UDC 621.396.933(045)

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EUROPEAN AIRSPACE CAPACITY FORECASTING AND PROVISION

Purpose: As air traffic of European air space tends to gradually increase, already applied measures for traffic estimation and capacity optimization recede into the background. Accordingly, the aim of this study is to investigate methods, means, methodology and models of European airspace capacity forecasting and provision being used on today's basis or planned to be used in short-run perspective. Another objective is to prove that air traffic and capacity maximization measures shall be one of the primary considerations during air traffic flow and capacity management activities. Methods: Generalization of pertinent information about existing types of air traffic and capacity forecasts. Theoretical analysis of appropriate literature and Internet resources with the aim of identification of methods, models and other ways of European airspace capacity optimization. Allocation of three major groups of tools directed on air traffic flow and capacity prediction and maximization. Result: Formalization and representation of simplified scheme of main stages of air traffic and capacity forecast creation as well as classification of tools used for traffic and capacity estimation were proposed. An overview of components of above mentioned classification and statistics on the rate of traffic flow and capacity in Ukrainian airspace for the year of 2016 were given. Discussion: The need and approach for air traffic and capacity forecast creation, informational tools, methodology and modeling tools used for capacity enhancement, necessity for air navigation service providers to consider foresaid as a powerful way not only to improve capacity and air traffic flows but also follow Eurocontrol recommendations.

Keywords: *ATFCM, forecast, capacity, flight efficiency, traffic flow, NM, NOP.*

Introduction

It is a well-known fact that air traffic demand is increasing a lot over the last years. Not only ANSPs (Air Navigation Service Provider), airports and airspace users, but also ATFCM (Air Traffic Flow and Capacity Management) units do their upmost to maximize the use of airspace capacity. But more is still needed.

In the phase of exponential traffic growth increasing safety, reducing delays and aviation emission will require new approaches. To resolve this and improve the management of the network capacity whilst minimizing constraints, a variety of ATFCM solutions have to be considered. The most recently agreed by EUROCONTROL (European Organization for the Safety of Air Navigation)ways are those which can be associated with capacity and flight efficiency enhancement. This involves planning activities on network level, processing of information from various repositories, its integration into a single forecast and, finally, finding the solutions for meeting capacity requirements.

Analysis of the latest research. ATFCM procedures, roles and responsibilities in this document have been established in line with European Network Operations Plan 2016-2019/20 that provides a consolidated view of the forecast seasonal, monthly, weekly and daily ATFCM situation. It incorporates the existing information on traffic demand and capacity plans, identifying bottlenecks and presenting the ATFCM and ASM measures foreseen to counterbalance them. The Network Operations Plan provides a short to medium-term outlook of how the ATM Network will operate, including expected performance at network and local level [1].

The importance of capacity management and ways to decrease capacity shortfall are described in [2]. The need for proactive and dynamic capacity management process as an effective mean to balance capacity with demand is constantly mentioned in [3].

Important statistics on setting capacity target for European airspace is partially enlightened in [4].

Activities in the area of ATFCM modelling tools development are profoundly described in EUROCONTROL articles concerning capacity and ATFCM simulation and modelling tools [5; 6].

Finally, some approaches for capacity and traffic flow forecasting are presented in ATFCM Users Manual [7].

1. Main stages of air traffic forecasting

Institution responsible for forecasting of air traffic is the EUROCONTROL Statistics and Forecasting (STATFOR) Unit. It mainly produces 7-year forecasts (also known as Medium-Term Forecast) of annual numbers of IFR flight movements for different volumes of airspace. The STATFOR User Group, consisting of civil aviation authorities, ANSPs and other industry organizations, meets once or twice a year to review and update previous forecast [1; 8].

The flight forecast is built up in four stages:

– Initial Annual Forecast.

– Monthly Trend Forecast.

– Airport capacity.

– Airspace network.

Initial Annual Forecast

It analyses various input parameters and on their basis splits up traffic on 5 segments:

– Cargo flights are based on GDP (Gross Domestic Product) growth.

– Small airport pairs (< 25 flights per year) are kept constant.

– Business aviation flights are based on observed trend at a State level together with economic growth, recent trends in annual traffic.

