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COST ANALYSIS OF AIR TRAFFIC FLOW DISRUPTIONS IN EUROPE

ABSTRACT

One of three main phases of European Air Traffic Management (EATM) system is strategic phase which is separately conducted at national, regional and Europe-wide level. It mainly includes a conduction of periodical activities and meetings with an aim to identify areas requiring performance improvements, higher airspace utilization level, optimizations etc. In addition, evaluation of airborne Air Traffic Flow Management (ATFM) delays is also a common activity that is being done at strategic phase. The reason is that airborne ATFM delays are also used as a measure to identify Area Control Centres (ACCs) with capacity shortage and to identify network bottlenecks. Usually such assessments are based on different internal and external data and information obtained from accredited sources, standardized measurement values and measurement principles. In 2018, due to high demand for air traffic services, airspace users have faced with a significant increase of airborne ATFM delays and consequently additional operational costs. Thereby, this research was carried out with an aim to estimate a value of additional operational costs of airspace users which have been generated during 2018 due to airborne delays. Hence the causes and appearance areas of different types of airborne ATFM delays have been studied, articulated in sense of additional operational cost and finally presented within this research paper. Lastly, this research also gives a background for evidence-based policy making by identifying where and how to further improve the competitiveness of European air traffic market.

KEY WORDS

Air traffic management; airspace management; air traffic flow management; cost analysis

1. INTRODUCTION

Airspace is a limited resource and the way it's organized has a strong impact on airspace capacity. As any other, airspace management system can be more or less effective. As one of the most obvious indicators of inefficient management is the occurrence of flight delays and associated costs which are caused by the lack of capacity. Due to the unacceptable level of flight delays during the 1990s, significant funds were invested with a goal to minimize their future occurrence. From then on, as a preventative measure of system efficiency monitoring, it was introduced a continuous measurement of flight delays at the level of the entire European ATM network. Nowadays in Europe a demand for traffic has been continuously increasing for last years. That is why one of the future major challenges of the EATM system is to develop a new concept that will be able to respond in long terms to future traffic demand. But before starting to look for new solutions and start implementing various projects, it's necessary to maximize as much as it's possible the efficiency in currently dysfunctional areas of EATM system. This is primarily true for areas in which airspace users are exposed to additional financial costs caused by airborne delays.

The choice of the research topic is based on its high relevance. This is in support by the fact that studied problem gets more attention from both, European aviation industry and public. Additional relevance arises from the fact that it's important to monitor changes which are occurring at European and regional level because they also reflect on the strategic programs and plans of national air traffic management and development. Therefore, within the scope of the research, the total area of the European airspace was analysed in the size of 17,917,600 km^2. Furthermore, research included consolidation of data from 37 Air Navigation Service Providers (ANSPs). Therefore, based on quantitative research, it has been conducted a cost analysis of additional operational costs which were paid by airspace users overflying Europe and which were primarily caused by airborne delays during 2018.

2. AIRSPACE CAPACITY MANAGMENT

In the nineties, the greatest problem with which European ATM network was facing was to provide capacity to continuously growing demand for air traffic services (ATS). Thereby, it often happened that the ACCs' capacities were exceeded. That was primarily manifested in large number of flight delays and associated additional operational costs. Therefore, European Civil Aviation Conference (ECAC) adopted European Air Traffic Control Harmonisation and Integration Programme (EATCHIP) with the goal to increase the capacity of the European ATM network. In general, airspace capacity can be defined as the maximum number of aircraft that can enter in specified airspace area thus giving to Air Traffic Control Officers (ATCOs) a certain level of workload that they must perform in a safe manner over a given period [1]. The result of EATCHIP was primarily expected in terms of improvements of Air Traffic Control (ATC) capacities. In that context, it's important to understand that airspace capacity differs from ATC capacity. Airspace capacity is divided into controlled and uncontrolled volume and it's greater than ATC capacity because for the calculation of ATC capacity only the controlled airspace is considered. The result of improvements of ATC capacities were achieved by enabling the aircraft to be less dependent on fixed navigational aids and routes and by increasing the possibility of flying on more flexible, more economical and more direct routes. However, that didn't completely resolve the problem of airspace capacity management. The reason can be found in the fact that in the meantime the traffic turnover has increased considerably in Europe. Therefore it's still existent the problem of balancing between demand (for air traffic services) and supply (ACCs' capacities) with a goal to ensure optimal and cost-efficient use of airspace.

