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AIRCRAFT SEPARATION FACTSHEET

The Next Step in Optimizing Runway Capacity – A London Heathrow Case Study

Introduction

London Heathrow airport (LHR) is one of Europe's busiest airports. Airport Coordination Limited (2016), the airport slot coordinator at LHR, has indicated that hourly runway demand exceeds the available capacity throughout most the day. To allow further growth, both the National Air Traffic Service (NATS) and EUROCONTROL started research to optimize the separation between aircraft in order to maximize runway capacity for approach and departure. NATS focused only on the airspace over the United Kingdom, whilst Eurocontrol developed the European Wake Vortex Re-Categorization (RECAT-EU), which was a revision of the already 40-year old separation system currently used (Eurocontrol, 2015a).

ICAO (1999) recommendations in Annex 14 state that aerodromes should orientate their runways in such a way that they can operate in 95% of all wind conditions. A significant headwind allows the aircraft to maintain a safe air speed whilst groundspeed decreases. This increases the time between aircraft touching down (Freville et al., 2003). Consequently, headwind conditions can seriously affect actual runway capacity by increasing time between landings.

Aircraft on approach are now separated by a Distance-Based Separation (DBS) model that uses fixed distances between aircraft. A significant headwind allows the aircraft to maintain a safe air speed whilst groundspeed decreases. This increases the time between aircraft touching down, thereby lowering actual runway capacity. NATS therefore introduced the Time-Based Separation (TBS) model at LHR in order to account for the decrease of runway capacity due to headwind.

This factsheet will present the benefits of the updated minimum required separation system, RECAT-EU, on actual runway capacity. Furthermore, the theory and the effect of TBS will be explained.

RECAT-EU; Redefining 40-year Old Standards

The introduction of the world largest passenger aircraft in 2007, the Airbus A380, created the need for a revision of the required minimum separation between aircraft. The separation minima were based on three aircraft categories (LIGHT, MEDIUM and HEAVY) and regulation depended on the Maximum Take-Off Mass (MTOM) of the aircraft. The regulation for aircraft separation was, however, already 40 years old (Eurocontrol, 2015a).

RECAT-EU was the response to the increased MTOM capacity of the A380 in order to ensure a safe operation. The aim of the project was to create a:

"New categorization of aircraft for the traditional ICAO [International Civil Aviation Authority, red.], whose aim is to safely increase arrival and/or departure capacity at airports by redefining wake turbulence categories and their associated separation minimum." (Eurocontrol, 2015a)

RECAT-EU changed the standard three category system, to a broader and more accurate six category system of: "Super Heavy", "Upper Heavy", "Lower Heavy", "Upper Medium", "Lower Medium" and "Light". Following a study from EUROCONTROL (2015b), who conducted over 100,000 wake-turbulence measurements, the European Aviation Safety Agency (EASA) approved the RECAT-EU separation scheme in October 2014.

The six separation categories decreases separation between several aircraft types, but also increase minimum separation for some. As figure **1** indicates, minimum separation between two "Super Heavy" aircraft is increased by 0.5 nautical miles (nm), whilst minimum required separation between two "Upper Heavy" aircraft is reduced by 1nm (EUROCONTROL, 2015b).

Leader \ Follower		"Super Heavy"	"Upper Heavy"	"Lower Heavy"	"Upper Medium"	"Lower Medium"	"Light"
		"A"	"B"	"C"	"D"	"E"	"F"
"Super Heavy"	"A"	(+0.5 NM)	-2 NM	-1 NM	-2 NM	-1 NM	
"Upper Heavy"	"B"		-1 NM		-1 NM		+1NM
"Lower Heavy"	"C"		-1 (-1.5) NM	-1 NM	-2 NM	-1 NM	
"Upper Medium"	"D"						
"Lower Medium"	"E"						-1 NM
"Light"	"F"						(+ 0.5 NM)

*Figure **1**, Difference in wake turbulence separation minima on approach between reference ICAO and RECAT-EU schemes (EUROCONTROL, 2015b)**.** Blank cells indicate no difference.*

Eurocontrol (2015b) reports RECAT-EU delivers an increase of at least 5% in available runway capacity, but the increase can also be up to 8% for some airports. The same report also states that the evolution of traffic mix, the forecasted shift to bigger aircraft, can provide a bigger capacity increase in the future. RECAT-EU will become one of several means by which airports can mitigate the lack of runway capacity foreseen in EUROCONTROL's 2013 'challenges to Growth' study.