– For other traffic, ('other' here is the majority of passenger flights) the use of supply-side or demand-side approach is considered, as well as historic flight data, demographics, low-cost market share, which reflects flight movements of low-cost airlines.

– *Supply-side* is used if traffic matches one of the standard histories (circular flights, long-term stable or declining traffic and direct relationship to GDP) and if demand exceeds the supply. Otherwise, it is demand that drives and limits the growth.

– In the *demand-side*, passenger numbers are estimated from flight counts, aircraft type and load factors, then grown according to GDP growth and the elasticity forth is flow, then converted back to a number of flights using a number of seats-to flights relationships calibrated on historical data.

Monthly Trend Forecast

It focuses on time-series modeling of traffic trends month-by-month. The final result is in terms of numbers of flights per month per pair of zones or regions. Five separate forecasts (with differing horizons and time and geographical resolution) contribute to the forecast as a whole:

– The State-flow method forecasts each State separately, and within the State, separate forecasts for a few main 'flows': internals, overflights and arrivals/departures.

– The schedules method uses data from published schedules for future months, and comparisons of previous schedules with actual flights.

– The forcastability component uses economic growth and fuel prices data as explanatory variables to calibrate a perfect-hindsight model on a known period so as to get a forecast model as close as possible to output forecast. It then applies the model found at State level for the short-term horizon.

– The first years of the Initial Annual Forecast also contribute to the monthly forecast.

Airport constraints

The initial annual forecast is then realigned with this new monthly trend forecast. The resulting growth per airport pair for all types of flight is then compared with future airport capacities that have been provided by the airports.

Overflights

The final step is to calculate how many flights are generated in each air space by these airport-to-airport flights. This is done using a combination of the routings through air space observed in the baseline year and trends in overflight growth per traffic zone. Each of the following forecast complements and at the same time constrains the previous one, leading to appearance of resulting flight forecast (fig. 1).

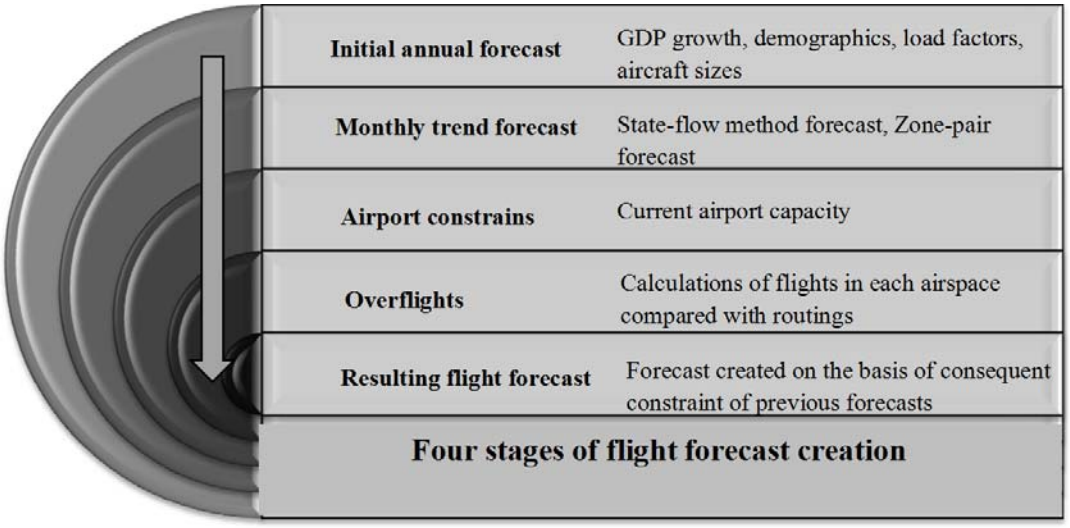

Fig. 1 .Stages and input datafor air traffic and capacity forecasting

2. Classification of tools used for traffic and capacity estimation

In order to ensure that all significant airspace changes can be assessed from ATFCM and flight planning perspective and accurately reflected in the Network operations systemsvarious means are used.

They are mainly orientated on collection, systematization of information and modeling of traffic flows and airspace structures. The ones presented in this paper can be classified in the following way (fig. 2).