Efficient airspace management is fundamental prerequisite to increase the capacity, to provide the optimum response to various user requirements and to achieve the most flexible use of airspace [2]. In addition, International Civil Aviation Organisation (ICAO) have defined that appropriate ATS authority should periodically review ATS capacities in relation to traffic demand and provide flexible use of airspace in order to improve the efficiency of operations and increase capacity.

International Civil Aviation Organisation also states that in the case that traffic demand regularly exceeds ATC capacity (resulting in continuing and frequent traffic delays) or it becomes apparent that forecast traffic demand will exceed capacity values, the appropriate ATS authority should maximize the use of the existing system capacity and develop plans to increase capacity to meet the actual or forecast demand [3]. Therefore, nowadays strategic planning of air traffic operations starts as early as possible by consolidating the air traffic forecasts and the capacity plans issued by the ANSPs (ACCs), airlines and airports. The goal of capacity planning is to easier identification of bottlenecks, situations where capacity is scarce and to reduce intervals of capacity shortfalls. Additionally, capacity plans are mostly focused on the summer period as it's the busiest period in Europe in which a large amount of delays are generated. Opposite to that, during the winter, individual ANSP transition plans are analysed and coordinated to ensure minimum effect of temporary capacity reductions due to implementation of changes to airspace, routes, sectorisation and ATC systems, which frequently occur during the winter period. More in-depth description of European network capacity planning process is detailed in EUROCONTROL's Capacity assessment and planning guidance document [4] which supports local and network ATC capacity planning for en-route airspace.

A vital part of managing European ATM network has Air Traffic Flow and Capacity Management (ATFCM) function. The objective of ATFCM is to manage the balance of demand and capacity, by optimising the use of available resources and coordinating adequate responses, in order to enhance the quality of service and the performance of the ATM system [5]. In the event of a lack of airspace capacity, after coordination with Flow Management Position (FMP), Network Manager decides on the activation of Air Traffic Flow Management (ATFM) regulations in a given area. ATFM regulations represent a safeguard method which are applied to match traffic demand to available capacity.

When traffic demand exceeds available capacity, i.e. if the number of flights exceeds available ATC capacity, ATFM regulations will be imposed to adjust demand to the capacity of ACC. Depending of the type and the entity responsible for the reference location protected by the ATFM regulation, the ATFM delay can be classified as either an airport (ground) or an en-route (airborne) ATFM delay and attributed to the relevant ANSP or airport. Since ground delays are less harmful to the environment, they are preferable than airborne delays [6]. ATFM en-route delay can be defined as an ATFM delay caused by regulations applied by the Network Manager Operations Centre at the request of the FMP to protect en-route ATC sectors from overload. The reason for the regulation is indicated by the responsible FMP. The reasons (causes) for the regulations which refer to the en-route ATFM delays are shown by Table 1.

Table 1 - Classification of en-route related ATFM regulations

Code	En-route ATFM regulation nomenclature	Code	En-route ATFM regulation nomenclature
C	ATC capacity	S	ATC staffing
T	Equipment (ATC)	R	ATC Routeing
I	Industrial Action (ATC)	N	Industrial Action (non-ATC)
M	Military Activity	A	Accident/Incident
G	Aerodrome Capacity	E	Aerodrome Services
P	Special Event	D	De-icing
V	Environmental Issues	W	Weather
O	Other	NA	Not specified

Listed ATFM regulations and associated delay values of entire European ATM network have been studied separately but also cumulatively within the framework of this quantitative research. In doing so, the reference data was obtained from Performance Review Unit (PRU). It refers to en-route ATFM regulations related delays (minutes) hence detailing performances of 37 ANSPs. In general view, PRU is independent part of EUROCONTROL which is responsible for monitoring and reviewing the performance of the Pan-European Air Navigation Services (ANS) system across several key performance areas and indicators [7].

