Performance management of functional airspace blocks

A preliminary study using gllamm analysis

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***Abstract*--- This study demonstrates the need for performance management of functional airspace blocks. Using a gllamm analysis of the 9 European airspace blocks, we find that the predictors of performance at the state level of the provision of air navigation services impact directly upon the performances of these hybrid airspaces. In this context, the gllamm technique operates under the condition that hybridization while optimizing performance increases the latent effects in the system of air traffic management. Also, the data is limited since the establishment of these composite airspaces is recent and ongoing. Given these circumstances, the study is a preliminary attempt at determining the predictors of FAB performance and reiterating the need for performance management at the organizational level of air navigation services.**

***Keywords**: FABs, gllamm, heterogeneity, hybridization, organization, performance management*

I. INTRODUCTION

If we have to summarize the documentation released in the past 5 years by the International Civil Aviation Organization (ICAO), we could use 2 words: Improving Performance.[1] The decision to implement hybridized airspaces that we commonly call functional airspace blocks (FABs) is one example of the bid to improve performance in air traffic management (ATM) across states. Since this is a consolidation of airspaces of organizations under a consolidation of goals, how do we check for consolidated improvement of the FAB initiative?

Performance management (PM) evaluates the need for adjustments at the organizational level.[2] This ensures that air navigation service providers (ANSPs) of each state are aligned with the prospective strategies so that FABs produce the desired results [1]. The evaluation is done via a measurement of different parameters that include organizational aspects along with the economic and technical features of FAB performance. The aim of this study is to demonstrate how we can assess those parameters using the comparative example of a generalized, linear, latent and mixed model (gllamm) analysis [2]. Because data collection in ATM is still in the nascent stages of development, this assessment of the parameters of FAB performance is part of an ongoing study and is therefore preliminary.[3]

The following sections will explain further the need for PM of the FAB initiative, the issue of heterogeneity in ATM, the methodologies used for assessing the parameters and the interpretation of the results.

II. PERFORMANCE MANAGEMENT OF THE FAB INITIATIVE

In research papers, it is customary at this point to introduce and recapitulate the various studies that relate to this topic [3]. Though PM first emerged in the seventies, the concepts of hybrid airspaces and ATM are new. The supporting data for appropriate analyses are even newer. Studies on PM are centered on the employee level [4]. We are more concerned with monitoring the performance of composite or hybrid airspaces and the impact of the performance of states via their affiliated ANSPs. In order to understand this concept of PM at the organizational level in ATM, we start by taking a step backwards in time to recall the context surrounding the initiation of the FAB approach (FABA).

A preliminary report by the European-directorate of Transport stated that the airspace and its routes had been structured around national borders. Even though the modus of aircraft separation had been based on global ICAO standards, the level and quality of air navigation services (ANS) were based on differential equipment and domestic operational

[1] ICAO Documents 9750 (primary document), 9824, 9841, 9859, 9883, 9906 and 9966; there is another document pending for the improved performance/quality management of Aeronautical Information Services

[2] For further reading see the book Strategy, Organizational Effectiveness and Performance Management: from Basics to Best practices by Soren Dressler,2004 Universal Publishers ISBN: 1-58112-532-1

[3] ICAO Journal, 2004, Vol. 66, 11

procedures for 63 ACCs of the ECAC area.[4] This resulted in an inefficient, fragmented air transport service that contributed to congestion, increased delays and exaggerated operational costs to provide a unit of air traffic control (ATC) and ancillary services[5] to 1 aircraft.

In 2004, a model of bottom-up regional cooperation[6] had been proposed to ANSPs of the EU to establish the regulatory framework for FABs of their upper air spaces. These FABs would be designed on the bases of uniform operational requirements and be free from the constraints of national borders. A more integrated airspace will mean less fragmentation, less delays, and lower costs of providing essential services to aircraft. These jointures would also fulfill the expectations laid out in ICAO's Global Air Navigation Plan for optimal efficiency which encompassed features of seamless interoperability, increased capacity, safety performance and environmental friendliness.

