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Evaluation of aircraft descent profile

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Abstract

Point Merge System (PMS) is a new method for merging and sequencing arrival traffic flows. It consists of sequencing legs, merge point. PMS allows Continuous Descent Approaches (CDAs) which reduces environmental impacts according to aircraft noise, fuel burn and emissions during approach. Aircraft could descend continuously from an optimal position in a low drag with minimum engine thrust. In this study, PMS arrival procedure model will be designed and vertical descent profiles of aircraft will be assessed both in terms of vectoring and PMS. The results show that PMS model achieves more standard vertical descent profiles over vectoring.

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Keywords: air traffic; point merge system; continuous descent approach; vectoring; emissions; environmental impact

1. Introduction

Open loop radar vectoring is usually used for merging and harmonizing arrival traffic flows for preparing landing phase. Vectoring is a flexible method for air traffic controllers but in high traffic density, controllers could give rapid decisions in a short critical time period. Moreover, aircrews also could perform instructions in a critical time. Thus, high frequency occupancy, the lack of predictability, difficulty of optimized vertical descent profiles and dispersion of traffic flows could occur. Also, by vectoring, aircraft are given a lot of kinds and numbers of instructions and it could be noted that the vectoring method in busy terminal control areas (TMAs) creates difficulty for the predictability of aircraft position and sequencing. Furthermore, aircraft entering TMA starts to descend in terms of

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minimum radar vectoring altitude, so, aircraft remains in a lower level in a longer time and in that case the fuel consumption is increased [1, 2].

A new method called Point Merge System (PMS) merges arrival traffic flows on a single merge point without using any heading instructions. PMS based on area navigation (RNAV) route structure and sequencing legs are iso-distance and equidistance from a predefined merge point. PMS allows path shortening or stretching by using sequencing legs [3, 4]. PMS allows continuous descent approaches (CDAs) [5] which is defined as a method that the aircraft intercepts glide path from optimal vertical profile down to touchdown with engines operating at low thrust power [6]. The most common benefits of CDA procedures are reducing aircraft noise, fuel burn and emissions [7]. Reduction in frequency occupancy time and workload, also by enabling CDA, reduction in fuel consumption and consequently reduction in emissions are the expected benefits of PMS procedure [5]. In the following, the benefits of CDA and PMS procedures are summarized.

Clarke et al. [8] tested CDA procedures by simulations in Louisville International Airport and the results indicate 400 to 500 lb. (181–227 kg) lower fuel consumption during approach [8].

In another study, Ivanescu et al. [1], assessed the performance of PMS and compared with vectoring in fast time simulator. 20 % reduction in workload, approximately 30 % reduction in number of controller instructions and 170 ± 14kg reduction in fuel burn were achieved [9].

Turgut et al. [6] made a study reporting fuel savings and a reduction of flight duration due to CDA. Conventional and CDA procedures were compared by using real flight data for B757. 7–9 % of fuel savings (more than 40 kg) and a reduction between 17.8 % and 19.3 % of flight duration (2.8 minutes) were reported for CDA procedures [6]. Different CDA scenarios were studied by Robinson [10]. Simulation results showed 50–150 kg fuel savings at medium or low traffic density [10].

Nowadays PMS has been implemented in Oslo. The results for Oslo present that PMS has more advantages over vectoring such as providing more efficient and predictable route, reducing workload, improving safety and minimizing environmental impacts by allowing CDA. The results present 300 kg reduction per flight in CO_2 emissions [11].

At Ahmadabad Airport in India, CDA procedures have been implemented. Fuel savings about 1164 tons and 3678 tons CO2 emission reduction annually were reported. Moreover, another study related to CDA was performed in Prague. It concluded that 65 – 96 kg fuel savings and 200–300 kg CO2 reduction per flight could be estimated and it corresponds to 1400 tons fuel savings and 4600 tons CO2 reductions annually [12].

Nomenclature

CDA	Continuous Descent Approach
CO_2	Carbon Dioxide
PMS	Point Merge System
RNAV	Area Navigation
TMA	Terminal Control Area

2. Methodology

PMS method aims to provide optimum vertical descent profiles for arrival traffic. PMS does not need any heading instructions and merges traffic on a single point not on an axis. Also, PMS is an innovative method for sequencing and to make standardization in controller working conditions. In this study, PMS model is designed for converging runways in order to make optimum traffic order in landing. Istanbul TMA traffic is analyzed and the direction, which traffic flow is intense, is found north and east. And the position of initial waypoints is located close to north and east directions. Arrival traffic enters to PMS procedure by using initial waypoints. Opposite direction sequencing legs are designed for merging and harmonizing arrival traffic from different directions. Considering the length of the arc between the converging runways, the length of sequencing legs is defined as 36nms. Also, the parallel segmented legs are preferred because the track angle changes will usually be more or less close to 90 degrees. Moreover, legs are separated vertically.