3. METHODOLOGICAL APPROACH FOR COST ANALYSIS

Given that the present forecasts predict a future increase of air traffic services within European ATM network additionally represents a major challenge for airspace capacity management [8]. Moreover, punctuality is generally considered to be the aviation industry standard indicator for air transport service quality [9]. Therefore, in the recent years, with the aim of meeting and adjusting the operational, strategic and development plans, various businesses within aviation industry are looking for studies and information which can help their decision makers to better understand their business environment. Such studies most often include valorisation of current and forecasted traffic effects which are important for their business and which could have a bearing on the business.

In Europe, all capacity related costs are borne by airspace users. As it's shown by Figure 1, that includes the costs of providing capacity (paid through user charges) and the costs of delay (when insufficient capacity is provided). The cost of capacity is based on the cost base of each ANSP. In cases where an ANSP is responsible for the operation of more than one ACC, either a distribution of costs between ACCs is directly provided by the ANSP, or the capacity cost is divided proportionately per ACC according to the number of sectors in each ACC. In addition, the capacity costs are assumed to vary linearly. However, the relationship between capacity and delay is not linear. Moreover, when the demand is above available capacity, there is a saturation of the ACC capacity leading to a sharp increase in delay. The cost of delay is estimated based on a study commissioned by the EUROCONTROL to the University of Westminster (United Kingdom). It's defined as the average cost per minute to the airline caused by ground or airborne delay of a commercial passenger flight. In the meanwhile, the University of Westminster has published more reports and modified the value of the cost of delay. For example, a first report published in 2004 have defined that the average cost value of delay was 72 EUR/min [10]. In the report from 2011, the average cost of delay was increased, and it was estimated to be 81 EUR/min [11]. Within the last report from 2015 it has been increased again and it equals to 100 EUR/min [12]. Nowadays reports published by University of Westminster represent the most comprehensive appraisal of the cost of delays in the air traffic management system in Europe. In addition, value defined within latest report is also used as a reference document for European delay costs incurred by airlines, both at the strategic (planning) and tactical stages as well as by EUROCONTROL as a standard input data for cost-benefit analyses [13].

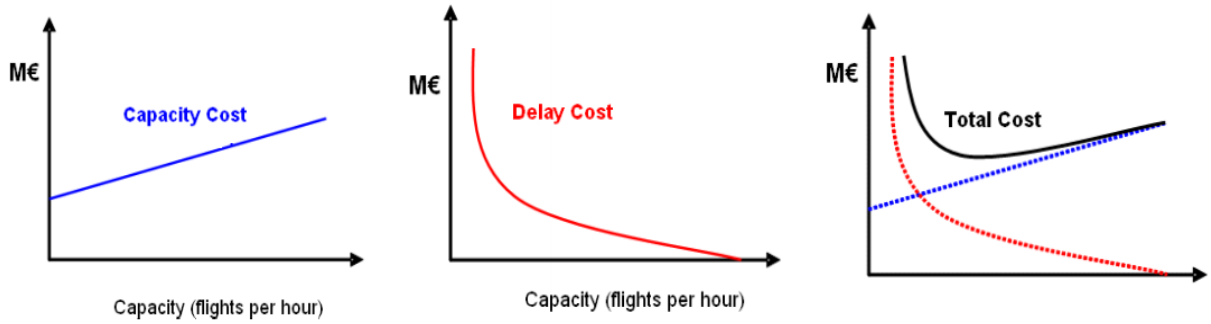

Figure 1 - Capacity related costs

Given that capacity provision has its cost and that the lack of capacity (resulting in delays) is even more expensive, it's possible to conduct cost analysis of air traffic flows disruptions in Europe. Therefore, applied delay cost value (EUR) within this quantitative research is based on the data from the latest report published in 2015 by the University of Westminster (100 EUR/min). However, it's important to keep in mind that applied value is a theoretical and highly averaged value. Therefore, applied value has been used only as an indicator to provide an insight into magnitude of delay costs with which have faced airspace users overflying Europe during 2018.

