In 2019, the number of ATFM delay flights increased by 0.3%.[35] The cost caused by the increase of ATFM delay cannot be ignored.

A key factor affecting ATFM delay is Air Traffic Control (ATC) capacity. ATC capacity reflects the ability to provide services, it is expressed in terms of the number of aircraft entering the designated airspace within a given time. The increase of ATC capacity can effectively reduce the occurrence of ATFM delay. More infrastructure investment and more staff investment can increase ATC capacity, but this also means an increase in the total cost of ANS.

In addition, EUROCONTROL has taken a series of measures to reduce ATFM delay. The NM plays a vital role in the competitiveness, operational capabilities and flight efficiency of the European aviation in terms of network performance. Its direct contribution to capacity and delay savings is to reduce delays by 10%.[36] The use of Functional Airspace Block (FAB) divides the fragmented European airspace into 9 sectors. Although the deployment of FAB is limited, FAB has made certain contributions to reducing airspace fragmentation, adapting to increasing traffic volumes, and minimizing delays by managing traffic more dynamically.[37] The use of these measures increases EUROCONTROL costs.

Although the increase in traffic volume increases the ATFM delay, it also reduces the unit cost of ANS. In 2019, the en-route ANS unit costs of pan-European system level dropped 1.4% compared with 2018, the terminal ANS unit cost in Europe dropped 0.2% compared with 2018.[38] The reason is that the grown rate of number of ANS much faster rate than the grown rate of the total cost of ANS. In other words, the total cost of growth can be allocated to more services units.

The conflicting relationship between the capacity area and the cost-efficiency area brings some reminders to the current performance assessment. The current performance assessment of four KPAs just focus on the KPIs in own area and cannot

well reflect the interdependence between different KPAs. Therefore, when conducting performance assessment, it is not only necessary to obtain the performance of four areas, but also to discover how different KPAs affect each other, which will enable decision makers to make better decisions. For example, how to measure the balance between ATFM delay cost and ANS cost.

4.2 Cost of ATFM delay

The continuous increase in ATFM delays has attracted the attention of many aviation stakeholders, because delays have brought many negative effects. For airlines, delays will not only bring passenger dissatisfaction, but also cause additional costs. For example, the compensation for delays. For ANSPs, the increase in ATFM delays is a manifestation of insufficient ATC capacity. The cost of ATFM delays caused by ANSPs is carried by the airlines. All in all, the main cause of ATFM delays is due to inefficiencies of ANSPs.

Finding the factors that affect ATFM delays is the key to reducing delays. For ANSPs, ATC Capacity (43.9%) attributed delays remain the main portion of ATFM delays, followed by ATC Staffing (24.3%), Weather attributed delays (21.2%), and ATC disruptions/industrial actions (7.2%).[39] This shows that the key to reducing ATFM delays is to increase ATC capacity.

On the other hand, increasing ATC capacity might reduce ATFM delay, however it also increases costs of ANSPs. Therefore, finding a break even point between ATFM delay cost and ATC capacity cost will become the key to reducing unnecessary costs.

First of all, we need to understand the relationship between ATC capacity cost and capacity, and the relationship between ATFM delay cost and capacity. As shown in Figure 11, the relationship between capacity cost and capacity is linear. As the provided capacity increases, the capacity cost increases linearly. The relationship between delay cost and capacity is non-linear. As the capacity provided increases, the delay cost is dramatically reduced first and then slightly reduced.

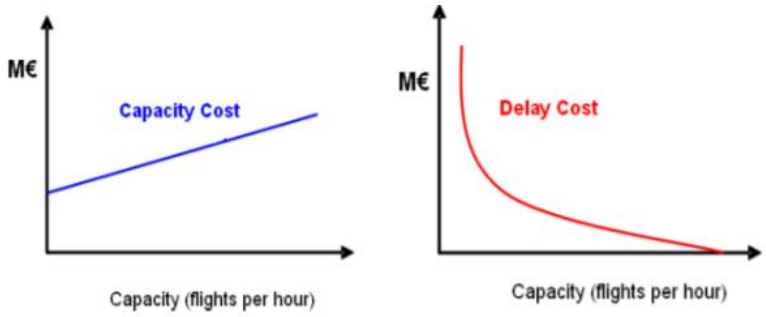

Figure 11: Capacity related costs (source: [40])

According to the analysis, the change of capacity cost and delay cost can be divided into three situations:

• The first case is to increase the capacity when the capacity is low. The result is that the reduced delay cost is much greater than the cost to increase capacity.

• The second case is to increase the capacity when the capacity is medium. The result is that the reduced delay cost is approximately equal to the cost to increase capacity.

• The third case is to increase the capacity when the capacity is high. The result is that the reduced delay cost is much smaller than the cost to increase capacity.