By the autumn of 2012, 9 Functional Airspace Blocks or hybrid upper airspaces were declared by the European Commission. Data analytics by way of Cost Benefit Analyses (CBAs) determined that the hybridization of Europe's upper airspace would counteract the growing problem of inefficient ANS. The CBAs examined the costs to or the impact upon civil and military ANSPs, civil and military air space users, as well as State administrations and consumers. The focal groups for the benefits were civil ANSPs and air space users.[7]

While the CBAs were prolific for the implementation of the FABA, performance management is more about the evaluation of the process. Also the CBA is based on the assumption that the benefits are worthy of generating revenue. Much of the focus is on the financial aspect of implementing a project. But the FABA is not just about hybridization of the upper airspaces of Europe. It is also a consolidation of organizational strategy, an alignment of organizational resources via technological innovation and the deployment of human resources which coincides with the definition of performance by one of the founding fathers of PM [5].

Thus monitoring the performance of FABs implies consistent assessment of organizational, technical and economic parameters – an integrative process which is novel to our realm of ATM but nonetheless important. The need for PM is made more crucial by the consequences of adopting hybrid measures. For economic hybridization while highly beneficial, also yields increased latency as a byproduct to the merging systems. In the case of ATM, the operations environment is already subject to a profound degree of heterogeneity.[8] The inadvertent introduction of more latent factors further detracts from the efficiency of the FABA. These latent factors are described in the following section.

III. LATENT FACTORS OF HYBRIDIZATION

A major challenge facing hybrid organizations[9] is the evolution of the organizational structure [6]. Organizational disorder (OD) becomes magnified after a hybridization process [7]. In this context, it is the merging of groups of enroute ACCs; each having an idiosyncratic organizational style; to follow innovative processes in ANS.[10] Organizationally deficient factors such as off-the-wall management policies, discord within the management hierarchy and a lack of clearly established organizational policy detract from the good intentions of hybridization. ANSPs are not exempt in this regard. One controller from the Middle East lamented that focus is usually placed on technical advancement but not much is done to promote the wellbeing of the controller.

Even small deficiencies in organizational structure (OS) negatively impacts upon ANSP performance. And the proverbial saying about one bad apple holds true in this case. One ANSP with a weak OS will affect the efficiency of a FAB for a group of ANSPs. OD is a latent effect in the FAB scenario. Very little documentation exists on the OS of ANSPs.

In addition to the role of OS, the second latent effect of economic hybridization is the operation of the unfortunate economic principle of marginal substitution.[11] There will always be a tradeoff between lowering the costs of ATM services and the quality of these services.[12] Let us assume that the strategic objectives of safety and efficiency for the FAB scenario are a set of goods that are available for each consumer – the ANSP. Efficiency is a composite good. It can

[4] For further reading, see the following link : http://www.skybrary.aero/bookshelf/books/1351.pdf
[5] Examples of this service include Aeronautical information and ATIS reports of localized weather and field conditions
[6] Model originally introduced by Wilmer, Cutler and Pickering, 2001; for further reading see paper by Tomislav MIHETEC, Sanja STEINER and Zoran JAKŠIĆ on Expected ATM changes in Central Europe, 2011
[7] FABEC feasibility study report, 2010 (PRC, Eurocontrol)
[8] ACE Benchmarking Report 2011, PRC EUROCONTROL
[9] For further reading, follow this link: http://rachelp0504.blogspot.com/2013/02/hybridized-to-be-or-not-to-be.html
[10] The hybridization of enroute upper airspace is a double process of merging and innovation which will not only increase the latent effect but the situation will also be more overwhelming for the stakeholders (internal and external)
[11] Jehle and Reny explored the issue of marginal rate of technical substitution in their book Advanced Microeconomic Theory 2001(Publishers: Prentice Hall)
[12] ACE Benchmarking Report 2011, PRC EUROCONTROL

be further subdivided into the goods of technical, operational, cost and environmental efficiency.

