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# Analysis of Level-Off Flight Segments of Descending Aircraft for Busy Terminal Maneuvering Areas

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**Abstract**

The demand for air transportation increases significantly worldwide, and the number of aircraft and passengers is also rising. This situation directly affects the major airports and their surrounding Terminal Manoeuvring Areas (TMAs) because they launch new destinations and increase flight frequency. However, airport and airspace structures have some difficulty meeting this increasing demand. Therefore, there is an increase in airborne delay in air traffic congestion. Airborne delay severely affects TMAs operations since they have several entry points, yet all arrival traffic lands mainly at the same airport. This problem also expands the flight duration within TMAs. Air traffic controllers regulate the arrival traffic with separation and sequencing methods, including vectoring, point merge approach or holding manoeuvres. These are generally implemented at a constant flight level. Therefore, they generate level-off flight segments during the descending profile of arrival aircraft. The level-off segments directly increase the fuel consumption and emissions values because of engine configurations. Therefore, this study aims to expose the level-off segments for the London Heathrow, Amsterdam Schiphol, Paris Charles de Gaulle and Istanbul airports. The results show that Amsterdam Schiphol has the lowest level-off time to total descent time ratio of 12.8% among other airports.

**Keywords:** Continuous descent operations, Vertical profile inefficiency, Airborne delay, Air traffic management, Terminal Maneuvering Areas Operations

## 1. Introduction

Civil aviation plays a crucial role in modern society, contributing significantly to various aspects of economic, social, and cultural development. Besides, air transportation connects people, businesses, and countries worldwide and international cooperation. It enables rapid movement of goods, services, and people across borders, facilitating global supply chains and enhancing global integration. Rapid developments have caused increases in air traffic operations. According to Eurocontrol's optimistic anticipation, the flight growth is expected to average 2.0% per year, with a range of ±1.4 percentage points. By 2030, the number of flights is projected to exceed 12 million [1]. While increasing air traffic operations signifies economic vitality and connectivity, it also presents challenges such as airspace congestion, environmental concerns, and infrastructure constraints. Therefore, effective planning, collaboration among stakeholders, and sustainable growth strategies are essential to manage the growth of air traffic operations responsibly. Air traffic congestion can adversely affect various aspects of the aviation industry, the economy, the environment, and society. It can cause flight delays and cancellations, leading to lost productivity, missed connections, and increased costs for airlines and passengers [2-5]. It can also increase fuel consumption and emissions, contributing to climate change and air pollution [6,7]. Additionally, air traffic congestion can affect other industries that rely on air transportation, such as tourism and international trade. Aircraft delays can be absorbed for the departure aircraft by updating the expected departure time, which helps to minimize fuel consumption and decrease ground traffic duration [8,9]. Furthermore, aircraft scheduling can be affected due to the congestion of airports and Terminal Manoeuvring Areas (TMAs), weather conditions, and air traffic control (ATC) Restrictions. Continuous Descent Operation (CDO) is introduced to ease the aircraft operation within the TMAs. CDO aims to operate aircraft to follow a flexible, optimum flight path that delivers significant environmental and economic benefits. These benefits include reduced fuel burn, gaseous emissions, noise, and fuel costs without adversely affecting safety [1]. When employing CDO, arriving aircraft use their optimal climb engine thrust and speed [10]. With this approach, the aircraft decides the top of the descent (TOD) point, affecting engine thrust configurations. This technique also significantly reduces intermediate level-offs, resulting in more time spent at higher cruising levels, which are more fuel-efficient [11, 12]. This situation reduces fuel burn, lower emissions, and lower fuel costs. Air traffic controls (ATCos) use vector manoeuvring [13, 14] and point merge system (PMS) [15, 16] approaches generally implemented in constant flight levels to maintain safe separation and provide efficient aircraft sequencing. When an aircraft enters the TMAs, It can experience level-offs during the descent phase. These level-offs can occur when aircraft enter holding patterns [17], wait for clearance to approach and land, or obey altitude restrictions while transitioning from en route airspace to terminal airspace. These procedures are necessary for ATCos to maintain safe separation between aircraft and ensure a smooth and efficient arrival process. During the level-off segments, aircraft must keep their altitude and change idle thrust settings to level flight thrust settings. Airbus says aerodynamic and engine characteristics usually deteriorate over time due to various factors, including maintenance actions [18]. Also, weather conditions, temperature and pressure differences create different idle descent arrival trajectories for each aircraft. Therefore, applying uninterrupted CDO for each aircraft, especially busy airspaces, is impossible due to traffic numbers. This study aims to investigate level-off flight segments for London Heathrow, Amsterdam Schiphol, Paris Charles de Gaulle and Istanbul airports, the most used airport TMA in Europe.

