Technical Report 17

Optimal Location of Cargo Area

London Thames Airport Planning Commission
Cargo Logistics Division

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Appendix

1 Executive Summary

This technical report presents a summary of the findings of the Cargo Logistics Division's study of the optimal location for the airside cargo facility at London Thames. We hereby recommend relocating the cargo center from its originally proposed location to the west of the runway and passenger terminal complex to a new location between the two runway pairs toward the east edge of the platform. This location is currently slated to house the aircraft maintenance hangars and we propose a swap in which the cargo facility takes its place and the maintenance area is moved to the west section.

This move is estimated to save £133mn in annual fuel costs, reduce taxi time for cargo aircraft by 119 hours per day, and reduce the carbon emissions of the airport by 37%. Additional one-time infrastructure costs are estimated at £210mn with ongoing maintenance well within the scope of the existing budget.

2 Background

The original concept for the London Thames airport submitted by Foster + Partners in the May 2014 proposal, *Inner Thames Hub Estuary Feasibility Studies*, proposed a master plan in which the airside cargo center is located to the west of the runway complex. Two alternative locations were also considered, as illustrated in Figure 5-4 of Section 5-2-3. In Alternative Concept Cargo 01, the cargo complex is placed between the southerly runway pair at the eastern edge of the platform. In Alternative Concept Cargo 02, the entire cargo complex is located south of the runway pairs in the southeast sector of the platform.

The primary design criteria for determining placement of the cargo area included the provision for at minimum 270 ha. of safeguarded space dedicated to airside cargo operations, efficient access to road links, and a minimum of disruption to passenger operations. The original plan calls for 24 to 26 Code F stands for the 110 mppa capacity phase with expansion to 40 Code F stands at 150 mppa capacity.

The finalized Master Plan approved by the Airport Commission in June 2016 made several amendments to the original concept drawings. The most significant change was the runway layout with selection of Alternative Concept 01, as shown in Figure 5-3 of the aforementioned document.

The June 2016 Master Plan retained the original location of the cargo area to the west of the runways. In order to retain its footprint of safeguarded space, the cargo center was moved 112 m north. This move would require only minimal alterations to the original plan for the airside/roadside interface and rail infrastructure.

Subsequent to the acceptance of the Master Plan, the Airport Commission further refined the original Feasibility Study in Technical Report 3, *Terminal Layout and Passenger Facilities Plan*, and also in Technical Report 9, *Taxiway Network*. A significant finding of TR 9 indicated that the location of the cargo area to the west of the runways would present several challenges in the routing of cargo aircraft to and from the runways[1]. The Cargo Logistics Division was then entreated to study alternative locations of the airside cargo facilities to mitigate the traffic problems highlighted in the proposed taxiway network.

3 Taxi Time and Fuel Burn Calculations

In this section we will compare and discuss projected taxi times and consequent fuel burn for cargo flights at London Thames under two scenarios that vary in the placement of the airside cargo facility. The present operating concept we refer to as Cargo West, in which the cargo center is located to the west of the runway complex as originally proposed in the May 2014 Feasibility Study. In the alternate scenario, Cargo East, we consider placement of the cargo center between the two runway pairs at the eastern edge of the platform.

The calculations are divided into two primary sections based on the runway operating pattern: West flow, in which departures and arrivals occur on runways 27 and 28, and East flow, where the traffic pattern utilises runways 09 and 10. The operating pattern will fluctuate based on prevailing winds, time of day, season, and traffic density.

We have made several simplifying assumptions in the interest of parsimony. The parameters involved in the calculations have a certain margin for error. By varying these parameters in multiple simulations we have estimated that the overall margin for error in our fuel burn and associated cost projections is within 2%. This level of accuracy is more than sufficient for evaluating the differences between the two cargo locations.

[1] During peak movement times, cargo aircraft dispatched from the cargo center would experience a mean delay of 12 minutes due to congestion at intersections TWY E3 to TWY F and TWY G. These calculations are discussed in Section 3.9 of Technical Report 9.

The measured distances and are based on the provisional taxiway network as specified in Technical Report 9. The turn count is the number of 90 degree turns required to taxi to or from the active runway, not including the final turn at the runway hold point. For departures, we assume a standard pushback by tug from a stand located nearest the center of the cargo complex. For arrivals we begin calculating distance from the corresponding parallel taxiway assuming exit from the second (of three) high speed taxiways of the arrival runway.