According to the principle of marginal substitution, each consumer or ANSP will substitute at least one unit of a good so as to gain 1 additional unit of another good in order to keep maximized utility constant. Neither will 2 ANSPs have the same utility nor the same combinations of figurative goods. ANSPs are of comparable ages; unequal sizes; manage air traffic differently and accomplish organizational aims at varying operational speeds. It is therefore not economically viable for FABs to achieve maximum safety and efficiency simultaneously, or even to achieve constant indications of optimal performance. One of the goods will always trump the other. Optimal efficiency will exist in a state of flux.[13] The same reasoning can be applied to the composite good of efficiency. One of the 4 aspects will always remain outstanding.

A third latent effect of hybrid organizations relates to the cohesion of the governance strategies that will satisfy the expectations of the stakeholders. One research paper identified the role of the stakeholders as an important measure of performance [8]. In the augmentation of optimal performance at the ANSP level and at the FAB scenario, who are the stakeholders? We may readily know about the government agencies and their subsidiaries but they are not the only stakeholders in this scheme. The Collins online dictionary (Complete and Unabridged, 10th edition) defines a stakeholder as "a person or group having an investment, or an interest, or who is affected by the decisions that affect the operations of a company". Can we identify the other stakeholders of the ATM industry and what is the extent of the symbiotic relationship between these stakeholders and ANSPs? Also, what criteria do ANSPs use to select compatible stakeholder aims? Instead of focusing only on their own aims or financial gains, stakeholders need to be more engaged or committed to the long-term prosperity of ANSPs [9]. It is certainly no easy feat for ANSPs to reconcile all the requests of regulatory agencies, interested parties, airline companies and air traffic controllers (ATCOs) under the umbrella of ATM hybridization.[14]

However, given the gains of economic hybridization of our airspaces, it is indeed worth facing up to the challenges of the above 3 latent effects. This paper does not aim to disqualify or even verify the FABA. To reiterate, the objective is to show that measuring and managing the performance of our FABs require a more holistic approach because it is about the consolidation of organizational strategies and the human resources to achieve better outcomes in ATM. We want to operate in an environment that includes less delay and efficient use of fuel and seamless data interoperability in air navigation among other wishes from a list of global objectives. To optimize the FABA effectively, we formulate a model that will allow us to assess, adjust and improve performance at the ANSP level. In the next section, we look at how the gllamm technique helps us to validate that model by estimating the significance of our predictors.

IV. EVALUATING FAB PERFORMANCE

Gllamm analysis estimates its predictors based on the maximum likelihood that the desired function is likely to occur given a limited set of observations from a population. Again, in research papers this is the point where the reader gets a synopsis of a pilot study and related examples from which the present study stems. In the absence of relevant material, we will step across into the domain of social sciences to help us understand the modus of the gllamm technique.

Health studies, survey polls, education and more recently animal science are areas where this technique has been applied [10]. It is often part of the preliminary processes in advanced regression analyses with data inconsistencies and the possibility that the fundamental lemma of statistical computation may be violated. The gllamm technique is used to explore, predict and validate relationships between concepts and the factors that influence them. It has the drawbacks of being novel as well as being a long and tedious methodology because of the nipping and tucking with additional constraints that result in heavy computation. It works best when the role is simple, predictors are few, the sample is weighted and the analysis proceeds in a step-wise manner.[15]

In the hybridization scenario, there are two sides to their activity: economic gain on one hand but the byproduct of censoring factors on the other. The FABA is similarly two-fold in significance. It can be likened to the activity of icebergs that support thriving marine ecosystems while posing a threat to the unhindered passage of ships. Thus in measuring FAB performance, we need to include the good outcomes that contribute to optimization of ATM as well as the latent events that undermine the operations. Latency is difficult to measure and ATM is shrouded in heterogeneity. We cannot directly

[13] A firm is always under the threat of uncertainty or random walk effects while also subject to a life-cycle of productivity and growth; in this context the ANSP is seen as a firm and as a consumer which will weigh upon FAB efficiency

[15] In the animal science study, the gllamm is used to assess the suitability of the predictor variables as part of an advanced regression analysis

gauge the quantum effect of inclement weather. Assessing the organizational parameters is best done via the perception of the employees and since this is a service industry, we definitely need feedback from the users of ATS.