4. RESULTS

Nowadays the availability of airspace capacities becomes even more important issue. Therefore, it's mandatory to look for resources (capacity, technical, financial etc.) optimization as much as it's possible. However, the aggravating circumstance to achieve that is the problem of the variability of air traffic flows in Europe. Mentioned primarily refers to the fact that within last decade variations in traffic demand, routes flown and unexpected flight profiles in Europe have started to occur more frequently than before [14]. The cause of that can be found in the high volatility level of the European ATM network which was the most obvious when it has faced with hardly predictable events - such as economic and geopolitical crisis or serious weather conditions. However, these reasons can't be used as a justification for air traffic flow disruptions during 2018. For example, International Air Transport Association (IATA) argues that air traffic flow disruptions during 2018 were significant because planned capacity improvements were not achieved in accordance with capacity plans [15]. In that context Figure 2 shows a time sequence from 2011 to 2018 of annual traffic evolution regarding to airborne flight delays which were caused by en-route ATFM regulations.

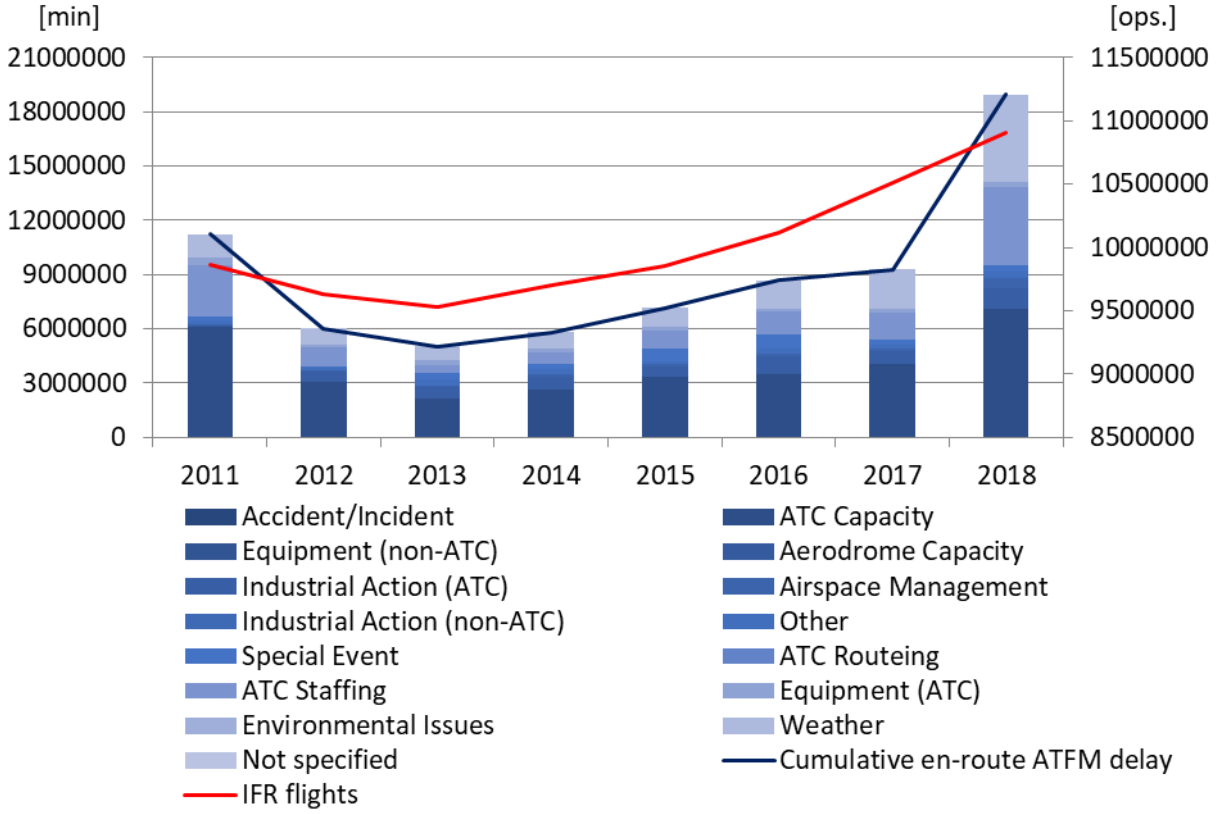

Figure 2 - Breakdown of ATFM regulations and associated delays in relation to traffic evolution [16]