In Table 3.1 we present our estimates for taxi time and fuel burn for a typical cargo flight.

Table 3.1 Taxi Time and Fuel burn scenarios

West flow departures

	Departure 28L/R		Departure 27L/R	
	Cargo West	Cargo East	Cargo West	Cargo East
Taxi distance (m)	7,638	905	11,267	905
Turns	4	1	4	1
Taxi time (min)	18.6	5.3	24.5	5.3
Fuel burn (kg)	1,067	303	1,405	303

West flow arrivals

	Arrival 28L/R		Arrival 27L/R	
	Cargo West	Cargo East	Cargo West	Cargo East
Taxi distance (m)	4,995	5,412	7,068	5,412
Turns	5	3	5	3
Taxi time (min)	15.1	14.2	18.4	14.2
Fuel burn (kg)	607	570	742	570

East flow departures

	Departure 10L/R		Departure 09L/R	
	Cargo West	Cargo East	Cargo West	Cargo East
Taxi distance (m)	3,647	5,701	7,276	5,701
Turns	5	3	5	3
Taxi time (min)	12.9	14.6	18.8	14.6
Fuel burn (kg)	742	841	1,079	841

East flow arrivals

	Arrival 10L/R		Arrival 09L/R	
	Cargo West	Cargo East	Cargo West	Cargo East
Taxi distance (m)	6,896	3,511	8,968	3,511
Turns	5	1	7	1
Taxi time (min)	18.2	9.5	23.1	9.5
Fuel burn (kg)	731	382	930	382

Our estimate of taxi time assumes a nominal straight-line taxi speed of 20 knots. This is the typical maximum taxi speed on TDG 7 taxiways for large aircraft such as the Boeing 747. In practice, this speed may be exceeded as conditions and ATC instructions permit and for smaller cargo aircraft. However, it may also not be achievable due to weather conditions, additional traffic ahead of the taxiing aircraft, and speed reductions when two large aircraft taxi past one another on parallel taxiways. For the mix of cargo aircraft projected to be used at London Thames as well as accounting for the range of weather conditions and ground traffic, 20 knots is a good estimate for the typical taxi speed on straight-line taxiways[2].

Each 90 degree turn is estimated to cost an additional 0.8 minutes as measured in contrast to maintenance of the nominal taxi speed in the absence of the turn[3]. Lastly, we include an additional 3 minutes to account for the Before Taxi flight deck preparations which will occur after an aircraft has been pushed back from the cargo stand and engines have been started.

Fuel burn calculations are a direct linear function of the estimated taxi time. In developing the formula for average hourly fuel burn during taxi operations, we use an annualized weighted average of the most important factors that determine how much fuel an aircraft will require. This includes atmospheric conditions (winds, temperature, and runway surface state) as well as the aircraft type. Based on traffic projections used in Technical Report 2, we project a mix of cargo aircraft at London Thames to be predominantly skewed towards heavier types (mainly Boeing 747-400F and 777F aircraft). We estimate that cargo operations will involve a mix of 70% large aircraft types, 20% medium, and 10% standard. We also take into consideration the typical load factors with which such cargo aircraft will be departing and arriving. Within each of these aircraft categories we further refine the estimates based on typical fuel consumption of the major aircraft types that make up each category. For example, in calm winds at sea level with an external temperature of 20 C, a Boeing 747-400F with a load factor of 86% will use 4,200 kg per hour during taxi. A Boeing 777F with the same atmospheric conditions and load factor will require 2,880 kg per hour. For the complete derivation of our assumptions used in the model for estimating fuel burn based on average taxi times, refer to Appendix C.

We will now walk through an example scenario for departing cargo aircraft. For a majority of operations, the airport will be in West flow and departing cargo flights will be preferentially assigned to RWY 28R[4] in the South pair. Using optimal taxiway assignments, the linear distance from the cargo center as located in the original airport concept at the west end of the airport grounds is 7,638 meters to the hold point of RWY 28R. Taxi to this point involves 4 90 degree turns. By comparison, if the cargo center is located at the east end of the platform between the North and South runway pairs, the taxi distance is reduced to a mere 905 meters with only one required 90 degree turn. The impact of this large gap in distance on taxi time and fuel burn is significant. In the Cargo West scenario, the expected taxi time will be 18.6 minutes

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[2] A complete list of assumptions, calculations, and models used to determine the estimated taxi speed is provided in Appendix A.