The gllamm technique tests the theory that FAB performance is a function of ANSP performance in each state and that the performance of the latter is a result of a combination of parameters that include the technical, economic and organizational aspects. It also takes into account the byproduct of latent or random effects at the hybridized level.[16] This method operates on the principle that the efficiency or performance of a FAB is affected by the productivity of ANS per state. If common strategic objectives are met that yield increases in safety performance, the state's inefficiency in providing ANS decreases and in turn, the FAB efficiency increases.

We develop a dependence structure for FAB efficiency based on the precepts that it is a generalized linear model, the data is clustered and the outcomes are predicted by both fixed and random effects. We also make the assumption that the intercept has a normal distribution with zero mean.

$$\eta_{ij} = x'_{ij}\beta + \mu_j^{(2)}$$

FAB efficiency η_{ij} depends upon the fixed effect $x'_{ij}\beta$ which is a vector of the explanatory variables with their fixed *Beta* coefficients that impact upon the state to provide ANS, which is also the primary level or the elementary unit. The intercept $\mu_j^{(2)}$ represents the random effect or any unobserved heterogeneity at the secondary level or the FAB level which is the clustering unit.[17]

The variables in the vector represent the key performance areas (KPAs) that states must strive toward in optimizing the management of air traffic in these hybrid air spaces. These variables are derived from 4 datasets that measured diverse indications of performance for 31 ANSPs of the European Union during the period 2006-2013.[18]

Data collection in ATM is still at the nascent stages of development. In the past, research on Air Traffic Control (ATC) systems focused on complexity and the technical aspects of ANS.[19] We expect that specific data will be difficult to obtain, inconsistent at both the ANSP and the state level and even nonexistent in some instances. In this study, we use state-specific data collected from the major ANSPs in Europe. The sample consists of 9 FABs and 28 states. Some states have established bipartisan aviation agreements and coexist as a single entity. States that recently joined the FAB initiative have been omitted from the study due to unavailability of data. Because the FABA is a recent development in ATM, this study is rather preliminary. The results and the scope for a more comprehensive data analysis will improve as more data becomes readily available.

Table 1 shows a synopsis of the parameters or KPAs at the state level and their corresponding predictors.[20] To quicken the gllamm process, we do a simple OLS regression to eliminate the variables that are not significant at the 90% Confidence Limit.[21]

[16] In ATM, the fixed effects refer to regulations that govern the operations of ANSPs across states as per ICAO codes or regional requirements such as by the Eurocontrol, FAA and IATA etc. while the random effects encompass latency and heterogeneity: unobservable and immeasurable/subjective deterrents of FAB performance

[17] Sophia Rabe-Hesketh and Anders Skrondal, Multilevel and Longitudinal Modeling Using Stata, 2nd ed., ISBN-13: 978-1-59718-008-5 already cited

[18] Data used from the e-dashboard of the Performance Review Commission, Eurocontrol

[19] There are at least 200 research papers devoted to the complexity of ATC up till March 2004, when a report on the psychocognitive complexity of ATC was presented by Eurocontrol

[20] The KPAs with the exception of Innovation; marked with a bold asterisk; have been established by the PRC

[21] Ordinary Least Squares regression is the simplest regression that estimates the significance of predictors by finding the best fit in a relationship between those predictors or inputs and the outputs of that relationship. According to its name, ordinary least squares work by minimizing the sum of squared errors. For further reading see Basic Econometrics 2009 by Damodar Gujarati, Mc Graw Hill ISBN: 9780071276252