If ANSPs want to achieve a break even point between ATFM delay cost and ATC capacity cost, they need make sure that the reduced delay cost is approximately equal to the cost to increase capacity.

4.3 Environment performance area

Nowadays, environmental issues are attracting more and more attention, especially the greenhouse effect. The greenhouse effect causes the increase of temperature, it leads to glaciers melting and thus lead to a rise in global sea levels. The aviation industry therefore has a responsibility to minimise its impact on the environment. The impact of aviation on the environment can be divided into three parts: global climate, air quality and noise. The most important of these impacts is reflected in global climate

change.

Aviation emissions are one of the fastest growing sources of GHG emissions in Europe. Carbon dioxide emissions from aircraft fuel combustion are the main source of aviation GHG emissions. In 2017, the carbon emissions in the EU 28 regions reached 174 million tonnes (an increase of 91 million tonnes per year compared to 1990 levels). The share of aviation emissions in total greenhouse gases has increased from 1.4% in 1990 to 3.8% in 2017.[41] The primary objective for European aviation is therefore to decarbonize aviation.

In order to achieve the protection of the European environment, the European Commission presented the European Green Deal plan on 11 December 2019. The plan states to achieve increase the EU's GHG emission reductions target for 2030 to at least 50% and towards 55% compared with 1990 levels, Europe climate neutral by 2050, and a 90% reduction in CO_2 emissions by 2050.[42]

The Performance Review Body assess this by counting the relevant data and converting it into a relevant index. The flight efficiency is a very important indicator of the environmental area. This is mainly because flight efficiency has a direct impact on greenhouse gas emissions. A high flight efficiency means that the aircraft will consume less fuel and thus emit less carbon dioxide. Conversely, low flight efficiency will lead to an increase in CO_2 emissions.

For GHG emissions, the influencing factors come from four pillars: aircraft technology, sustainable aviation fuel, economic measures, improvement of infrastructure and operations (Operational efficiency).[43]

The goal of reducing carbon emissions from the European aviation industry requires the joint efforts of all stakeholders. Aircraft manufacturers can improve the airframe design and improve the engine to increase combustion efficiency. Fuel providers can provide airlines with sustainable and clean fuel. The committee can take corresponding economic measures, such as setting different charges for flights with different GHG

emissions. The more GHG emissions, the higher the charges.

For air navigation service providers, the most important thing is to improve flight efficiency. This requires upgrading infrastructure, adopting new technologies, strengthening network management, and improving the ability of ATCOs to provide high-quality and efficient services. But the impact of ANSPs on the environment is limited. Although improving flight efficiency can reduce GHG emissions, the key factor for reducing GHG is the improvement of aircraft technology and the application of sustainable aviation fuel.

In addition, there is not much room for improvement of the current KPIs in the environmental area. First, with the technological innovation, the strengthening of network management and the improvement of ATCOs' working ability in recent years, the improvement of flight efficiency will slow down and gradually reach the limits. Secondly, the current airspace has been well utilized, and it is difficult to make great improvements in the use of flexible airspace and conditional routes. The way the KPA is formulated right now, will not bring any further benefits to the performance optimization and therefore should be modified in a reasonable manner to support and address further improvements to the infrastructure.

4.4 Limitation to reflect current and future European aviation market

The performance assessment is summarised and assessed by collecting data from ANSPs. The assessment also includes a comparison of the current year's data with that of the previous year or earlier, in order to forecast future trends in aviation development and to identify shortcomings and make recommendations for improvement. However, as a result of Covid-19, European air traffic has decreased considerably, in contrast to previous years when traffic continued to grow. This has happened for exceptional reasons and is not a normal trend for European aviation. It is unreasonable to use data under the crisis to find out what improvements have been

made compared to the previous ones, what problems have not been improved and what still needs to be improved. The performance evaluation at this stage should take into account the particular situation at hand and find solutions from it to help European aviation emerge from the crisis. Therefore, the original-based performance assessment under the Covid-19 crisis is limited.

Prior to the outbreak, the continuous increase in traffic flow has caused many problems in the ATM system. For example, airspace congestion, severe ATFM delays, flight inefficiencies and aviation emissions. In the current crisis, these problems will no longer be a problem due to the reduction in traffic. In the PRR, important data are evaluated such as traffic growth, en-route ATFM delay flights, en-route flight efficiency and en-route ANS cost. The assessment of these figures does not reflect the real plight of European aviation in the current crisis.

Table 4 shows the en-route ATFM delay data for 2020 compare to the 2019. The data shows that the performance of en-route ATFM delay in 2020 is much better than in 2019, with total en-route ATFM delay being the most significant with a 90.1% reduction. It can't mean that the good improvements in the ATM system have led to a reduction in en-route ATFM delays. it is simply due to the significant reduction in traffic due to Covid-19.