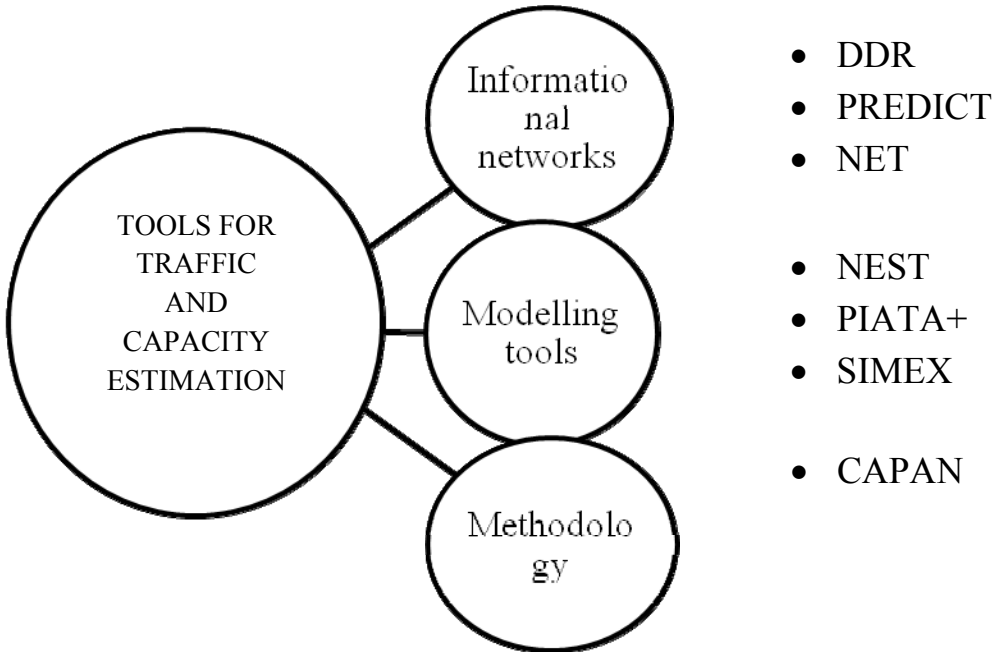

Fig. 2. Classification of tools used for traffic and capacity estimation

3. Informational network tools

The Demand Data Repository (DDR) was created to support the Network Collaborative Planning Process, giving access to a consolidated and integrated European strategic view of traffic demand and distribution.The DDR2 Web portal provides a simple and comprehensive interface allowing generation and download of future traffic for planning purposes and past traffic for post-ops analysis of traffic trends, statistics and routings comparison to support flight efficiency. It also provides tools download for airspace design and capacity planning simulations.The DDR web application can generate a variety of traffic samples as follows:

– Future traffic samples according to the low, baseline or high STATFOR forecast.

– Future traffic samples with current demand distribution (flight plan / flight plan enhanced with radar data).

– Future traffic samples with new routings calculated on future environment.

– Past traffic samples with new routings calculated on future environment.

Two options are available for the generation of new routings:

– shortest path (minimum route length);

– cheapest path (minimum cost taking into account route length and route charges).

The future traffic samples can be enriched in the DDR2 using the flight intentions [8–10].

PREDICT is the main network operations tool used to support the Pre-Tactical planning for the day being planned (D).PREDICT input consists of:

– Flight Data: Historical demand derived from (first filed) flight plans at D-7, by default, isused to build the future traffic forecast. Several corrections of historical demand areapplied in Predict to generate:

– Replacement of historical RPLs (Repetitive Flight Plan) by future RPLs;

– An enrichment of historical FPL(Flight Plan) data with DDR2 flight intentions in order to betterreflect new flights or remove historical flights reported as not being operated inthe future;

– Routing connections resulting from airspace constraints/changes;

– ENV (Environment) Data: PREDICT receives new Environment data every 4 weeks as part of thenormal AIRAC Cycle, as well as on-line environment updates.

Network Events Tool (NET) represents a move towards a centralized approach to facilitate the planning and coordination of events at network and local level.

