An Algorithm for TMA Entrance Point Multiplicity

Fulya AYBEK CETEK
Department of Air Traffic Control
Anadolu University
Eskisehir, Turkey
faybek@anadolu.edu.tr

Prof. Aydan CAVCAR, PhD
Department of Air Traffic Control
Anadolu University
Eskisehir, Turkey
acavcar@anadolu.edu.tr

***Abstract*—**

In this study, building an algorithm for creating new dynamic approach routes and TMA entry point multiplicity. This algorithm can reduce total airspace delays and/or specific fix congestions. Algorithm confirmation has done with a fast time simulation model (SIMMOD). A SIMMOD model has been established to analyze relationship number of entry point and delay. In experiment Istanbul Yesilkoy TMA is used as well.

I. Introduction

The current airspace system is under growing strain as the demand for air travel steadily increases according to traffic statistics and air traffic demand forecasts. As the conjunction of airports and air routes, TMAs (Terminal Air Space) have a significant impact on the throughput of airports and en-route airspace. Therefore, reorganization of TMAs is crucial to accommodate the increasing number of flights [1]. Air traffic statistics show that traffic demand is not homogenous during a day. Usually early hours of a day are peak hours and at night demand might be down to half. For that reason, airspace planning should have a dynamic planning regarding peak hours.

TMA routes are designed as either conventional-based or RNAV-based approach-departure procedures. In most conventional-based TMAs, open-loop radar vectoring techniques (i.e. heading instructions) are used as the traffic demand increases. Although this technique is efficient and flexible, it is highly demanding for air traffic controllers and flight crew under the intense traffic load. In such cases, the use of vectoring technique leads to peaks of workload, high frequency occupancy, lack of anticipation, difficulty to optimize vertical profiles and to contain the dispersion of trajectories [2].

The introduction of area navigation (RNAV, P-RNAV) allow defining new route structures to revisit the merging of arrival flows [3]-[6]. ICAO defines Area Navigation (RNAV) is a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these [7,8].

Depending on the conventional route network, RNAV procedures can be built more flexibly and reflect the ease enabled by the vector technique on the procedure. RNAV procedures also allow building off-set route from navigation aids. This convenience permits dynamic route planning and allocation for airspace designers. During the peak hours, new TMA entrance points and approach routes can be created using dynamic planning.

Numerous studies have been done regarding TMA capacity and delay analyses using SIMMOD, a common fast time simulation and modeling tool for airspace and airport [13]. As an example, Gao and Huang [9] studied capacity and delays of SID and STARs in a TMA modeled in SIMMOD. Kleinman et al [10] have introduced an optimization algorithm for air traffic delay cost using SPSA/SIMMOD tool [10]. In another study, Gao et al [11] performed delay and cost analysis in a multi-airport system using SIMMOD. Aybek and Cavcar [12] previously studied delay analysis in Yesilkoy TMA modeled in SIMMOD.

In this study, it is aimed to build an entry point multiplication algorithm for creating new TMA entry-points and dynamic approach routes connected to airports. This algorithm can reduce total airspace delays and specific fix congestions. In order to verify the algorithm, a fast time simulation model was built using SIMMOD tool. Istanbul Yesilkoy TMA is selected for the case study. The simulations were run for different entry-point numbers from 11 to 18.

II. Algorithm

The entry point multiplication algorithm first aims to separate arrival traffic sequences at each delayed entry-point according to destination airports (Fig. 1). For instance, if an entry point with delay serves more than one airport, the algorithm creates new gates serving for a single airport. New entry-point must be minimum 5NM far away from the existing entry-point. After selecting the new entry point, the algorithm checks the availability of direct route to the destination airport without crossing any other route in the TMA. Route crossings are not desirable since they increase conflict probabilities within the airspace. Therefore, if the new direct route does not cross any other route, it will be defined as the new route to the destination airport. In case of any crossing, the algorithm will look for an alternative route to an existing fix connected to the destination airport. This process is iterated n times in order to look for a fix connected to the destination airport with no route crossings. The number of iterations, n is a user-defined parameter and it is set to 5 for this sample study. If crossing-free route is not found, the algorithm will search for fixes that can be merge with another fix to reduce route intersections. The number of iterations, m is a user-defined parameter and it is set to 5 for this sample study. Even if fix merging is not provided after 5 iterations, the new route will be created regardless of intersection numbers. After creating the new route, the algorithm terminates.