Table 4: En-route ATFM delay (2020 vs 2019) (source: [44])

	Year to date	
	2020	vs 2019
En-route ATFM delay per flight (min)	0.35	-1.25
En-route ATFM delay flights (%)	1.97%	-8.2%
Total en-route ATFM delay (min)	1,620,000	-90.1%

Table 5 shows a comparison of the en-route ATFM delay data between 2021 and 2020. It shows that in 2021 there is a continuation of the decrease in delay from 2020, but

the problem is that this is also based on traffic flow. Because the epidemic was not severe in Europe in the first three months of 2020, the traffic flow did not decrease much. From the other hand, in August 2021, the ATFM delay increased compared with August 2020. The reason is also relative to the traffic flow.

Table 5: En-route ATFM delay (2021 vs 2020) (source: [45])

	Aug		Jan-Aug	
	2021	vs 2020	2021	vs 2020
En-route ATFM delay per flight (min)	0.67	+0.65	0.30	-0.17
En-route ATFM delay flights (%)	5.11%	+4.96%	2.11%	-0.54%
Total en-route ATFM delay (min)	508,000	+5,775.4%	1,046,000	-34.7%

The limitation of performance evaluation is not only reflected in the current situation, but also in reflecting the demand of the European aviation market in the future.

The current performance scheme includes four KPAs: safety, capacity, environment and cost-efficiency, which to some extent reflect the current and future needs of the European aviation market. For example, the growth in traffic reflects the need for more airspace users and more ANS for current and future aviation.

The above analysis is based on a conventional period (before the outbreak of Covid-19) and may not be a relatively accurate reflection of future demand in the aviation market in the current crisis. First of all, the capacity area, the current significant reduction in traffic is not indicative of future aviation trends. The traffic volume is at the lowest point in European aviation, and even though the threat of Covid-19 will continue in the future, traffic will not decrease further as a result, but fluctuations cannot be ruled out. A very important point for the future of European aviation and indeed the rest of the global industry is the vaccine.

In terms of environment and cost-efficiency, aviation emissions and ATFM delays were significantly reduced under the epidemic, flight efficiency increased. This is mainly due

to the significant reduction in the number of flights and is not an accurate indication of how well the ATM system is performing. It may give decision makers a false impression of what appears to be true and will cause them to drop the ball. Perhaps these problems will remain in the future when European aviation resumes. What can be believed is that in the meantime it would be a good option to improve the performance of the staff within the ATM system.

In summary, the KPAs in the current performance scheme reflect the needs of the European aviation market without major external interference, but can be stretched in the face of significant external disruptions, illustrating the lack of scalability of the current ATM system. The situation of European aviation under Covid-19 is a good example.

5 Proposal of the new indicators and assessment process

The process of analysis, assessment and limitations of the methodology have been done in previous chapters. The last part of the methodology, proposal, is described in this chapter. The proposed KPIs also will be described in this chapter.

For the proposal of performance indicators for the upcoming reference periods, firstly, it was crucial to determine which KPIs from SES 2 can be retained based on their validity for future assessment. Then, on this basis, it is determined which new KPIs to propose by combining the analysis of the SES 2+ package and other industry drivers that have emerged in recent years and are not considered for assessment within the SES 2+ period.

Based on the methodology (Figure 1), the following 10 new KPIs covering four KPAs are proposed. In Table 6, the KPIs in yellow mean which from SES 2 are still previous valid for next period. The KPIs in green mean that are proposed from SES 2 +. What needs attention here is the difference between assessed and monitored. "Assessed" means that this KPI can be evaluated through specific data. "Monitored" means that this KPI cannot be evaluated through data and can only be monitored.

Table 6: Proposed new and previous valid KPIs

KPA	KPI	Assessed/Monitored
Safety	• Effectiveness of safety management	Monitored
	• Application of severity classification based on risk analysis tools	Assessed
	• Level of presence or absence of just culture	Monitored
	• Application of automated safety data recording for separation minima infringement monitoring	Assessed
	• Application of automated safety data recording for runway incursion monitoring	Assessed
	• Level of occurrence reported	Assessed
	• Number of separation minima infringements, runway incursions, airspace infringements	Assessed
	• Effectiveness of ground-based safety nets	Assessed
Capacity	• En-route ATFM delay per flight attributable to ANS	Assessed
	• ATFM slot adherence	Assessed
	• ATC predeparture delay	Assessed
	• Utilization rate of ATC capacity	Assessed
	• Different delay time	Assessed
	• Military-civilian cooperation effectiveness	Assessed
	• Dynamic airspace configuration	Monitored
Environment	• Average horizontal en-route flight efficiency of the last filled flight plan trajectory (KEP)	Assessed
	• Average horizontal en-route flight efficiency of the actual trajectory (KEA)	Assessed
	• Effectiveness of booking procedures for flexible use of airspace	Assessed
	• Effective use of conditional routes	Assessed
	• Energy consumption of infrastructure	Assessed
	• Implementation of free route airspace	Assessed
Cost-efficiency	• Determined Unit cost for en-route ANS	Assessed
	• Determined Unit cost for terminal ANS	Assessed
	• Terminal ANS costs	Assessed
	• Terminal ANS unit rate	Assessed
	• EUROCONTROL costs	Assessed
	• Effectiveness of ATCO with double endorsement	Assessed
	• Additional ATC capacity cost	Assessed
	• Remote and virtual tower	Monitored