By reviewing a data referring performances of European ATM network, it can be concluded that in 2018 there were on average 30,168 daily flights what represents an increase of 3.8% compared to 2017. Although September was the month with the lowest traffic growth, the busiest day ever in the network was Friday 7 September with 37,088 flights [17]. In addition, the network performances in terms of airborne delays were within first months of 2018 slightly better than in 2017 while later the situation worsened. Combination of high demand for air traffic services with a major drop in ATC capacity, record number of adverse weather events, ATC staffing issues and industrial actions have severely disrupted the network in 2018. At the end of the year airborne delay was 1.74 min/flight what is double than the delay captured in 2017 (0.88 min/flight) and well above the 2024 target of 0.5 min/flight - as it's defined by European Commission and third reference period (RP3) of the Single European Sky (SES) performance scheme. However, strategic air traffic planning and development shouldn't be only indicated by network's technical elements nor the handled transport volume. It needs to be also placed in the context of network's availability or connectivity [18].

Many successful aviation businesses manage to grow simply because they understand their business environment [19]. However, since major or minor delays are inevitable, airlines should also invest in delay management, creation of policies and into implement of measures that will help them to minimise the impacts of delay [20]. Quantification of additional operational costs caused by airborne delays should have an important role when evaluating performances of European ATM network. Moreover, because in aviation industry profit margins can often be very low and even small changes in the increase of total costs have a major impact on the overall profit. In that context, if the trend of increased airborne delays will continue, it's expected that such situation will firstly affect low-cost carriers due to fact that these airlines have already maximally optimized all components of their operational costs. Based on the obtained research results it can be concluded that there are areas with extremely high values with airborne delays. Figure 3 shows spatial distribution of areas in which air traffic flows disruptions are the most significant. Additionally, all singled out areas were determined based on the Pareto distribution. In terms of inability to respond to weathering, Areas of Responsibility (AoR) of Spain, France, United Kingdom, Germany, Austria and Hungary can be outlined from the others. The total cost of studied area associated to airborne delays caused by weathering is estimated to be EUR 481,097,100 and it covers 25.38% of overall cost generated during 2018. Furthermore, in terms of disruptions caused by the lack of ATC capacity it can be concluded that France and Germany are facing with a significant problem. In their AoRs it has been generated 99.91% (~EUR 399,898,300) of all airborne delays caused by lack of ATC capacity. Additionally, these two countries, i.e. AoR of their ANSPs as well of Greek ANSP can be distinguished as areas with ATC staffing problems. By analysing the overall cost of that segment, it can be concluded that for 2018 it's estimated to be EUR 436,048,600. That represents an increase of 186% compared to value generated one year before. ATC industrial actions can be outlined as fourth significant cause of airborne delays during 2018. The overall magnitude of cost associated with ATC industrial actions is estimated to be EUR 113,415,300. Cost analysis of all other causes of delays during 2018 is estimated to be EUR 155,382,500. Lastly, it can be defined that in 2018 the additional operational cost of airspace users caused by airborne delays equalled to EUR 1,895,797,700.