TABLE I Variables for assessing FAB performance using STATA™

Key Performance Areas*	**Variable**	**Ability to predict FAB performance at 90% statistical significance**
FAB performance	FAB Efficiency **(FABE)** [a]	Dependent variable
*Safety Performance and Management (SPM)	Effectiveness of Safety Management (**ESM**) [b]	Significant predictor
*Economic efficiency	Costs of gate-to-gate delays per composite flight hour (**COD**) Military airspace Thriftiness (**MTS**) [c]	Significant predictor Not a significant predictor
*Operational efficiency	Volume of Controlled Airspace **(VCA)** Number of Operational units: ACCs, TWRs and AFIS (**NOU**) Size of staff **(SOS)** Scope of Services (**OSS)**	Significant predictor Not a very significant predictor Not a significant predictor Not a significant predictor
*Technical efficiency	Aggregated complexity score (**ACS**)	Significant predictor
*Environmental efficiency	Traffic Variability Indicator (**TVI**)	Not a very significant predictor
Innovation [e]	Innovation Strategy (**IST**) [f]	Not a significant predictor

[a] Data Envelopment Analysis (DEA) is another statistical technique that is discussed in Section V
[b] Data used from the e-dashboard of the Performance Review Commission, Eurocontrol
[c] Ibid
[d] Data used from the e-dashboard of the Performance Review Commission
[e] The data for the rest of the variables for the KPAs in this table have been taken from the ACE Benchmarking report, 2011, PRC Eurocontrol
[f] PRB final report National/FAB Performance Plan Assessment Vol ii

V. PREDICTORS OF FAB PERFORMANCE

The variable for FAB performance was determined from a Data Envelopment Analysis (DEA) plus an OLS regression of the gate-to-gate ATM costs as inputs and the total IFR flights controlled by the state as outputs.[22] The aggregated complexity score (**ACS**) is the interaction between flight density in the enroute region and modal states of flight configuration in close proximity. There is a lack of supporting data for continuous descent operations. This program is still in maturation stage. The traffic variability indicator (TVI) was used as a proxy for environmental efficiency. The innovation strategy (**IST**) score is based on the ANSP Performance Plan Checklist 2011.

Table 2 shows the results of the gllamm analysis. In formulating a model for assessing the performance of the FABA, we use only the significant and the not very significant variables obtained from the OLS regression. The gllamm confirms that FAB performance is a function of the state's ability to provide effective ANS. The cost of delays, safety management and volume of controlled airspace, number of operational units, the complexity of operations and the organizational resources of each state are statistically significant predictors of FAB performance. The traffic variability indicator even though it does not appear to be a significant predictor of FAB performance does play a role and belongs in the initial model of assessment.

The intercept represents the organizational efficiency of ANSPs at the state level in the absence of supportive data. The variance at the FAB level confirms that hybridization of the European upper airspaces introduces latency into the system. It is also an indication that the FABS are not performing as uniformly and perhaps as consistently as we wish. Since the study is preliminary, we can opt to assess the suitability of additional predictors of FAB performance. Alternatively, we can go a step further and attempt to determine the contributors of variations in the performances of the FABs. Then, we utilize benchmarking to assist the ANSPs that require help to improve their performance which will in turn, regulate the performance of the hybrid airspaces.[23]

This study shows that there is a need for PM of the FAB initiative. Certain parameters of ATM performance at the state level are significant predictors of FAB performance. FABs are conglomerations or hybrids of upper enroute airspaces and as such, optimizing ATM performance at the FAB level requires the monitoring of ATM performance at organizational levels [11].

[22] A non-ratio 1 input 1output DEA based on the fundamental concept that efficiency is a ratio of inputs to outputs

[23] Benchmarking analysis is the comparative analysis of organizations within a cluster with a view to improving performance by adapting successful strategies of partner organizations

TABLE II GLAMM TABLE OF FAB PERFORMANCE

Predictors of FAB performance at the state level	**p value**	**z value**
Safety management	0.005	2.79
Cost of delays	0.000	3.54
Volume of controlled airspace	0.000	-3.68
Number of operational units	0.024	2.26
Traffic variability indicator	0.481	-0.71
Complexity	0.069	1.82
Organizational efficiency	0.000	456.01
Variance at FAB level Log likelihood Number of level 1 units Number of level 2 units		0.02 123.597 28 9

What do the predictors indicate about FAB performance? Table 3 shows the effect of these predictors according to an OLS regression of FAB efficiency. These predictors account for 63% of FAB performance.[24]

We are already aware of the backlash to performance that comes from delays which is an interesting topic for a future research paper. Delays are not the fault of the ATM system alone. How many airports are truly international or even intercontinental? How many of them are capable of handling ramp congestion and unusual situations that contribute to delays? How many airports of the developing nations still integrate helicopter traffic in their circuits? What feedback do we have from pilots and other users of ANS about delays in the ATM system?