TBS; Decreasing the Impact of Headwind on Runway Capacity

Headwind has a negative effect on an aircraft its ground speed, as shown in equation **1**. In this equation T is the time between landings, D is the separation distance between aircraft and GS represents the ground speed. GS can also be formulated as the Indicated Air Speed (IAS) minus the Wind Speed (WS) (Freville et al., 2003).

$$T = \frac{D}{GS} = \frac{D}{IAS - WS}$$

Equation 1, Time between landings

With a headwind component, the ground speed decreases. In case of DBS, a decreased ground speed automatically increases the time between landings (T), as distance between aircraft is fixed, thereby reducing the runway capacity.

In the case of TBS, time replaces distance as the fixed variable. Because the ground speed decreases due to headwind, distance between aircraft needs to be decreased in order to ensure the time between aircraft remains the same. This is illustrated in figure **2** (NATS, 2017). The question is whether this is safely possible, while keeping in mind wake vortexes produced by other aircraft. NATS (2015b) completed a study at LHR where the wake vortices have been analysed. They found that wake vortices dissipate quicker with an increased wind speed. Without the danger of flying into a preceding vortex, which could result in loss of control, shorter distances, and thus TBS, can be facilitated (CAA, 2013).

*Figure **2**, Graphical overview of the effects of TBS (NATS, 2017)*

During headwind conditions, DBS is a burden to the usage of the available capacity. The implementation of TBS would counteract the negative effect of headwind. According to NATS (2014) the maximum amount of landings LHR can handle with light headwinds whilst using DBS is between 40-45 aircraft. In this case strong headwinds reduce the capacity to 32-38 aircraft per hour. TBS would limit the negative effect and facilitate 36-40 landings per hour, thereby reducing delays.

Reducing Airline Costs by Means of Reducing Delay

The beneficial impact of RECAT-EU and TBS on runway capacity has been described extensively above. Obviously, it is also very interesting to analyse the financial impact. This is dependent on the operational impact, so this has to be analysed first. LHR is currently operating its runways at 98% of maximum capacity throughout the day (Airports Commission, 2015). Figure **3** illustrates the capacity constraints by highlighting the slot usage. Furthermore, with almost no slack or redundancy in available slots, minor disruptions seriously influence delay.

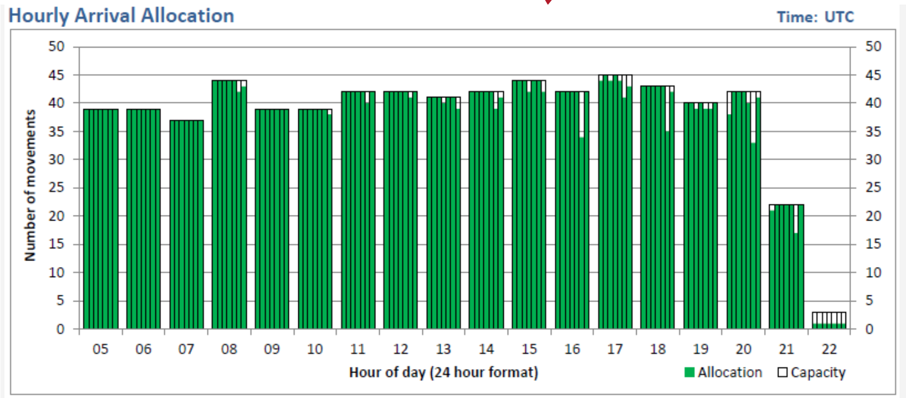

*Figure **3**, Slot allocation at LHR during IATA Summer Season 2016* (Airport Coordination Limited, 2016) *[White areas indicate slots are still available during that 10 minute period. Red.]*

Air Traffic Flow Management (ATFM) aims at optimizing traffic flows and minimizing congestion, taking into account the air traffic control capacity, while enabling airlines to operate safely and efficiently (EUROCONTROL, 2016b)**.** To achieve this, ATFM delays are assigned to aircraft that still have to depart and are expected to arrive during a period of congestion (EUROCONTROL, 2014).

ATFM arrival delays are issued every day at many airports, also at LHR. This is caused by multiple reasons. Data collected by EUROCONTROL (2016a) illustrates that headwind is the biggest cause of ATFM delay at LHR, which can be seen in figure **4**.