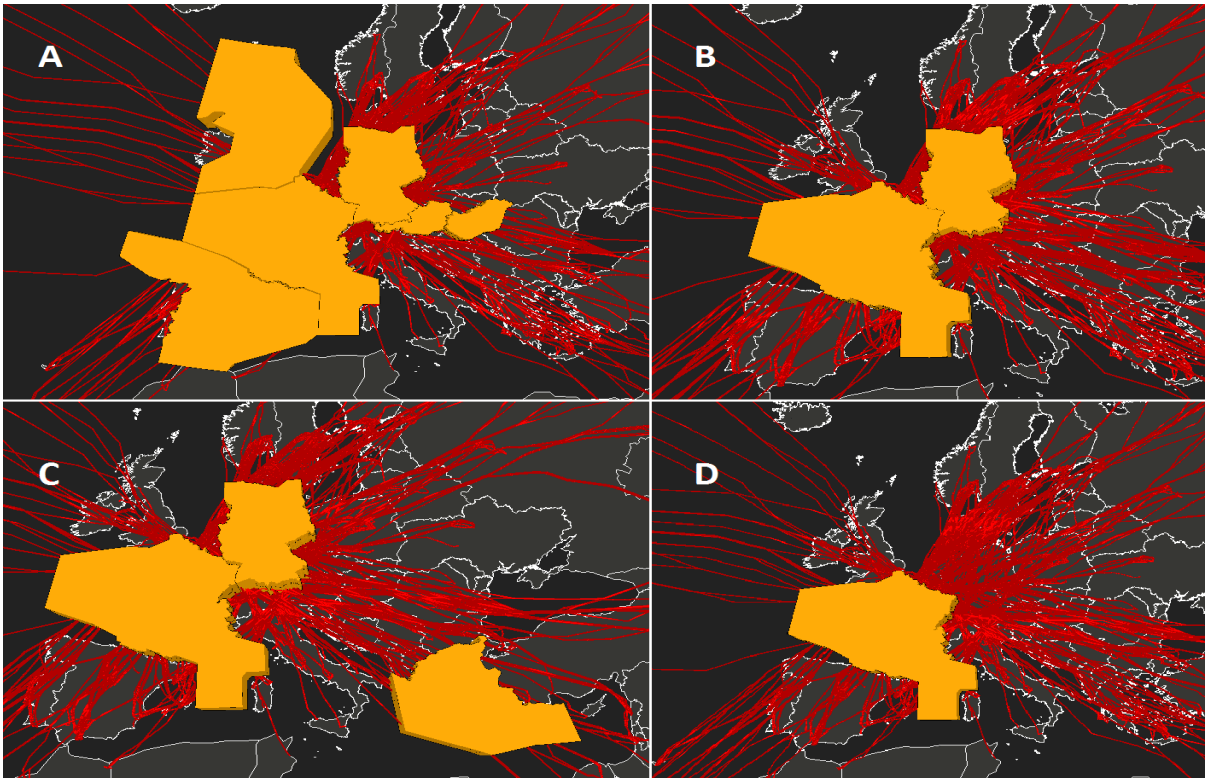

Figure 3 – Spatial overview of air traffic flows and significant areas in which en-route ATFM delays were caused due to weather (A), ATC capacity (B), ATC staffing (C) and ATC industrial actions (D)

5. DISCUSSION

In an ideal world, aircraft would fly directly from point of departure to point of arrival. Between these two points ANSPs should manage flight operations and continuously try to minimize any potential constraints which could negatively influence flight efficiency level. Considering the current state of the European ATM network, it can be concluded that it's still far away from ideal design [21]. When it comes to strategic air traffic planning and development it can be stated that in Europe it can't be no longer based on meeting the short-term demand and nationally limited. Therefore, within future European ATM network, air traffic demand needs to be controlled and channelled by modelling various technical and operational options. Moreover, stakeholders of European ATM network need to set the imperative at ensuring additional airspace capacity with a goal to parry the forecasted increase of traffic demand. Steiner et al. [22] suggest that there are several potential changes that can increase capacity and efficiency of European ATM network. Some of these changes concern comprehensive dynamic harmonization programs and introduction of new concepts, while some changes can be achieved by relatively simple improvements of existing procedures [23].

The year of 2018 was marked by changes in traffic patterns. Some flights have used different routes compared to the ones used in 2017 mostly because airlines have optimised their routes and the network was also continuously refined, e.g. recently with the development of free route airspace. However, despite improvements in terms of network optimization, due to airspace saturation and capacity constraints, airspace users were not able to fully exploit these benefits. Although Network Manager during 2018 has delivered en-route delay savings of 2.7 million minutes, there were record numbers of ATFM regulations with over 400 regulations applied on some days. Therefore, it was not uncommon for flights to be subject to up to seven regulations at once, making rerouting and delay mitigation virtually impossible [24]. That is also supported by the actual trajectory indicator (KEA) which has worsened in 2018 as compared to the previous year. Moreover, during 2018 aircraft were frequently forced to fly at lower flight levels and at suboptimal flight levels thus increasing operational costs in terms of higher fuel consumption. Besides aforementioned, during 2018 fuel costs were very variable what have additionally created financial pressure on airspace users.