Some studies have been conducted on selected airports [19-21]. Several studies have analyzed aircraft vertical profiles for descending operations. Lemetti et al. analyzed the TMA of Stockholm Arlanda Airport for arrival operations and showed the vertical inefficiency of descending profiles. It could lead to additional fuel burn, a vital cost and environmental impact to consider [22]. Aksoy et al. presented a study about the arrival of aircraft descending the profile of Trabzon Airport. They showed that arriving aircraft have vertical efficiency problems after 6000 feet of TOD points [11]. Gui et al. proposed a path-stretching method to eliminate level-off segments during the TMA operations of Guangzhou Baiyun International Airport. Their results showed that they reduced the total fuel consumption and total flight time for the selected airspace [23]. Saez et al. presented a method for managing terminal airspace traffic using two zones: a Pre-Sequencing Area, where 4D trajectory synchronization occurs, and a Dynamic-Trajectories Area, where adaptive arrival routes are created. These routes enable fuel-efficient CDOs with idle thrust and no speed-brake use [24]. Lui et al. presented a study comparing the PMS and trombone route systems. PMS supports the CDO, and the results showed that PMS increased the arrival capacity [25]. Kaplan et al. presented a mixed-integer nonlinear programming model for aircraft sequencing and scheduling problems using vector manoeuvring and CDO approach [13].

## 2. Materials and Methods

This study uses Automatic Dependent Surveillance-Broadcast (ADS-B) data sets for the aircraft descending profile analysis. ADS-B data set, an Excel format, includes aircraft identification, position, altitude, velocity, and other flight parameters. They enable researchers to identify the flight phases of an aircraft for the entire flight operation. ADS-B data also presents valuable parameters for calculating the aircraft flight time within the TMA using time of position and altitude. A filtering algorithm is developed in Python to reveal the level-off duration for arrival aircraft. Four significant TMAs were selected among the top four airports that provide the most service in Europe [26]. Hourly arrival traffic number for each airport was considered, as shown in Figure 1. Blue, orange, grey and yellow lines represent London Heathrow, Istanbul, Paris Charles de Gaulle Airport and Amsterdam Schiphol airports.

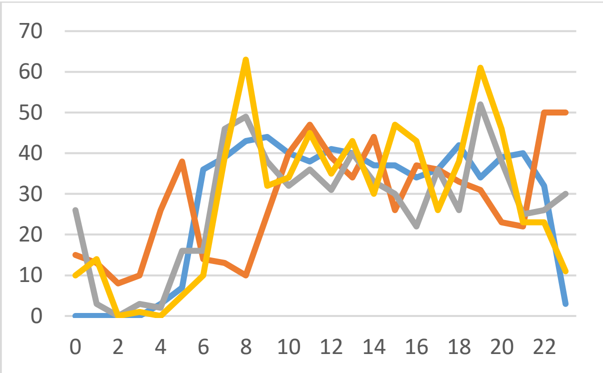


**Figure 1.** Hourly arrival traffic numbers for the selected airports

According to the traffic numbers, the 17:00-18:00 time duration was selected for London Heathrow, Paris Charles de Gaulle, and Istanbul airports. Also, 18:00-19:00 was chosen for the Amsterdam Schiphol airport. All the airports served almost equivalent traffic numbers per hour for the selected time durations. After determining the duration, we collected the ADS-B data from the Flightradar 24 website in Excel CVS format. Several traffic numbers were evaluated for the selected duration between 15-18 April 2024. The final arrival traffic numbers are 80, 77, 88 and 79 for London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol, and Istanbul airports for the selected days and periods. The flight phase consists of ground taxiing, take-off, climb, en-route, descend, approach, landing, and arrival taxiing. The entire flight profile is shown in Figure 2.