[3] See Appendix B for additional detail on how we arrived at the turn penalty.

[4] Under typical anticipated traffic patterns, departing aircraft will utilise the inner runway (eg. 28R in the South pair and 27L in the North pair) while arrivals will land on the outer runways (28L and 27R). However, differences in taxi times between the inner and outer runways are negligible so we treat them as interchangeable for the purposes of these calculations.

and the average taxi fuel consumption from the cargo center to the hold point at RWY 28R is 1,067 kg. In the Cargo East scenario, the expected taxi time becomes 5.3 minutes and the required taxi fuel consumption figure drops to only 303 kg.

When the North runway pair is used for a cargo departure, additional distance is required from Cargo West while in Cargo East, due to the symmetry of placing the cargo center between the North and South runway pairs, the distance remains the same. In the case of departures from the North runway pair, taxi distance from Cargo West is 11,267 meters, with an estimated taxi time of 24.5 minutes, translating into a fuel burn of 1,405 kg. For the Cargo East scenario, the distance will again be 905 meters, for a taxi time of 5.3 minutes, and a fuel burn of 303 kg.

The full spectrum of departure and arrival scenarios is shown in Table 3.1. Of the eight possible scenario, there are only two in which the Cargo East location will involve a longer taxi distance than Cargo West: West flow Arrivals on 28L/R and East flow Departures on 10L/R. However, the only scenario in which estimated fuel burn is higher for Cargo East is with East flow Arrivals on 10L/R.

For arrivals on the South runway pair, 28L/R, taxi distance to Cargo West would be 4,995 meters, compared to 5,412 meters to Cargo East. Note, however, that taxi to Cargo West involves five 90 degree turns versus only three to Cargo East. This results in an estimated taxi time of 15.1 minutes to Cargo West versus 14.2 minutes to Cargo East. (Ftn: as noted above taxi to Cargo West also involves traversing a hot spot at intersections E3 and E5. We have not modelled the additional hold times that would be likely to occur during peak operations). As a result, fuel burn would continue to be higher to Cargo West (607 kg) as compared to Cargo East (570 kg), despite the shorter linear distance.

For East flow departures on the South pair, 10L/R, taxi distance from Cargo West would be 3,647 meters with 5 90 degree turns. Taxi distance from Cargo East would be 5,701 meters with 3 90 degree turns. This is the only scenario in which expected taxi time, and hence fuel burn, would be higher with Cargo East (14.6 minutes with 841 kg, versus 12.9 minutes with 742 kg).

4 Economic impact

In this section we will apply the fuel burn estimates developed in the previous section to derive an estimate of the economic impact of the two proposed airside cargo facility locations. We refer to the extensive analysis conducted for Technical Report 2, *Air Traffic Routing and Preliminary Procedures*. The wind rose study outlined in TR2 which was performed at the proposed airport site provides the basis for our assumptions about the operation of the runways throughout the day and year. In addition, the guidance provided in that document based on forecast traffic for London Thames, with due consideration of air traffic routing for neighboring airports and associated regional airways, enables us to estimate the proportion of flights that will be conducted under West flow operation (predominant) and East flow operation.

Whether the Cargo center is located in its originally proposed westerly location or in the herein proposed East location, as noted in both Technical Reports 3 and 9, the operating plan for the airport is to prefer cargo flight operations to and from the South runway pair. This is in fact the ideal runway pair for either cargo location and does not present any difficulties or compromises for passenger traffic. However, the South runway pair will not always be available and we must thus consider the occasional necessity for cargo flights to operate to and from the North runway pair.

From guidance provided in Section 4-4 of Technical Report 2, we project that the airport will operate in West flow for approximately 86% of cargo flights[5]. Based on our review of the operational requirements for runway maintenance, special traffic considerations, and other contingencies, we estimate that the South runway pair will be available for use in 92% of cargo flights[6]. These two estimates, when placed alongside the estimated fuel burn for a typical cargo flight, will allow us to estimate the differential fuel burn between the Cargo West and Cargo East scenarios. Table 4.1 shows the weighted average taxi time and fuel burn.