European ATM network represents a complex and interdependent network with a high number of participating stakeholders which may, in different areas, have a greater or smaller impact on the performances of entire European ATM network [25]. In that context, it would be unfair to state that the overall performance of European ATM network is deficient. However it's necessary to distinguish ANSPs that are almost periodically causing significant airborne delays from many other ANSPs who are delivering a good performance. By reviewing the performance of European ATM network during 2018 it can be found that very large shares of airborne delays were caused by "controllable" reasons. That primarily refers to airborne delays caused by ATC industrial actions which have in some areas during a recent years became a common practice rather than exception.

When valuing the current state or determining development projections within strategic phase it's important to include several different factors - ranging from social to economic impacts [26]. Accordingly, ATC industrial actions represent one of the causes of airborne delays whose reduction, as compared to other causes, could have the fastest positive effect. Consequently, that would lead to better performance of entire European ATM network and lower operational cost of airspace users. In the broader sense, that should be the interest of the entire European air traffic market. Particularly due to fact that ATC industrial actions are nowadays occurring more frequent and lasting longer than ever before. Also, that is the reason why this issue gradually gets higher attention from public media, but also from public since they are final users of air traffic services. However, despite the consensus that ATC industrial actions have a negative impact on the competitiveness of European air traffic market and pressures coming from recognized organizations representing interest of airspace users, this problem still remains unsolved. Hence nowadays there are no adequate solutions which are applicable on the European level, such as cost recovery policies, that could significantly minimise financial exposure of airspace users to the ATC industrial actions.

Compared with data from year before, in 2018 airborne delays caused by ATC industrial actions have increased for 59.72% while compared with data from 2011 they have increased for 1154.98%. Moreover, breakdown of ATC industrial actions during 2018 indicates that three French ATC industrial actions in March, May and December and several local actions at Marseille ACC from April to June have generated the most of the airborne delays. Hence it can be concluded that due to partial and nationally limited interests, French ANSP has generated an additional operational cost to the airspace users of EUR 110,656,500. In addition, that value covers 97.57% of all costs caused by ATC industrial actions. However, although the number shown is quite significant, displayed value does not represent the total cost of the airspace users generated due to ATC industrial actions. Reason is that presented cost estimation doesn't include any additional costs such as the costs of cancelled flights and passenger's compensations.

Considering aforementioned, in the decision-making process, responsible national boards for strategic air traffic planning and development, as authorized representatives of national governments, must be aware that not acting in given time can be seen as rejection or denial of existence of problems (which are frequently "out of their control" although they are under their jurisdiction). In this case, such an approach results with ineffectiveness and disruptions of European ATM network and continuous increase of additional operational costs of airspace users. Moreover, absurdity of such a situation stems from the fact that airspace users are obliged by air navigation services charging scheme [27] to financially support different national Civil Aviation Authorities, Air Navigation Service Providers, National Supervisory Authorities etc. Therefore, within future concept design of European ATM network it should be also considered options of modification of some existing regulations by empowering interests of all stakeholders, by implementing non-discriminatory cost recovery policies and by supporting more stringent conduction of performance measurement activities. In addition, regulations which are detriment to certain stakeholders and which don't go in line with real improvements in terms of capacity, cost-efficiency, environment and safety (as four pillars of future development of European ATM network) should be modified.

Furthermore, a special attention should be given to the areas identified as bottlenecks. Short-term measures (even temporary) should be implemented in such areas in order to increase airspace and ATC capacity until it's possible to go for implementation of long-term solutions. Also, ANSPs should seek for cooperation with neighbouring ANSPs as much as it's possible. Application of such an approach can be observed in short-term and long-term. Short-term cross-border cooperation can facilitate better allocation of the required airspace structures on a daily basis. That should result with the provision of the highest possible level of service, at the right time and at the right place. In the long run such an approach would results with facilitated regionalization of the entire European ATM network (as it's anticipated by Single European Sky (SES) initiative).