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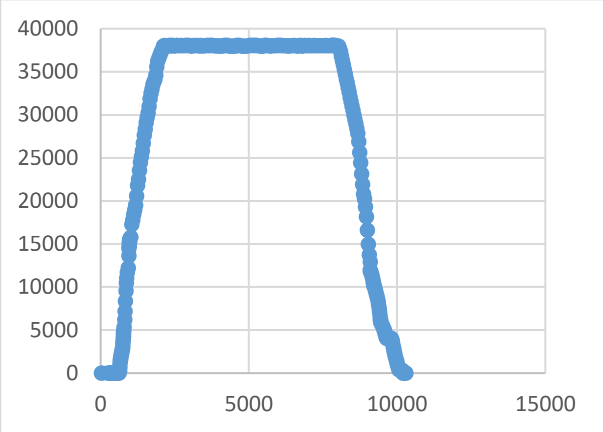


**Figure 2.** An entire flight profile for an aircraft landing at Paris Charles de Gaulle Airport.

In Figure 2, the vertical axis represents the altitude in feet, and the horizontal axis represents the flight time in seconds. Level-off segments are determined using information on aircraft flight phase, altitude, and rate of descent value. Our algorithm first analyzes the flight profile and finds the TOD point in the filtering mechanism, a critical point for descending operations. After determining the TOD, the algorithm focuses on altitudes below 25000 feet and above 3000 feet. An example of the arrival of aircraft ADS-B data is given in Figure 3.

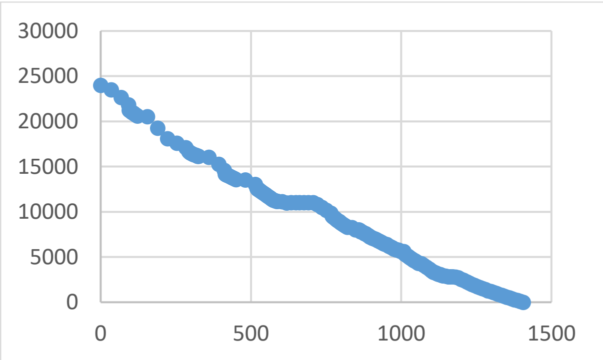


**Figure 3**. Descending profile of an aircraft landing at Heathrow Airport in the TMA.

The algorithm searches for every altitude change after 25000 feet to determine the rate of descent value. Suppose it finds a value as a zero. It shows that the aircraft performs a level-off flight within the selected TMA. Level-off durations for each selected TMA are analyzed carefully according to the detailed altitude distribution and the level-off time percentage regarding the entire descending operation.

## 3. Results and Discussion

The proposed algorithm detected the level-off segments for each TMA of the airports. The average level-off duration is presented in Table 1 for the selected traffic numbers.

**Table 1.** Average descending and level-off duration for each airport (sec).

| Airport | Average Descending Duration | Average Level-off Duration |
|---|---|---|
| London Heathrow | 1261.6 | 161.5 |
| Paris Charles de Gaulle Airport | 1216.2 | 176.7 |
| Amsterdam Schiphol | 1155.8 | 151.1 |
| Istanbul | 1259.8 | 218.3 |

The results showed that the minimum level-off duration occurred at the Amsterdam Schiphol Airport. The average level of duration is 12.8% of the entire descending operation. The rest are 13.1%, 14.5% and 17.3% for the Amsterdam Schiphol, Paris Charles de Gaulle Airport, and Istanbul Airport. While ATCos aims to provide effective and safe aircraft sequencing, they need instructions to maintain safe separation among the aircraft set. These can be vector manoeuvre, holding, and point merge systems. ATCos generally apply these constant flight-level methods. Furthermore, the need for separation techniques can arise more than once, according to the demand for air traffic in this airspace and airport. Altitude distributions for level-off flight are presented in Figure 4.