The proposed 10 KPIs covering 4 KPAs will be detailed introduced in the below, including name, measured data, description and assessment process of them.

5.1 Proposal of the new performance indictors

(1) Safety area

The current performance scheme lacks an evaluation of ground-based safety nets. The usage of ground-based safety nets will reduce the risk of collisions. With the continuous increase in traffic flow in the future, more comprehensive assessment will help improve aviation safety. The following KPIs are proposed in safety area (Table 7).

Table 7: Proposed new KPIs in safety area

KPI	Measured data	Description
Effectiveness of ground-based safety nets	• the number of alerts • the number of risks potential risks resolved	the number of alerts divided by the number of risks potential risks resolved

Effectiveness of ground-based safety nets KPI

The ground-based safety nets use surveillance data to provide up to two minutes of warning time. After receiving the alert, the ATCOs should immediately assess the situation and take appropriate action.[46] It contains four alert systems:

• Short-Term Conflict Alert: It helps ATCOs prevent collisions between aircraft by promptly generating alerts for potential or actual violations of the minimum interval.

• Area Proximity Warning: It warns ATCOs of unauthorized intrusion into the airspace space by generating a timely warning of potential or actual violation of the required spacing of the airspace space.

• Minimum Safe Altitude Warning: It warns ATCOs of the increased risk of a controlled flight collision accident by generating a timely warning that the aircraft is approaching

terrain or obstacles.

• Approach Path Monitor: It warns ATCOs of the increased risk of a controlled flight collision accident by generating a timely warning that the aircraft is approaching terrain or obstacles during the final approach.[47]

The effective use of ground-based safety nets greatly reduces the risk of aircraft collisions during flight. Effectiveness of ground-based safety nets is reflected in the percentage of the number of potential risks resolved to the number of alerts.

Measured data: the number of alerts, the number of risks potential risks resolved

Formula: the number of alerts divided by the number of risks potential risks resolved

(2) Capacity area

The KPIs proposed below make the assessment of the environmental area more detailed. The goal is not to concentrate just on one indicator (horizontal flight efficiency) but to address the environmental issue with a broader portfolio of targets. This can contribute to a more efficient use of airspace, delay reductions, and better understanding of the impact delays have on environment. The following KPIs are proposed in capacity area (Table 8).

Table 8: Proposed new KPIs in capacity area

KPI	Measured data	Description
Utilization rate of ATC capacity	• demand • capacity • actual workload	• capacity divided by actual workload (demand is greater than or equal to capacity) • demand divided by actual workload (demand is smaller than capacity)
Different delay time	• the number of delayed aircraft in each range • the delay time in each range	divide delay time into 5 ranges: 1-5 minutes, 6-15 minutes, 16-30 minutes, 30-60 minutes, and more than 60 minutes.
Military-civilian cooperation effectiveness	• the number of conditional route • the number of conditional route used	the number of conditional route divided by the number of conditional route used
Dynamic airspace configuration	-	It is difficult to evaluate the performance of dynamic airspace configuration through data. But it can be monitored in real time.

(a) Utilization rate of ATC capacity KPI

Utilization rate of ATC capacity has a very important impact on en-route ATFM delay, which reflects the working ability of ATCOs. It contains three factors: demand, capacity and actual workload. The evaluation is divided into two types: demand is greater than or equal to capacity and demand is lower than the available capacity. When the demand is greater than or equal to the capacity, the evaluation standard is to divide capacity by the actual workload. When the demand is less than the capacity, the evaluation standard is to divide the demand by the actual workload. Table 9 shows some examples of utilization rate of ATC capacity KPI.

Table 9: Example of evaluating utilization rate of ATC capacity

Demand	Capacity	Actual workload	Utilization rate
98	100	98	100%
100	100	99	99%
110	100	96	96%

Measured data: demand, capacity, actual workload

Formula: capacity divided by actual workload (demand is greater than or equal to capacity) or demand divided by actual workload (demand is smaller than capacity)

(b) Different delay time KPI

Current performance assessment focuses on the cost of average delay time, but this does not accurately reflect the true cost of delay. As shown in Figure 12, the delay time is divided into 10 ranges – delay intervals, and the total cost of the average delay time is much higher than the total cost of the 10 delay time ranges.