To sum up, in order to achieve fast and effective performance improvements of European ATM network, it's necessary to draw the question of legal responsibility for ineffective airspace management. In that context, it's important to stress out the role and lack of authority of certain National Supervisory Authorities and different national airspace management committees. The reason is that they have regulatory defined obligation and responsibility to formulate and supervise implementation of national airspace management policies and to conduct strategic air traffic planning by promoting flexible use of airspace at a regional level (as it's regulated by SES initiative [28]). Hence, they should prioritize national, but also consider the requirements and interests of all other international stakeholders and business entities operating in airspace volume under their jurisdiction. Lastly, since the trend of increase of airborne delays caused by ATC industrial actions is continuously occurring, it's necessary to strengthen awareness of their harmfulness and look for implementation of new or modified legal measures. Such solutions should be equally applicable within European ATM network and their goal should be to reduce financial exposure of airspace users from future increases of additional operational costs because defective national airspace management policies and from partial interest articulated throughout ATC industrial actions.

6. CONCLUSION

Nowadays the availability of airspace capacities becomes even more important issue than before. This also confirms the performances of European ATM network during 2018. It have often happened that ACCs' capacities were exceeded what have reflected to airspace users in form of airborne delays. During 2018 disruptions of air traffic flow were mostly caused because of lack of ATC capacity, ATC staffing problems, the inability to respond to weathering and because ATC industrial actions. However, when evaluating air traffic flow disruptions and their impacts it's important to differentiate disruptions that are difficult to predict or control from those that are result of poor national airspace management policies, limited interests etc. In that sense, airborne delays caused by ATC industrial actions can be singled out from all other causes as an example. By imposing operational limitations (and so purposely reducing capacity) these activities during 2018 have negatively affected the competitiveness of the European air traffic market. In addition, although they were not the cause for ATC industrial actions, airspace users were the ones that have been mostly affected by disturbances and the ones who needed to financially cover additional operational costs.

Given that capacity provision has its cost and that the lack of capacity (resulting with delays) is even more expensive, it was essential to conduct cost analysis of air traffic flow disruptions in Europe. On the basis of carried quantitative research, it can be concluded that an additional operational cost to airspace users which was primarily caused by airborne delays in 2018 was EUR 1,895,797,700 - what represents increase of 104.24% compared with cost occurred during 2017.

By considering the interests of the entire European aviation industry, it can be concluded that it's necessary to conduct more frequent and stricter activities in domain of performance measurement and do not hesitate in the realization of the agreed performance targets. Also, it's important to introduce higher application of cost recovery policies and evidence-based policy making with a goal to improve competitiveness and promote inclusiveness and openness of European air traffic market. Furthermore, the gap between airspace capacity and traffic demand in Europe is so large that it cannot be overcome in short period. Therefore the application of such an approach should aim to minimize the impacts of obscured national policies, partial interests and dissatisfaction of certain stakeholders which negatively affect the overall efficiency of the European ATM network. Moreover, considering that Chicago Convention states that every Member State has complete and exclusive sovereignty over the airspace above its territory, consequently they should also consider about their legal responsibility for ineffective airspace management. In that context, Member States need to take a full responsibility of generated additional operational cost of airspace users which were caused by ATC industrial actions and poor national airspace management policies.

In the last two decades, as the most obvious weakness of the European ATM network, it was recognized the problem of decision-making at national levels. Therefore, with an emphasis on the international dimension of air traffic delays this research has identified areas which require capacity improvements and better conduction of activities within domain of the strategic phase - as one of three main phases of European Air Traffic Management system. In addition, applied research method, which quantifies ratio between lack of airspace capacity and associated costs, can be also useful to different authorities and policy makers, both professional and political, to help them to understand importance of their (non)acting. Lastly, it's important to emphasize that the strategic planning and development of European ATM system must be in function of overall economic development. Instead of being nationally limited and being driven by partial interest, strategic programs and plans of national air traffic management and development should be in the function of the development of the wider region and include the business interests of all stakeholders, thus promoting inclusiveness and openness of European air traffic market.

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