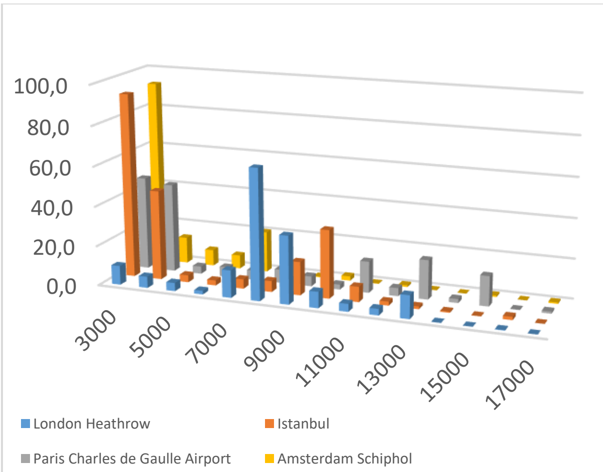


**Figure 4.** Level-off distributions for each airport.

The outputs showed that arrival aircraft generally fly about 3000 feet for the final sequencing of Istanbul and Amsterdam Schiphol. Also, arrival traffic for Istanbul and Paris Charles de Gaulle used 4000 feet for constant level flight for approximately the same duration. London

Heathrow arrival traffic performs level-off flight segments, mostly 8000 and 9000 feet. Paris Charles de Gaulle airport also utilizes high flight levels, such as 13000 and 15000 feet. Istanbul TMA has a point merge system; therefore, aircraft use sequencing legs located at 9000 and 10000 feet. In addition to this, the need for an extra level-off segment emerges due to the runway assignment strategy. This situation mainly occurs to maintain safe separation before flight level differences maintain the final approach point. This situation raises the level-off segment percentage for Istanbul Airport. Amsterdam Schiphol Airport uses a dynamically changing runway system. They can operate different runways for arrival and departure operations to optimize airport and airspace operations. Similarly, London Heathrow and Amsterdam Schiphol adopted a time-based separation system using intelligent approach tools. The results prove London Heathrow and Amsterdam Schiphol airports have a lower value of level-off flight duration in Europe.

## 4. Conclusion

The level-off flight segments during the TMA operations are investigated in this study for the most popular airports. We analyzed the results and found that London Heathrow and Amsterdam Schiphol have lower level-off segments. More than 40% of the arrival traffic performed level-off of segment no longer than two minutes for Amsterdam Schiphol and Paris Charles de Gaulle. The aircraft ratio, which has a level-off duration of less than a minute, is approximately %24, 16%, 31% and 5% for London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol, and Istanbul Airports, respectively. While level-off flight within a TMA is necessary to maintain safe separation between aircraft and ensure efficient traffic flow, it poses some disadvantages. Finally, level-off flights pose several challenges related to congestion, fuel burn, increased workload, traffic conflicts, and noise pollution. However, efforts to improve airspace management, optimize routing, and implement new technologies like CDO can help mitigate some of these disadvantages. By reducing the time aircraft spend level-off, CDO improves fuel efficiency, reduces noise pollution, and minimizes traffic conflicts. Furthermore, optimizing arrival routes and using advanced surveillance systems can help controllers manage airspace more effectively and reduce congestion while improving safety and efficiency for all aircraft. For further research, we can explore how the level-off segments affect fuel consumption and noise pollution. Additionally, we can investigate how to design TMA airspace to reduce or eliminate level-off segments effectively.

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## Author's Contributions

**Ramazan Kursat Cecen:** Drafted and wrote the manuscript, supervised the progress of the experiment, and performed the experiment and results analysis.

## Ethics

There are no ethical issues after the publication of this manuscript.

## References

**[1].** Eurocontrol. Continuous climb and descent operations. Available online: https://www.eurocontrol.int/concept/continuous-climb-and-descent-operations (accessed on 04.05.2024).

**[2].** Vlachos, I, Lin, Z. 2014. Drivers of airline loyalty: Evidence from the business travelers in China. *Transportation Research Part E: Logistics and Transportation Review*, 71:1-17.

**[3].** Kafle, N, Zou, B. 2016. Modeling flight delay propagation: A new analytical-econometric approach. *Transportation Research Part B: Methodological*, 93:520-542.

**[4].** AhmadBeygi, S, Cohn, A, Guan, Y, Belobaba, P. 2008. Analysis of the potential for delay propagation in passenger airline networks. *Journal Of Air Transport Management*, 14(5) : 221-236.

**[5].** Kim, M, Park, S. 2021. Airport and route classification by modelling flight delay propagation. *Journal of Air Transport Management*, 93: 102045.

**[6].** Kwasiborska, A, Skorupski, J. 2021. Assessment of the method of merging landing aircraft streams in the context of fuel consumption in the airspace. *Sustainability*, 13(22): 12859.