NET consists in a consolidated repository of event information obtained byEUROCONTROL from various sources and stored in various databases, and provides aunique access point to that repository to interested users both internal and external to theAgency.NET is available as a “Calendar of Network Events” portlet on the Network Manager Portalandaccessible in all planning phases (strategic, pre-tactical, tactical, post operations). As such,NET increases the visibility of events that may have an impact on network operations, andaims to enable identification of interdependencies and support efficiency gains in thecoordination and planning of mitigation actions in a collaborative manner withstakeholders.Currently, the NET repository (database) stores event information from the followingsources:

– ERNIP (European Route Network Improvement Plan) Part 2 – ARN Version 2016-2019/20, which includes airspace proposalsscheduled for implementation

during the specified period; as wellas all completed proposals stored in previous versions of ERNIP Part 2; (100%proposals data coverage);

– Airport Corner Database, which includes Airport On-going and planned activities;selected events only (60% event data coverage);

– Special Events (100% data coverage);

– Military events (100% data coverage);

– ATFCM events (100% data coverage);

– Direct input through its own interface on the NOP portal.

NET data supports several sections of the Network Operations Plan, such as Chapter 7, Annex 3, Annex 4, Annex 5 (ACC Capacity enhancement measures), Annex 6 (Airports On-going and Planned Activities). The NET database provides direct input to DDR2 (included in DDR2 Calendar of events) and in the future may provide data directly to other planning tools on a need basis e.g. STATFOR, SIMEX, NEST, etc.

4. Modelling tools

NEST(Network Strategic Tool) is a scenario-based modelling tool developed by EUROCONTROL. It is used by the Network Manager and the Air Navigation Service Providers (ANSPs) for:

– Designing and developing the airspace structure;

– Planning the capacity and performing related post operations analyses;

– Organizing the traffic flows in the ATFCM strategic phase;

– Preparing scenarios to support fast and real-time simulations;

– Ad-hoc studies at local and network level [9].

NEST is used to optimize the available resources and improve performance at network level. NEST can also be used locally by Area Control Centres (ACCs) or airports and also globally for strategic planning at network level. NEST can process and consolidate large quantities of data spanning multiple years, but also allows the user to drill down into the detail and analyze and observe 10-minute periods of data.

NEST is scenario based: users can make changes to the original dataset or reference scenario to model an unlimited number of different operational planning options. NEST uses datasets describing the consolidated pan-European airspace and route network, the traffic demand and distribution as well as the STATFOR traffic forecasts which are provided byEUROCONTROL at the end of each AIRAC cycle (fig. 3).

The simulation algorithms include:

– Future traffic samples;

– 4D traffic distribution;

– Configuration optimizer;

– Regulation builder;

– Delaysimulation.