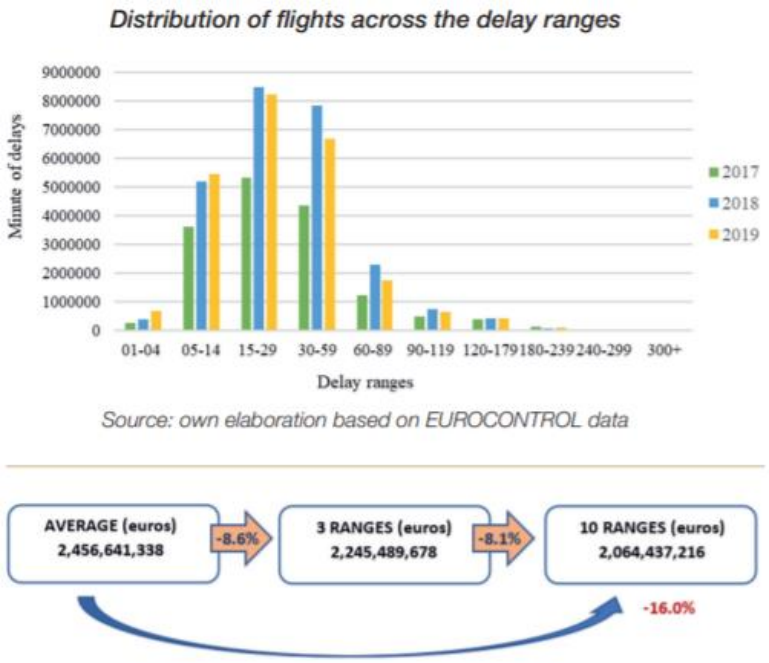

Figure 12: Different delay time ranges (source: [48])

Therefore, the delay needs to be divided into different ranges according to the delay time. For the convenience of data collection, it can be divided into 5 ranges: 1-5 minutes, 6-15 minutes, 16-30 minutes, 30-60 minutes, and more than 60 minutes.

Measured data: the number of delayed aircraft in each range, the delay time in each range

Formula: There is no formula determined for this KPI. The purpose of it is to use measured data to better understand the influence of different delay time.

(c) Military-civilian cooperation effectiveness KPI

Today's airspace is no longer purely military or civil airspace, it will be allocated according to the needs of airspace users. Improved military-civilian coordination can make better use of airspace. Military-civilian coordination can be reflected in the use of conditional route. The condition route specifies whether a special route is available. In general, civil airspace users can use conditional route most of the time, but they are not available when there are military activities. Using conditional route in the absence

of military activity can increase airspace utilization and reduce delays.

Military-civilian cooperation effectiveness is reflected in the percentage of number of conditional route used to number of conditional route.

Measured data: the number of conditional route, the number of conditional route used

Formula: the number of conditional route divided by the number of conditional route used

(d) Dynamic airspace configuration KPI

Dynamic airspace configuration allows ANSP to organize, plan, and manage the airspace configuration with sufficient flexibility to respond to changes in traffic demand. For example, design sectors based on predicted traffic flow. This not only increases capacity, but also reduces delays and emissions. Dynamic airspace configuration includes two types of dynamic mobile areas. Type 1: military reservations at a specific reference point that satisfies airspace users' requirements. Type 2: military needs at any geographical location along the trajectory.[49] This can minimize conflicts between military and civil aviation.

Unfortunately, it is difficult to evaluate the performance of dynamic airspace configuration through data. But the dynamic airspace configuration can be monitored in real time.

(3) Environment area

With the development of aviation, the energy consumption of infrastructure can be ignored. By assessing it can help European aviation to achieve decarbonization. Focus on implementation of free route airspace will better improve the flight efficiency. The following KPIs are proposed in environment area (Table 10).

Table 10: Proposed new KPIs in environment area

KPI	Measured data	Description
Energy consumption of infrastructure	• annual CO_2 emissions of infrastructure • renewable energy consumption • total energy consumption • number of new renewable energy infrastructure • total number of infrastructure	• Carbon emissions of infrastructure: annual CO_2 emissions of infrastructure • Utilization rate of renewable energy: the total energy consumption divided by the renewable energy consumption • Conversion rate of infrastructure: the total number of infrastructure divided by the number of new renewable energy infrastructure
Implementation of free route airspace	number of free route used in free route airspace	The number of free route used reflects the implementation of free route airspace.