**[7].** Irvine, D, Budd, L, Ison, S, Kitching, G. 2016. The environmental effects of peak hour air traffic congestion: the case of London Heathrow Airport. *Research in Transportation Economics*, 55: 67-73.

**[8].** Montlaur, A, Delgado, L. 2017. Flight and passenger delay assignment optimization strategies. *Transportation Research Part C: Emerging Technologies*. 81:99-117.

**[9].** Dönmez, K. 2023 Aircraft sequencing under the uncertainty of the runway occupancy times of arrivals during the backtrack procedure. *The Aeronautical Journal*, 127(1310): 562-580.

**[10].** ICAO, "Continuous Descent Operations (CDO) Manual – Doc 9931/AN/476," Montreal, 1st edition, 2010

**[11].** Aksoy, H, Turgut, ET, Usanmaz, Ö. 2021. The design and analysis of optimal descent profiles using real flight data. *Transportation Research Part D: Transport and Environment*, 100:103028

**[12].** Turgut, ET, Usanmaz, O, Ozan Canarslanlar, A, Sahin, O. 2010. Energy and emission assessments of continuous descent approach. *Aircraft Engineering and Aerospace Technology*, 82(1): 32-38.

**[13].** Kaplan, Z, Çetek, C, Saraç, T. 2024. A multi-objective nonlinear integer programming model for mixed runway operations within the TMAs. *The Aeronautical Journal*, 128(1320) : 340-370.

**[14].** Omer, J. 2015. A space-discretized mixed-integer linear model for air-conflict resolution with speed and heading maneuvers. *Computers & Operations Research*, 58: 75-86.

**[15].** Demirel, S. 2023 Comparison of RECAT-EU and ICAO wake turbulence category on the Point Merge System. *The Aeronautical Journal*, 127(1315): 1623-1637.

**[16].** Dönmez, K, Çetek, C, Kaya, O. 2022. Air traffic management in parallel-point merge systems under wind uncertainties. *Journal of Air Transport Management*, 104: 102268.

**[17].** Dönmez, K. 2023. Evaluation of the performance of the multi-objective scalarization methods for the aircraft sequencing and scheduling problem using multi-criteria decision-making. *Aircraft Engineering and Aerospace Technology*, 95(4): 501-511.

**[18].** Airbus, L. (2002). Getting to grips with Aircraft Performance Monitoring.

**[19].** Olive, X, Sun, J, Basora, L, Spinielli, E. 2023. Environmental inefficiencies for arrival flights at European airports. *Plos one*, 18(6): e0287612.

**[20].** Scala, P, Mota, MM, Delahaye, D. 2021. Air Traffic Management during Rare Events Such as a Pandemic: Paris Charles de Gaulle Case Study. *Aerospace*, 8(6): 155.

**[21].** Dönmez, K, Çetek, C, Kaya, O. 2022. Aircraft sequencing and scheduling in parallel-point merge systems for multiple parallel runways. *Transportation Research Record*, 2676(3): 108-124.

**[22].** Lemetti, A, Polishchuk, T, Sáez, R, Prats, X. Evaluation of flight efficiency for Stockholm Arlanda airport arrivals. In 2019 IEEE/AIAA 38th Digital Avionics Systems Conference. 2019. IEEE.

**[23].** Gui, D, Le, M, Huang, Z, Zhang, J, D'Ariano, A. 2023. Optimal aircraft arrival scheduling with continuous descent operations in busy terminal maneuvering areas. *Journal of Air Transport Management*, 107:102344.

**[24].** Sáez, R, Polishchuk, T, Schmidt, C, Hardell, H, Smetanová, L, Polishchuk, V, Prats, X. 2021. Automated sequencing and merging with dynamic aircraft arrival routes and speed management for continuous descent operations. *Transportation Research Part C: Emerging Technologies*, 132: 103402.

**[25].** Liu, W, Delahaye, D, Cetek, FA, Zhao, Q, Notry, P. 2024. Comparison of performance between PMS and trombone arrival route topologies in terminal maneuvering area. *Journal of Air Transport Management*, 115: 102532.

**[26].** OAG: Flight Database & Statistics | Aviation Analytics Available online: https://www.oag.com/blog/europes-busiest-airports (accessed on 04.05.2024).