Some readers may question the issue of safety management as a deterrent to FAB performance. As stated earlier in the paper, the principle of marginal substitution does not make it viable to achieve optimal safety management and prime FAB performance simultaneously. Both of these aspects are perfect economic substitutes. Effective safety management is also costly and economic efficiency is a KPA of FAB performance. Thus increasing safety management will cause a decrease in FAB performance.

[24] According to the Adjusted R^2 value

According to the last published report on FAB evaluation, discussions are underway to reconstruct the dimensions of the airspace of the SW FAB with reference to the Santa Maria Flight Information Region (LPPO FIR).[25] Currently, this oceanic airspace is undergoing a series of risk analyses due to its large size. Large portions of controlled airspaces, fewer operational units and constant flows of heavy traffic all contribute to lower FAB performance. The traffic variability indicator was chosen as a proxy under the assumption that the inconstant traffic flows should be a boon to the environment.

Recall that complexity refers to the quantity of flight configurations in relation to the volume of a unit cell of airspace. Upper enroute airspaces that are technically capable of handling more configurations will have a higher degree of complexity. The more technically efficient an ANSP is the better will a state be in providing ANS and thereby increasing FAB performance.

To help states to be more ready and to have a smoother initiation into the FABA, the process of network management was established to give ANSPs the required assistance that they need.[26] Management teams of ANSPs should not allow pride to get in the way of the help that this infrastructural assistance offers.[27] This is part of organizational development, a process that has received very little attention in ATM until now. Throughout the analysis of FAB performance, the undercurrent of organizational efficiency and its role in FAB performance has been very strong. It is not unreasonable to include organizational perspectives in performance analyses because legally, ANSPs are organizations. Secondly, performance is defined by the way an organization utilizes its resources and thirdly, hybridization is about the consolidation of organizational strategies and resources to achieve desired aims. Hence, if organizational efficiency increases, FAB performance also increases.

[25] SW FAB Safety Case Annex K, INAC, Aena, NAV Portugal, June 2012

[26] According to the report prepared by the PRC , October 2008 on the evaluation of the FAB initiative and its contribution to performance improvement

[27] Network management is primarily for IT platforms; because it is about assisting ANSPs to progress along the path of performance improvement, we alternatively refer to the process as infrastructure management

TABLE III FAB PERFORMANCE BASED ON STATE LEVEL PREDICTORS

State level predictor	Effect upon FAB performance at 90% statistical significance
Cost of gate-to-gate delays	Decrease
Safety management	Decrease
Volume of controlled airspace	Decrease
Number of operational units	Increase
Traffic variability	Increase
Complexity	Increase
Organizational efficiency	Increase

VI CONCLUSION

THE state's ability to provide effective ATS impacts upon the performance of FABs. These are hybrid upper enroute airspaces that are geared towards increased optimization of air traffic management. But with economic hybridization comes increased latency. As such, the evaluation of FABs will not be complete without the inclusion of the impacts of the latent effects as well as the organizational, economic and technical parameters of performance at the state level.

Given those proclivities, the gllamm technique is well-suited for assessing FAB performance as a function of the state's capability to optimize the provision of ANS. Even though the process is tedious, the gllamm technique is flexible enough for use in situations where there are data inconsistencies. The collection and analysis of data in ATM is still at a nascent stage so this study was a preliminary attempt. As more data becomes available, the analyses will yield better results; a concept which is a fundamental tenet of statistics.

Since the FAB initiative is a recent development in ATM, to assess their performance requires a consistent examination of the performance at the state level in providing ANS. The aim is to make improvement via organizational assessments and adjustments. This appropriately sums up the PM or performance management of organizations. Publishing studies on PM for hybrid airspaces will not only be a pristine step for ATM research and innovation but also for the domain of hybrid organizational development.

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