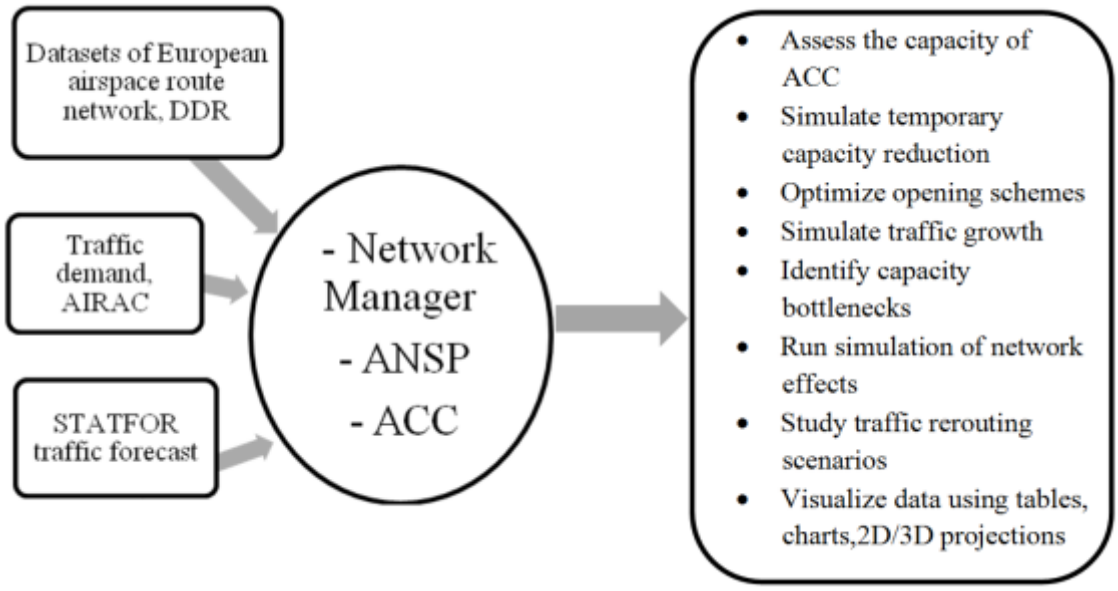

Fig. 3. Network Strategic Tool capabilities

The Performance Indicator Analysis Tool for Airports (PIATA+) is a PC-based configurablesystem that can be used to analyze any mode of operation of an airport, including the use ofmultiple runways. It supports a step-by-step approach to the improvement of airport performance and efficiency.

The results of this analysis can be incorporated into the local capacity declaration processand the resulting figures are used as inputs into the Network Planning process. PIATA+ canadditionally be used in capacity enhancement exercises to determine potential capacity-gains when modifications are being considered to existing infrastructure such as theconstruction of new rapid

exit taxiways. The output of PIATA+ is a set of data andinformation on how the airport runway system is currently used by ATC Services and AircraftOperators.

A simulation platform **SIMEX (Simulation and Experiment)** is provided to enableoperational staff to simulate and assess the impact of the application, modification orcancellation of ATFCM measures before they are applied operationally.

The simulation platform is used in various ATFCM phases;

– Tactical activities (from simple evaluation of short-term ATFCM measures on ETFMSoperations before application, to evaluation of the best approach to solve unexpectedevents).

– Pre-tactical activities (preparation of an ATFCM regulation plan, starting with flightsfrom a reference day).

– Special events and long term activities (e.g. airspace restructuring, pre-validations ofENV data).

5. Methodology

CAPAN (EUROCONTROL Capacity Analyzer) is a methodology which was developed by EUROCONTROL to calculate sectorcapacities – based on the evaluation of the workload – through a fast time simulation. Each CAPAN study is performed in close coordination with operational controllers at the ACCsconcerned, to determine the workload of simulated controller positions for a given trafficsample. The capacity of the sector is reached when the workload reaches a threshold of 70%.

The CAPAN methodology takes into account a highly customizable controller task list andcontroller working method simulation methodology, making it adaptable to all ATC systemsand working environments.

The CAPAN methodology is normally used for defining sector capacity, which is particularly useful in case of changes to the airspace structure, to the route structure, or to the ATC procedures. The introduction of major ATC system changes can also be analyzed using the CAPAN methodology, either before to confirm expected benefits, or after to help redefine the sector capacity with the new ATC system [11].

Despite world-wide acknowledgement of CAPAN another methodologies for capacity and rate of air traffic are used now. One of them has already been applied in several STATFOR forecasts [12; 13].

6. Application of methods and means of capacity forecasting in Ukrainian air navigation system

Being a contributing State in EUROCONTROL is a privilege, the one requiring not only presence, but mainly involvement. In this direction Ukraine has been working a lot. For instance, our country have successfully implemented FUA (Flexible Use of Airspace) concept and joint civil-military coordination procedures. Despite this fact, a lot still can be done in reorganization of current Ukrainian air navigation system. Here is a quick overview of means and methods that can be applied in Ukraine for capacity forecasting and provision.

To begin with, UkSATSE (Ukrainian Air Navigation Service Enterprise) can initiate a counsel responsible for air traffic flows and capacity forecasting, so that they will produce four types of forecasts mentioned in part 1 of this study.

On the first stage Initial Annual forecast will be prepared. As for its composition a lot of data is required, then it would be appropriate to use DDR tool which can provide traffic demand and supply rates needed for passenger flights prediction. Moreover, DDR contains statistics of flight that can be used for further analysis. NEST may be also helpful, because it is a powerful modelling tool which uses datasets from DDR and simulates various flight scenarios, helps to assess traffic distribution, capacity shortfalls, flight efficiency etc. Afterwards, in order to estimate capacity properly CAPAN methodology is proposed. It can serve as a great way for final capacity calculation after simulation and data collection.