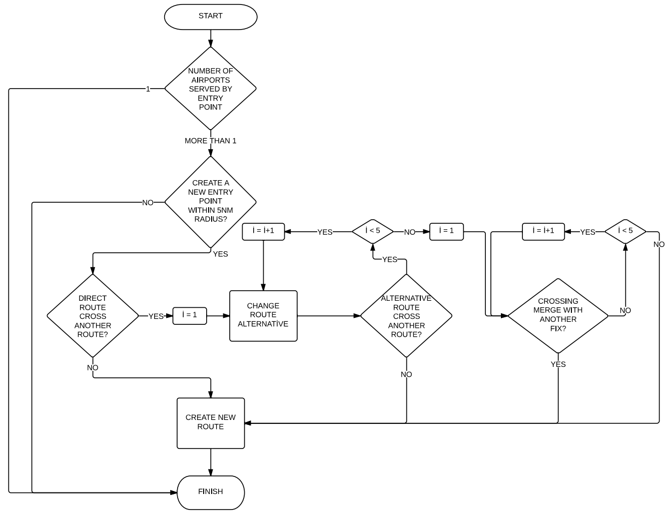

Fig. 1. Entry-point Multiplication Algorithm

III. Model Description

Yesilkoy TMA is chosen for the analysis because of its high traffic density in Turkish Airspace. Since the traffic density at the TMA entry points are also investigated, the en route airspace above Yesilkoy TMA is included to the model.

A. RNAV Procedures

Yesilkoy airspace is a TMA that provides radar approach control service. Until 2011, conventional approach and takeoff procedures were used, and since the early 2011, approach and takeoff procedures based on RNAV methods have been in use. The RNAV procedures that are designed for Yesilkoy TMA are obtained from the related section of Turkish AIP [14].

B. Modeled Air Space Structure

Radar service is provided in Yesilkoy TMA. Surveillance radar and Precision radar approaches are not available. Primary service is to vector arriving aircraft to instrument approach courses or to aerodrome traffic circuits for visual approach and departing aircraft to en-route structure. Yesilkoy approach Control operates in four sector as North, South, West and East [14].

In the Yesilkoy TMA, there are three major airports: Ataturk, Sabiha Gokcen and Corlu. Among these airports Ataturk Airport has the highest traffic density. Ataturk Airport has three runways, namely, 35L-17R, 35R-17L and 05-23. Sabiha Gokcen and Corlu has one runway of each.

C. Assumptions

In this study, in the Yesilkoy TMA, Ataturk, Sabiha Gokcen and Corlu Airport arrival traffic to runway 05 is analyzed. Departure traffic and other airports might be covered in further studies.

Separation within the airspace is determined as 5NM according to ICAO Separation minima [7].

D. SIMMOD Model

TMA entrance points have been analysed with SIMMOD model. The number of current entry point is 11. For current situation analysis, the traffic demand is assumed as 90 aircraft per hour. The demand is distributed to each entry-point as even as possible. For each experiment, all airports are set to receive equal amount of traffic (i.e. 30 aircraft) as it was done in the previous study [15]. The effect of each new entry-point generated by the algorithm is tested by a simulation experiment. In total 8 experiments have been done. In each experiment, one more number of the entry-point is increased by one. Fig 2 shows the current and new TMA entry point and routes. The Current entry points are shown in red whereas the new ones are shown in blue. The bold green lines represent the new routes generated by the algorithm.

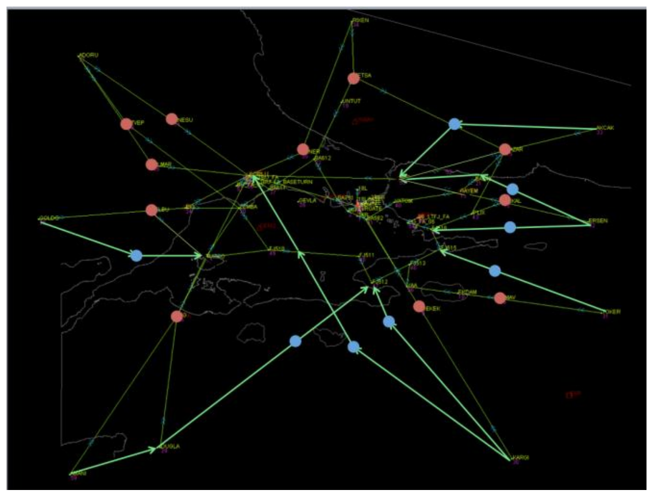

Fig. 2. Air space view with new entry points and routes.