(a) Energy consumption of infrastructure KPI

When mentioning GHG emissions from the aviation industry, people will first think of aircraft emissions and ignore the emissions caused by the energy consumption of infrastructure. ANSPs consume 1,140 GWh of electricity each year, roughly equivalent to 55% of Malta's annual electricity consumption.[50]

Regardless of whether emissions from aircraft exhaust or infrastructure energy consumption, the focus is on carbon emissions. Decarbonization of aviation industry as a whole is the core of environmental initiative. The decarbonization of the ground infrastructure of European ATMs can save a lot of potential emissions every year, and provide strong support for the overall decarbonization goal of the aviation industry.[51] EUROCONTROL estimates that switching to renewable energy and investing in energy conservation can save ANSP more than 311,000 tons of CO_2 each year.[52]

The key to decarbonization is the use of renewable and clean energy. The British air navigation service provider NATS has purchased renewable electricity, which will account for more than 96% of the total electricity consumption in 2020-2021.[53] Skeyes, the Belgian ANSP, has used 100% green electricity since 2015 and has approved the installation of a solar farm at its main site adjacent to Brussels airport.[54]

These measures can reduce a lot of carbon emissions.

The energy consumption of infrastructure KPI will focus on the carbon emissions of infrastructure, the utilization rate of renewable energy and the conversion rate of infrastructure. The following are the measured data and formula:

Measured data: annual CO_2 emissions of infrastructure, renewable energy consumption, total energy consumption, number of new renewable energy infrastructure, total number of infrastructure

Formula: Utilization rate of renewable energy: the total energy consumption divided by the renewable energy consumption

Conversion rate of infrastructure: the total number of infrastructure divided by the number of new renewable energy infrastructure

(b) Implementation of free route airspace KPI

Free route airspace is a designated airspace in which users can freely plan routes between defined entry and exit points. Depending on airspace availability, routing can be done through intermediate waypoints without reference to the air traffic service route network.[55] This not only improves flight efficiency, but also reduces fuel consumption and emissions. Implementation of free route airspace can be reflected in the number of free route used.

Measured data: the number of free route used in free route airspace

Formula: There is no formula determined for this KPI.

(4) Cost-efficiency area

The following proposed KPIs can better help ANSPs control costs, thereby improving cost-efficiency without affecting normal operations. The following KPIs are proposed in cost-efficiency area (Table 11).

Table 11: Proposed new KPIs in cost-efficiency area

KPI	Measured data	Description
Effectiveness of ATCO with double endorsement	• the number of ATCOs with double endorsement • the total number of ATCOs	the total number of ATCOs divided by the number of ATCOs with double endorsement
Additional ATC capacity cost	• the increase in staff costs • the increase in infrastructure investment costs	the increase in staff costs plus the increase in infrastructure investment costs
Remote and virtual tower	-	It cannot be assessed at a European level. It can only be monitored

(a) Effectiveness of ATCO with double endorsement KPI

The current ATCOs work method lacks flexibility. Currently they can only be working only in the sector family of their endorsement, therefore if there is an ATCO shortage at one sector family and overhang of ATCOs in some others, ANSPs cannot use them to cover the shortage. The dual use of ATCOs not only saves some staff costs for ANSPs, but also increases ATC capacity.

Measured data: the number of ATCOs with double endorsement, the total number of ATCOs

Formula: the total number of ATCOs divided by the number of ATCOs with double endorsement

(b) Additional ATC capacity cost KPI

For ANSPs, the main cause of ATFM delays is insufficient ATC capacity. Therefore, in order to better improve ATFM delays, ANSPs need to increase ATC capacity, which means more costs. For example, the increase in staff costs and the increase in infrastructure investment costs. These additional costs increase the cost of ANS. ANSPs need to control the additional ATC capacity cost within a reasonable range.

Measured data: the increase in staff costs, the increase in infrastructure investment costs

Formula: the increase in staff costs plus the increase in infrastructure investment costs

There is a trade-off relationship between additional ATC capacity cost KPI and different delay time KPI. ANSPs should ensure that the additional ATC capacity cost cannot be higher than the delay cost.

(c) Remote and virtual tower KPI

The implementation of remote and virtual tower allows ATCOs to leave the airport tower and work in the remote tower center, or to perform ANS from one ground station for more airports. The data is transmitted to the remote tower center through airport cameras and sensors and presents a high-resolution video panorama on a large screen. The advantage of this is that the cost is greatly reduced. Compared with traditional towers, the construction and operation costs of remote towers and facilities are much lower. Human resources can be better utilized by serving multiple airports with low and medium traffic levels from a centralized location.[56]

Remote and virtual tower KPI is difficult to evaluate in the entire ATM system, because the use of remote and virtual tower is mainly for airports with lower traffic, and may not be implemented for airports with higher traffic. So, the most effective way is to monitor it in real time.

5.2 Assessment process

This section will discuss the assessment process of the proposed KPIs, including the basic process, regional scope, time frame, and the incentivization mechanism of ANSPs.