In Fig. 1, PMS model proposal is presented 17L and 23 converging runways for Istanbul Ataturk International Airport (LTBA) [13].

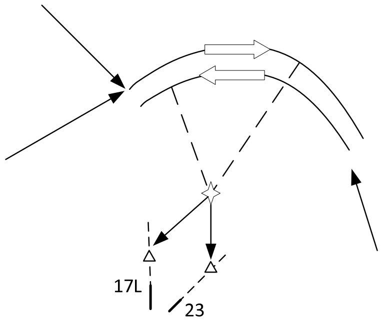

Fig. 1. PMS model proposal for LTBA.

Aircraft, flying on sequencing legs, maintain flight level (FL) 120 and FL 100, after left sequencing leg, aircraft starts to descend to 6000 ft. (1830 m) until merge point if possible and appropriate aircraft descent from a sequencing leg to a final approach point continuously. While designing the PMS model, the flight path angle (FPA) is considered as 3 degrees (5 % gradient-optimum value). While determining the distance (21 nms/39 km) between the legs and merge point, it is considered that aircraft could apply continuous descent approaches (CDAs) from optimum position.

CDA allows aircraft to descend from optimum position continuously in a low drag with minimum engine thrust. In approach phase, CDA aims to reduce aircraft noise, emissions and fuel burn. Aircraft stay higher flight level for a longer time by the side of conventional step down approaches (Fig. 2).

Continuous descent operation procedures are divided into open path and close path procedures. In open path, vectoring is used with speed control and the controller is flexible and comfortable for handling, separating and expediting high density air traffic flows. Open path is suboptimal according to environmental issues. Open path procedures could be applied but for environmental benefits close path procedures are preferred nowadays. In close path procedures, which have limited flexibility, aircraft follow a fixed lateral path. Tactical interventions are not allowed and unwanted, because tactical instructions draw out traffic from the airways and decrease the ability of aircraft to implement optimum descent profiles. In addition, environmental advantages could be lost [2].

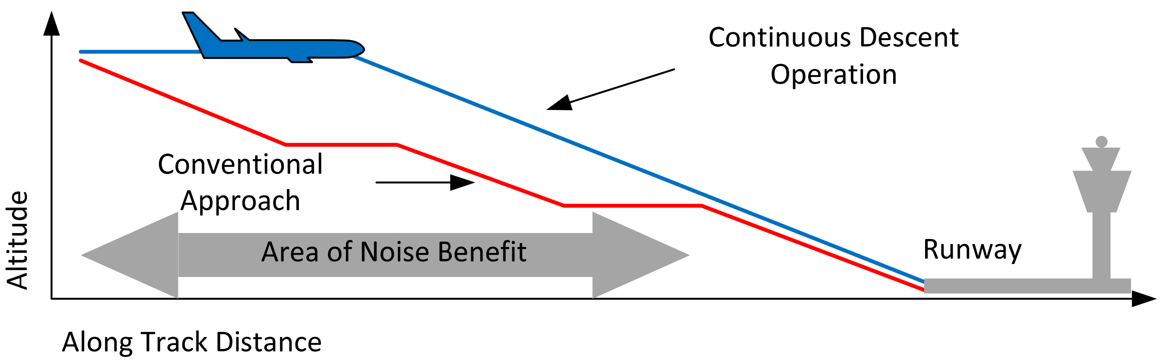

Fig. 2. Profiles of CDA and step down approaches [2].

3. Results and Discussions

Comparing PMS method with vectoring, it could be seen that aircraft remain at higher levels for a longer time and traffic stays orderly in a particular tight area and large traffic dispersion was not observed. Moreover in PMS method, vertical descent profiles are similar for all traffic however in vectoring some of aircraft remain at lower levels for longer period (for instance, aircraft maintain 5000 ft (1524 m) or keep minimum radar vectoring altitude from TMA entry points to landing) and descent profiles could be different and also it is shown that the traffic is distributed over a wide area due to vectoring instructions. For PMS, flight levels are predefined and aircraft does not need to fly at lower levels. In Fig. 3, six traffic, called A, B, C, D, E and F are implementing PMS and it is shown that aircraft descent with a standard vertical profiles namely vertical descent profiles are similar. Instead of step down approaches, aircraft descend continuously from sequencing legs to final approach waypoint. Aircraft remain on the sequencing legs till spacing and approach sequence. It could be noted that these traffic apply CDA procedures and so vertical descent profiles are similar.