IV. Simulation Results

In the current situation, total delay in TMA is 160 minutes. As the number of entry points is increased, TMA delay decreases as shown in Table 1. In the first experiment, there is a 8-flight demand for each entry point. When the number of entry points is increased to 18, the delay reduces to 95 minutes. In the current situation 59 aircraft have less than 5 minutes delay, 23 aircraft have 5-10 minutes delay, 5 aircraft have 10-15 minutes delay and 2 aircraft have more than 15 minutes delay. In the last experiment, all aircraft have delay less than 5 minutes.

Table 1. Simulation results

Entry point number	Flight demand each entry point	Aircraft number with delay				TMA Delay min.
		t<5	t=5-10	t=10-15	t>15	
11	8	59	23	5	2	160
12	8	68	15	4	1	145
13	7	68	18	2	1	115
14	6	73	13	2	0	127
15	6	69	18	2	0	98
16	6	75	13	2	0	102
17	5	79	8	2	0	91
18	5	75	14	0	0	95

V. Discussion and Future Work

Results of this study indicate a positive impact of new entry-points and routes on total delays in the selected TMA. Introduction of new existing point serving for a single airport relieves congestions at the existing ones. Since the algorithm also provides alternative routes to the destination airports with minimum number of route crossings, the delays at fixes within the TMA reduces in the alternative scenarios. Therefore, the entry-point multiplication algorithm offers effective alternative solutions that can be used in dynamic airspace planning at peak-traffic periods. In the future work, the algorithm will be developed for more realistic TMA models including departure routes and aircraft performance differences.

References

[1] Gao Wei, Huang Chaowei, "Application of Computer Simulation Research on Chongqing TMA Airspace Structure", *Computer Science and Information Technology (ICCSIT), 2010 3rd IEEE International Conference*, 2010.

[2] Boursier L., Favennec B., Hoffman E., Trzmiel A., Vergne F., Zeghal K. "*Merging Arrival Flows without Heading Instructions*", 7th USA/Europe Air Traffic Management R&D Seminar, Barcelona, Spain, July 2007,

[3] EUROCONTROL, "Manual for Airspace Planning Volume 2 Section 5 - Terminal Airspace Design Guidelines", Edition 2.0 -Amendment 1, 2005.3

[4] EUROCONTROL,"RNAV Application in Terminal Airspace: an ATC Operational Perspective", Edition 2D, 1999. 4

[5] EUROCONTROL, "Guidance Material for the Design of Terminal Procedures for Area Navigation (DME/DME, B-GNSS, Baro-VNAV & RNP-RNAV)", 5Edition 3.0, 2003.

[6] EUROCONTROL, "Standard Document for Area Navigation Equipment – Operational requirements and functional requirements", Edition 2.2, 1998.

[7] ICAO: Air Traffic Management, Doc. 4444-2011.

[8] EUROCONTROL Guidelines for Airspace Management - The ASM Handbook, Edition 3.0 Edition date: 15/06/2010 Reference nr: EUROCONTROL-GUID-140

[9] Gao W., Houng C., "*Application of Computer Simulation Research on Chongqing TMA Airspace Structure*", Computer Science and Information Technology (ICCSIT), 3rd IEEE International Conference, 2010.

[10] Kleinman, Hill ve Ilanda, SPSA/SIMMOD Optimization of Air Traffic Delay Cost, Proceedings of the 1998 Winter Simulation Conference D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan.

[11] Gao W., Xu X, Diao L. and Ding H. "*SIMMOD Based Simulation Optimization of Flight Delay Cost for Multi- airport System*", 2008 International Conference on Intelligent Computation Technology and Automation.

[12] Aybek,F. and Cavcar,A. "*Delay Analysis for the RNAV Approach Procedure at Istanbul Yesilkoy TMA Using SIMMOD*", 5th International Conference on Research in Air Transportation ICRAT 2012, University of California, Berkeley, USA, May 2012.

[13] Çetek C., Çınar E., Aybek F., Cavcar A., "*Capacity and Delay Analysis for Airport Manoeuvring Areas Using Simulation, Aircraft Engineering and Aerospace Technology*", Vol.86 Iss:1, pp.43-55, Jan 2014, Emerald, DOI: 10.1108/AEAT-04-2012-0058.

[14] AIP aerodrome.

[15] Aybek, F., Cavcar, A., "*Enhanced Delay Analysis and Capacity Improvement in a RNAV TMA*", Multidisciplinary Academic Conference-Transport, Logistics and Information Technology, Prag, Czech Republic, May 2013.