(1) Basic process

The assessment structure has not changed. ANSPs should submit data to the PRB

and be evaluated as before. ANSPs should ensure the accuracy and authenticity of the data, and ensure that it is submitted within the specified time frame.

(2) Regional scope

The regional scope of the assessment is divided into all-European regions and partial regions. In addition to the remote and virtual tower KPI, other proposed KPIs are applicable to each ANSP and should be evaluated in all-European regions. At present, for the remote and virtual tower KPI, it only applies to some ANSPs with remote and virtual towers and should be evaluated in partial areas. With the development of aviation in the future, maybe all ANSPs will use remote and virtual tower. By that time, the remote and virtual tower KPI should also be evaluated in all-Europe regions.

Also the assessment is done on national basis, which also should be kept, as many of the decisions differ among countries or are a question of national sovereignty.

(3) Time frame

The time frame of the assessment includes the year and the reference period. Due to the rapid development of global aviation and the increasing probability of disruptions, proposed KPIs should be evaluated every year. This helps to better understand the real situation of the aviation industry, and can detect existing problems in time. In addition, the proposed KPIs should also be evaluated at the end of each reference period, which can help PRB adjust KPIs to conform to future aviation development trends and establish new targets for the next reference period.

(4) Incentivization mechanism of ANSPs.

The application of penalty and reward mechanism helps to spur ANSPs to make better performance. For example, reward ANSPs that use new renewable energy infrastructure and renewable energy, and penalize ANSPs that still use infrastructure with high CO_2 emissions. This will encourage all ANSPs to improve infrastructure and reduce GHG emissions.

Sometimes penalty and reward mechanism becomes meaningless. One reason is different KPIs affect each other. For example, different delay time KPI and additional ATC capacity cost KPI, reduced delays maybe lead to increased costs. Another reason is many factors that are not controlled by ANSPs will affect the evaluation. For example, the limited airport capacity and severe weather will increase the delay time. In this case, it is difficult to have a standard to judge whether ANSPs should be rewarded or punished.

In short, the penalty and reward mechanism depends on the situation. This mechanism can be implemented for simple KPIs that are not affected by other factors. The KPIs that will affect each other must be judged after weighing. For KPIs affected by additional factors, this mechanism is not implemented.

6 Discussion

The new KPIs are proposed based on the thorough research of the current situation in aviation industry and its expected development. The current situation of the European aviation industry is not optimistic, this is reflected in two aspects. One aspect is that Covid-19 has caused a significant reduction in traffic flow. The other aspect is that capacity and environment problems brought by the increasing traffic flow before the arrival of Covid-19. The conflicts between capacity area and cost-efficiency area also need to be resolved. EUROCONTROL predicts that the traffic flow of European aviation will return to the level in 2019 around 2024. When the traffic flow returns and further increases, capacity and environmental issues and conflicts will become more apparent.

The proposed KPIs focus on solving the above-mentioned problems and conflicts caused by the substantial increase in traffic flow. For example, the evaluation of Military-civilian cooperation effectiveness KPI and dynamic airspace configuration KPI can better know the usage of airspace, so as to further improve the utilization of airspace. The cost of different delay times is clearer by evaluating the different delay time KPI. On this basis, combining the additional ATC capacity cost KPI can help ANSPs find that how much delay time is acceptable, which reduces the conflict between capacity area and cost-efficiency area. Unfortunately, the proposed KPIs did not take into account the impact of Covid-19. This will be described in detail when discussing their limitations.

Performance assessment is not always fair for all counterparts. This is reflected in many external factors that affect the performance of ANSPs, such as severe weather, airline flight schedules and airport capacity. But ANSPs have only minor options how to react to these external factors. This is also one of the limitations of the proposed KPIs. Therefore, in order to evaluate the performance of ANSPs with the most objective measurement standards, the influence of external factors should be minimized or

disregarded as far as possible already during the definition phase of the indicators.

The proposed KPIs can make up for the limitations of the current performance evaluation to a certain extent, but they also have own shortcomings. These are reflected in the following three aspects:

The performance assessment targets are ANSPs, but there are many additional factors affect the evaluation results. For example, delays caused by insufficient airport capacity, bad weather and other non-ANSPs reasons will affect the evaluation results of the different delay time KPI. It reflects the increase in delay time. Airport capacity can be defined as an extension to the utilization rate of ATC capacity. Insufficient airport capacity will lead to a decline in the utilization rate of atc capacity. For example, the ATC demand is 100, the ATC capacity is 100, and the actual workload is 96. At this time, the utilization rate of ATC capacity is 96% (100 divided by 96), but the airport capacity is only 90, which means that the maximum ATC demand and the maximum actual workload have become 90, which leads to utilization rate of ATC capacity is reduced to 90% (100 divided by 90).