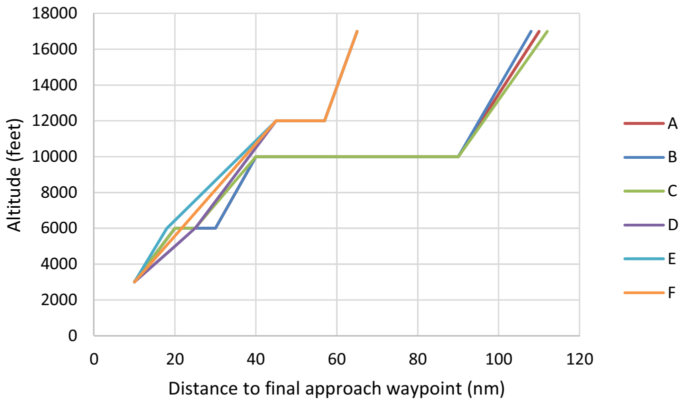

Fig. 3. Descent profiles of traffic from east (A, B, C) and north (D, E, F).

Implementing vectoring for the same traffic data is presented in Fig. 4. Aircraft descend step by step instead of gradually. As shown see in Fig. 4, descent profiles of aircraft are not similar.

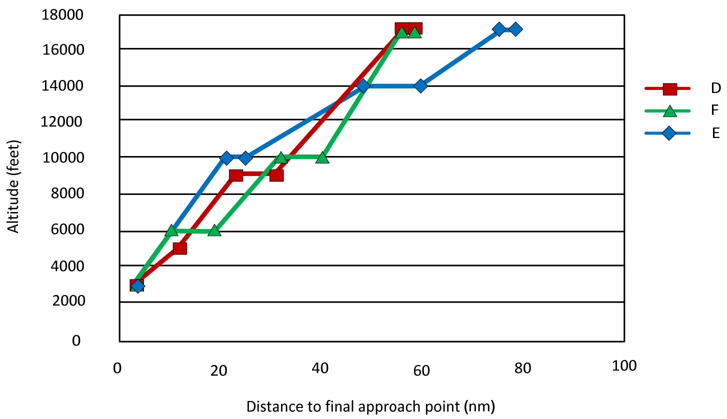

Fig. 4. Descent profiles by using vectoring.

In Fig. 5, the descent profiles of aircraft called G, which enters TMA from west, applies both vectoring and PMS procedure separately. In PMS, aircraft maintain FL 120 (FL 120 is defined as a level of sequencing leg) and then starts to descend gradually. Besides in vectoring, after FL120 same traffic starts to descend step by step.

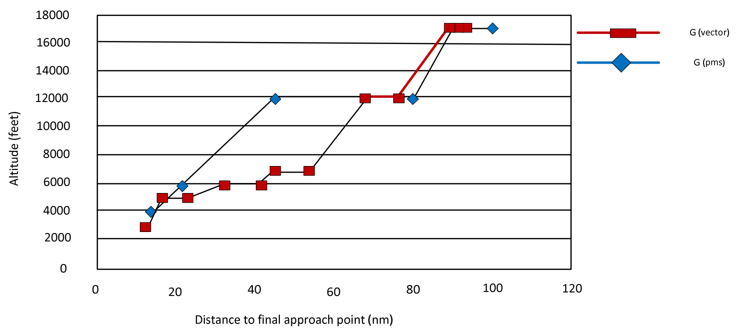

Fig. 5. Descent profiles of aircraft G.

4. Conclusion

Point merge system based on RNAV route structure is a new standard arrival route. PMS does not need to use heading instructions anymore. Also, continuous descent approaches are allowed from sequencing legs to final approach waypoints. With CDA procedures, aircraft descent with a constant FPA (3 degrees) with minimum engine thrust. CDA procedures keep aircraft at higher cruise altitude for a longer time and allow aircraft to descend as late as possible. This descent type achieves a predictable and standard vertical descent profile. Moreover, comparing step down conventional procedures with CDAs with idle thrust descent, it could be noted that with CDAs, a significant reduction in noise, fuel burn and emissions due to keeping aircraft at their cruise altitude for a longer time [14, 15].

In this study, PMS model is designed and offered which allows CDA procedures for converging runways at Istanbul Ataturk International Airport, and real traffic data is used in order to compare PMS model with vectoring. The results show that PMS model achieves more standard vertical descent profiles over vectoring. In PMS, aircraft do not remain at a lower level for a longer time and so reduction in fuel burn and emissions are expected. Furthermore, in terms of trajectory dispersion, traffic is within a narrower triangular area, while in vectoring - large traffic dispersion appears. The numerical benefits of PMS CDA procedures related to fuel savings and emissions will be done in the next study.

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