Table 4.1 Weighted Taxi Time and Fuel Burn

	Cargo West	Cargo East
Departure taxi time (m)	18.3	6.6
Arrival taxi time (m)	15.8	13.5
Total Per cycle taxi time (m)	**34.1**	**20.1**
Departure taxi fuel (kg)	1,049	377
Arrival taxi fuel (kg)	636	544
Total Per cycle fuel (kg)	**1,685**	**920**

The original planned location of a westerly located airside cargo location will incur an average of 34.1 minutes of total taxi time (18.3 minutes taxi out for departure and 15.8 minutes taxi in from arrival), and 1,685 kg of fuel burn. The proposed easterly location reduces taxi time by 41% to 20.1 minutes (6.6 minutes on departure and 13.5 minutes on arrival) with a 45% lower fuel burn of 920 kg.

[5] This takes into account the fact that cargo flights will have 24 hour operation and a larger proportion of them will occur in the night hours when East flow is more feasible. A complete derivation of this figure is provided in Appendix D.
[6] A detailed discussion of the assumptions required for estimating runway pair allocation is provided in Appendix E.

In the original feasibility study for an Inner Thames airport hub, two forecast capacity modes were derived: 110 mppa and 150 mppa. This translates into roughly 1,068 and 1,370 daily cycles, respectively. We estimate the cargo share[7] of these movements to be 34% and 37%, respectively, translating to 360 cargo flight cycles in the 110 mppa capacity mode and 512 cycles in the 150 mppa mode. Estimates of daily and annual taxi time and fuel costs is shown in Table 4.2.

Table 4.2 Forecast Economic Impact

	110 mppa		150 mppa	
	Cargo West	Cargo East	Cargo West	Cargo East
Daily taxi time (hr)	204.4	120.5	290.7	171.3
Daily fuel cost (mn GBP)	0.564	0.308	0.802	0.438
Annual taxi time (hr)	74,603	43,969	106,102	62,534
Annual fuel cost (mn GBP)	205.9	112.5	292.8	160.0

Here we begin to see the scale of the costs involved and our rationale for proposing moving the cargo facility to the east location. In the initial forecast capacity mode of 110 mppa, cargo aircraft will save a combined 84 hours of taxi time per day, which becomes 119 hours per day in the 150 mppa capacity mode. The annual fuel cost for taxi operations will initially amount to £205.9mn and eventually forecast to rise to £292.8mn under the Cargo West scenario. When the airport reaches 150 mppa, relocating the cargo facility to the east will save cargo airlines nearly £133mn per annum[8].

5 Emissions impact

Carbon emissions are an important consideration and every effort is being made to design London Thames with an eye toward maintaining a state of the art airport that minimises the emissions profile of

[7] Specifically, we consider only those cargo flights that will originate or terminate at the airside cargo facility.
[8] This analysis assumes an average cost of £0.93 per kg. This is a reasonable estimate of the annualized cost of jet fuel that will be made available to cargo airlines at London Thames.

the airport to protect the environment. Emissions from taxiing aircraft are one of the most significant factors contributing to the overall emissions profile of an airport. By reducing average taxi times for heavy cargo aircraft, we will directly reduce the airport's overall carbon footprint.

Estimating carbon emissions from aircraft taxi operations is a complex process although it scales almost linearly with taxi time. As noted in section 4, moving the cargo center to the proposed east location will reduce taxi time by 41% with no concomitant increase in projected taxi times for passenger operations.

Based on our model for estimating carbon emissions, we forecast an overall reduction of 37% in carbon emissions by choosing Cargo East as the location for the airside cargo facility. Details of this model are presented in Appendix F.

6 Infrastructure Implications

Additional infrastructure will be required to support the new cargo location. The majority of these are one-time fixed costs while upkeep and maintenance will add a minor burden to the ongoing cost projections for the airport complex. The South access road will need to be reconfigured as an extension of the M25 interchange that leads into the main terminal. The South access road will require 4 lanes to account for increased lorry traffic. We also propose a tunnel underneath the South runway pair to provide direct road access to the airside/landside interface.

The additional infrastructure costs are well within the contingency costs outlined in Table 4.5 of the *Inner Thames Hub Estuary Feasibility Studies*. We estimate an additional £210 mn in infrastructure improvements to relocate to Cargo East. Further details of the revised infrastructure plan are presented in Appendix G.