Some KPIs are difficult to evaluate because it is difficult to collect data, these can only be monitored. For dynamic airspace configuration KPI, it focuses on airspace planning, which is a macroscopic measure. There are many dynamic airspace configurations due to differences in the composition of different airspaces. Also, the ANSPs do not apply unified processes. Therefore, it’s impossible to use data to evaluate this KPI or to compare ANSPs among each other. However, this monitoring may provide the Network Manager with useful information that can be deployed for various strategic and pre-tactical measures.

With regards to the remote and virtual tower KPI, at present, remote and virtual tower can only be used in airports with low traffic flow, which means that it cannot be evaluated at the European level, so it can only be monitored.

The proposed KPIs have a very limited role in the Covid-19 crisis. First, this is reflected

in that the proposed KPIs cannot find out inefficient performance of ANSPs. The performance assessment mechanism is to evaluate ANSPs, find out where they are inefficient and then propose changes and amendments to minimize the inefficiencies. This is very effective under the normal development of the European aviation industry, but it has become ineffective under the current Covid-19 crisis. Due to the significant reduction in traffic flow, the performance of ANSPs in each KPAs will be much better than before, which brings the illusion that there is no underperformance for ANSPs under Covid-19. Second, it's reflected in assessment cannot help ANSPs solve the crisis. The biggest problem of current ANSPs is the financial crisis, but performance assessment does not include the evaluation of its financial aspects. Moreover, ANSPs cannot make major changes on their own to deal with the financial crisis. They are more seeking government financial assistance and bank loans.

The aviation industry is constantly developing, and the new KPIs proposed should also keep developing. For example, when the infrastructure is completely decarbonized, the focus of the energy consumption of infrastructure KPI may become how to reduce the consumption of clean energy. With the further substantial increase in traffic flow in the future, the number of delays and delay time may further increase. The different delay time KPI should further refine the delay range. All in all, the proposed KPIs are not static and should follow the development trend. The aviation industry is developing more and more rapidly, so the proposed KPIs must be evaluated every year, and the reference period should be shortened in order to better comply with the development trend. The KPIs should serve as kind of roadmap for the whole industry, and a constant review is necessary with regards to the actual situation otherwise the penalty and reward mechanism of ANSPs for their performance may be obsolete.

Conclusion

The aviation is sensitive to any kind of disruption, the drastic reduction in traffic flow will cause stakeholders in the aviation industry to face various crises. As an important member of the aviation industry, the performance of ANSPs has a great impact on the development of the aviation industry now and in the future.

Performance assessment is an important tool to enable the future development of European ATM and accommodate the predicted increase in the demand for air travel. However, the methods applied within the performance assessment are very inflexible and do not reflect the changing nature of aviation industry and particularly its impact on ANSPs, which is often completely out of their control. Unfortunately, there is no straight forward solution to this problem. Because the substantial reduction in traffic flow is the main reason for the good performance of ANSPs, and no one can control the changes in traffic flow. Therefore, the current European performance policy does not take into account the impact of Covid-19, but instead focuses more on solving the capacity and environmental problems caused by the significant increase in traffic before the crisis. However, the limitations of current performance assessment will prevent it to achieve goals.

The limitation is reflected in the current KPA's KPIs focus on solving problems in their own areas, ignoring the interdependence and conflicts between different areas. In addition, most of the current KPIs have been sufficiently improved. There is not much room for improvement. The current KPA cannot accurately reflect the problems of the ATM system, which makes it impossible to better reflect the current and future needs of the European aviation market.

The SES 2+ package is currently in the trilogue stage and has not been fully adopted, which means that no particular KPIs have been formulated by now. Therefore, within the scope of this thesis proposal of new KPIs discussed in detailed and recommendations for the future development of performance assessment are

formulated.

This thesis provides a deep analysis of the European performance assessment policy with respect to the nature of aviation industry. Further, based on the analyses, limitations, and contra factors of each of the KPAs and respective KPIs are discussed in detail. This research provides a bias for the main goal of the thesis, which aims to propose new indicators to better assess the current and future needs of the European Air Traffic Management. As a result, 10 new KPAs covering 4 KPAs based were proposed. These new KPIs are mainly aimed at the problems caused by the substantial increase in traffic flow after the revival of European aviation in the future. The proposed KPIs do not consider the problems caused by Covid-19, because the purpose of performance assessment is to find the shortcomings of ANSPs in the ATM system, not to solve their financial crisis.

The proposed KPIs still have limitations. Firstly, many external factors will affect the evaluation of KPIs. Secondly, some KPIs are difficult to evaluate because it is difficult to collect data, these can only be monitored. Thirdly, they still cannot solve the problems caused by Covid-19 or any other crisis that might have an impact on ATM in the future.

However, the proposed new KPIs are conform with the predicted future development in terms of demand for air travel as well as the trends of the European aviation industry.

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