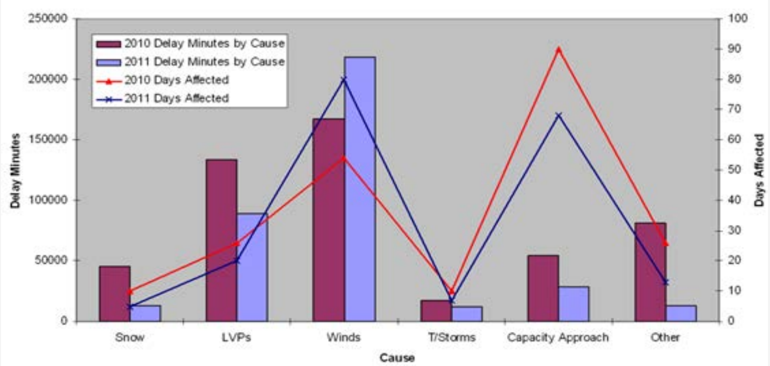

*Figure **4**, Cause of ATFM arrival delay at London Heathrow (2010/2011) (EUROCONTROL, 2016a)*

As described, headwind has a negative impact on runway capacity whilst using the DBS method during approach. NATS (2015a) has calculated that more than 40% of the total ATFM arrival delays at LHR are attributable to the strong headwind. This is equal to approximately 160.000 ATFM delay minutes. EUROCONTROL stated that TBS, compared to DBS, reduces this delay with a minimum of 50% (Trêve, 2016). This was before implementation. The European Commission (2016) stated that the reduction in delay turned out to be 60%. As a result, there has been a notable reduction in flight cancellations attributable to weather circumstances.

A study by the University of Westminster, commissioned by EUROCONTROL, created an overview of the costs of delay for airlines (Cook, 2011). The estimated 50% ATFM delay reduction has been applied this study, leading to a projected benefit for airlines around £6M - £7.5M per year (NATS, 2015a). This is only for airlines. Societal impact of delay (value of time) is disregarded in the calculations. Since delay reduction at LHR turned out to be even higher than estimated, it can be assumed that the benefit will also be higher. Since wind conditions vary between airports, delay reduction will vary as well. Cost benefits will therefore differ per airport. The cost reductions for other parties involved are yet to be determined.

Conclusion: RECAT-EU and TBS is a Reinforcing Structure

As mentioned in this factsheet, both RECAT-EU and TBS have a positive impact on runway capacity (maximum- and actual-capacity respectively).

The re-categorized separation minima RECAT-EU introduces promise to deliver an increase of at least 5% to maximum runway capacity. The benefit is expected to increase as a shift towards larger aircraft is also expected.

The implementation of TBS at LHR highlighted the effects it can have on actual runway capacity. By separating aircraft based on fixed time intervals rather than distance, the negative effect of headwind can be mitigated. This has a positive effect on ATFM delays at airports and costs for airlines.

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Image references (top to bottom, left to right)

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1 EUROCONTROL. (2015, July 15). RECAT-EU: European Wake Turbulence Categorisation and Separation Minima on Approach and Departure. Retrieved from: http://www.eurocontrol.int/sites/default/files/content/documents/sesar/recat-eu-released-september-2015.pdf

2 NATS. (2015). Intelligent Approach Time and Distance Based Separation. NATS.NATS scheme

3 EUROCONTROL. (2016, March 4). Time Based Separation. Retrieved September 26, 2016, from European Commission: http://ec.europa.eu/transport/modes/air/ses/ses-award/projects/doc/ppttbs_nats_wac.pdf

Dutch Summary

Constante groei van vliegverkeer veroorzaakt drukte in de lucht en op de grond. Optimalisatie van capaciteit wordt dus belangrijker. Onderzoek van NATS en EUROCONTROL wijst uit dat fysieke separatie kan worden geoptimaliseerd door het her-categoriseren van vliegtuigentypes; RECAT-EU. Door de verkleinde onderlinge afstand neemt de tijd tussen twee landingen af, wat de effectieve baancapaciteit vergroot.

Echter, bij forse tegenwind neemt de grondsnelheid af waardoor de onderlinge tijd toeneemt. Onderzoek op LHR heeft uitgewezen dat in dit geval er beter op tijd kan worden gesepareerd (TBS), dan op afstand (DBS). Hierdoor neemt de onderlinge afstand af, terwijl de tijd tussen landingen gelijk blijft. Naast optimalisatie van de beschikbare capaciteit neemt door TBS wind gerelateerde vertragingen met minimaal 50% af.

RECAT-EU vergroot de beschikbare baancapaciteit en TBS zorgt dat hiervan optimaal gebruik wordt gemaakt in geval van forse tegenwind.

This is a Luchtvaartfeiten.nl / AviationFacts.eu publication.

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AviationFacts.eu is an initiative by the Aviation Academy at the Amsterdam University of Applied Sciences (AUAS). Students and teachers share knowledge with politicians and the general public to ensure discussions are based on facts.

May 2017