On the second stage Monthly Trend forecast will be presented. For its creation PREDICT database is recommended. It contains historical demand data, a lot of updated rerouting and schedules of flight. Then this information can be used as a basis for simulation in NEST which is helpful on this stage of capacity forecasting.

After these two forecasts being prepared another two will serve rather as augmentations than separate forecasts. Airport constrains prediction can be based on NET data repository. This exact tool contains information about all local Ukrainian airports, airlines and events planned in advance. PIATA+ can in its turn provide necessary analysis of aerodrome movements and possible flight efficiency in aerodrome area.

Finally, the resulting forecast will be amended by overflights prediction. For this NET can be used. It contains information on transit flights, some planned activities and statistics. Modelling of capacity can be done on NEST which is recommended for usage on all stages of flight forecasting due to its completeness and universality.

So, usage of highly-mentioned tools and databases can simplify air traffic flow and capacity forecasting, increase accuracy of EUROCONTROL's predictions and not onlymaximize flight efficiency in Ukrainian airspace, but also make the work of UkSATSE much easier and reliable.

Conclusions

One of the ultimate objectives of this scientific article is to prove that ATFCM measures are aimed at

optimization of traffic flows according to air traffic control capacity. And in order to cope with this task, authorized units start to plan operations, forecast air flows and create models of possible traffic events. They use a wide range of tools to achieve the goal of predicting the capacity required for provision in each of regional air traffic control centers. Some means are mainly presented in form of databases with previous, current and future flight information, others are modelling tools used by ANSPs and Network Managers for traffic flows simulations and performance level assessment. But the most important is that these measures are being tested and implemented as Network pillar for SESAR (Single European Sky) framework.

In addition, air traffic flow forecast and capacity estimation tools were recently applied on Ukraine too. Network Operations Plan 2016-19/20 contains a 7-year traffic forecast on the example of Kyiv Area Control Center (ACC). It indicates up to 20.3 % traffic growth until 2020. Moreover, the results of capacity analysis using highly-mentioned tools showed Ukrainian current and possible capacity. According to this data, maximum number of movements per hour in 2016 is 73.

That is why, thanks to competent approaches and reorganization of ATFCM forecasting activities EUROCONTROL States, in particular Ukraine, can precisely estimate supplied and required capacity. But what is even more important - these tools help not only to plan capacity enhancement measures, but also force ANSPs to consider implementation of Free routes, Cooperative Traffic Management and some major changes in regional ATS system, thereby leading the country to technical and operational progress.

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Надійшла до редколегії 12.01.2017

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ПРОГНОЗУВАННЯ ТА ЗАБЕЗПЕЧЕННЯ ПРОПУСКНОЇ ЗДАТНОСТІ ЄВРОПЕЙСЬКОГО ПОВІТРЯНОГО ПРОСТОРУ

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Описані методи та засоби прогнозування та забезпечення європейського повітряного простору. Етапи прогнозування повітряного руху і різні типи прогнозування пропускної здатності були диференційовані. Надана класифікація засобів для оцінки пропускної здатності. Запропонований підхід до застосування методів та засобів прогнозування пропускної здатності в українській аеронавігаційній системі. Узагальнені основні переваги прогнозування пропускної здатності повітряного простору.

Ключові слова: *ATFCM, прогнозування, пропускна здатність, ефективність польоту, потік повітряного руху, NM, NOP.*

ПРОГНОЗИРОВАНИЕ И ОБЕСПЕЧЕНИЕ ПРОПУСКНОЙ СПОСОБНОСТИ ЕВРОПЕЙСКОГО ВОЗДУШНОГО ПРОСТРАНСТВА

А.Е. Луппо, О.М. Алексеев, А.М. Голубова, Т.А. Колесник

Описаны методы и средства прогнозирования и обеспечения европейского воздушного пространства. Этапы прогнозирования воздушного движения и разные типы прогнозирования пропускной способности были дифференцированы. Предоставлена классификация средств оценки пропускной способности. Предложен подход к использованию методов и средств прогнозирования.

Ключевые слова: *ATFCM, прогнозирование, пропускная способность, эффективность полета, поток воздушного движения, NM, NOP.*