Operational Freedoms Trial

Final Report

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Heathrow
Making every journey better

Executive summary

This document is Heathrow Airport Limited's report on the 'Operational Freedoms' trial at Heathrow Airport and covers the two phases of the trial. The first phase ran from November 2011 to February 2012 and the second phase ran from July 2012 to February 2013.

This phased trial was introduced to examine the consideration of new operating procedures at Heathrow to reduce delay, improve punctuality and increase resilience whilst maintaining a balance with impacts on local communities. It was approved by the then Minister of State for Aviation, the Rt. Hon Theresa Villiers MP and announced on 14th July 2011.

The Operational Freedoms trials, undertaken collaboratively by Heathrow and NATS, were based on the premise that a segregated mode of runway operation is unable to withstand or recover from typical fluctuations in air traffic demand caused by weather, schedule perturbations and network effects.

As the UK's only hub airport, Heathrow already operates higher levels of throughput on its two runways than other competitor airports and is necessarily more complex in delivering these volumes. In addition, Heathrow is full and lacks the degree of headroom needed to overcome schedule perturbations and poor weather. Heathrow is regularly reported by Eurocontrol as having the highest level of inbound delays due to weather.

In collaboration with the Department for Transport and the CAA, Heathrow designed a series of operational freedoms involving more flexible use of the runway infrastructure to address the root causes of disruption. These included the use of both runways for arrivals, the use of both runways for departures, redirecting departures after take off to achieve early separation and hence increase runway throughput and the increased use of the southern runway for A380 aircraft, small and light aircraft and Terminal 4 traffic. Heathrow contracted Cambridge University's Institute for Manufacturing to provide independent oversight on the trial design and methodology.

During Phase 1, the freedoms were used regularly whilst in Phase 2, the freedoms were staggered to provide, as far as possible, a means to assess the benefit of each freedom independent from the others.

Throughout the trial, regular communications were maintained between the Department for Transport, the CAA, Heathrow and NATS to ensure the progress of the trials were accurately tracked and to capture any feedback from regulators.

Heathrow supported an unprecedented level of community engagement throughout both phases of the trial consisting of detailed operational data reported daily on the company's public website, leaflets and advertorials in local newspapers, public meetings in local communities, engagement with politicians, and regular meetings and consultation with local authority experts.

It was to be anticipated that, with more flexible use of both runways, community reaction, particularly from those resident in close proximity to the extended runway centrelines, would be less than positive and the numbers of these complaints were tracked accurately and are reported in more detail in the body of the report.

All airports are affected to a great extent by weather conditions and the trial periods at Heathrow were no exception. At the beginning of the trial, the winds were predominantly easterly which meant that departing aircraft could be seen to the east and south east of the airport and whilst this is not unprecedented, would have appeared unusual. At the start of the second phase there were unusually high levels of poor weather and thunderstorms around Heathrow which meant that operations were highly disrupted. These factors would have contributed significantly to the complexities of matching freedoms with data on benefits and impacts.

While reaching clear conclusions from the evidence produced is not easy, it is Heathrow's view that, on balance, Operational Freedoms, as trialled, delivered useful operational performance improvements in limited areas. While their use did not provide the wholesale significant benefits that could be required to facilitate recovery from the most severe episodes of disruption, Heathrow believes that operational freedoms do help to mitigate against, and recover more quickly from, those less serious disruptive events which still result in poor performance and passenger experience. It is recommended therefore, that the following operational freedoms should be integrated into standard procedures as soon as practically possible:

TEAM : Use of both runways for arrivals in either direction when disruptive conditions prevail subject to:-

- Actual or anticipated arrival delays which are likely to impact operations
- The headwind component on approach to Heathrow is forecast to be greater than 20 knots at 3000ft.
- Aircraft are arriving on their stand more than 30 minutes later than their scheduled time or if 30% of all aircraft (arrivals and departures) operating from Heathrow are running 15 minutes late.
- There is disruption to the operation, for example from snow.
- Usage to increase from 6 landings per hour up to 12 landings per hour

Early Vectors : Use of early vectoring procedures for departures in either direction and on any route subject to:-

- Actual or anticipated departure delays which are likely to impact operations
- The headwind component on departure from Heathrow is forecast to be greater than 20 knots at 3000ft.
- Evidence of routing bias leading to excessive delays
- There is disruption to the operation, for example from snow.

Proactive Freedoms : Option to use the southerly runway for A380, Terminal 4 and small/light wake vortex category aircraft.

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1 Background to the trial

1.1 Introduction

The Government's South East Airports Taskforce (SEAT) was established in June 2010 to investigate options for making the best use of existing capacity at Heathrow, Gatwick and Stansted Airports. The Taskforce's final report was published on 14 July 2011 and the main recommendation was to explore the scope for a set of Operational Freedoms to be established at Heathrow. These would enable the greater use of tactical measures in defined and limited circumstances to prevent or mitigate disruption and to facilitate recovery. As a result, the Government announced its support for a phased trial of Operational Freedoms in parallel to the publication of the SEAT report.

Subsequently, Heathrow developed a two stage trial to assess the impact of Operational Freedoms on the local community, the environment, passengers and airport operations. The trial design was agreed with the Department for Transport (DfT) and Civil Aviation Authority (CAA) and its implementation was overseen by the CAA. The trial was undertaken collaboratively by Heathrow and NATS in two phases to test both winter and summer conditions.

Phase 1 of the trial ran from 1 November 2011 to 29 February 2012 inclusive. A comprehensive report into Phase 1 has been produced by Heathrow and is available at:

http://www.heathrowairport.com/static/Heathrow_Noise/Downloads/PDF/Heathrow_Operational_Freedoms_trial-Phase_1-report.pdf.

As part of its role overseeing the two phases of the Operational Freedoms trial, the CAA has produced a report on Phase 1 of the trial. The report can be found at www.caa.co.uk/apfg.

The summer season part of Phase 2 of the trial ran from 1 July to 27 October 2012 inclusive. A comprehensive report of this part of the trial has also been produced by Heathrow and is available at:

http://heathrowoperationaldata.com/images/Summer2012/Summer_Season_2012_Report.pdf.

The winter part of Phase 2 of the trial ran from 28 October 2012 through to 28 February 2013 inclusive.

This document and its supporting annexes comprise the complete, final report for both Phases 1 and 2 of the Heathrow Operational Freedoms trial. Phase 1 of the trial was a learning process that informed the design and analysis of Phase 2. Therefore in this report there is much more emphasis in this report on the outcomes of Phase 2 of the trial. Similarly, the analysis undertaken during the summer season of Phase 2 has informed the analysis techniques described herein and is superseded by the results presented in this report.

This remainder of this section describes the background to the trial covering:

- the methodology applied to the operation of the trial
- the traffic volume experienced during the trial period, compared to the baseline period
- the east/west split of operations by movement during the trial
- the major events impacting on the trial

- the extent to which Operational Freedoms were applied during the trial and the associated trigger conditions.

1.2 Trial methodology

1.2.1 Introduction

Phase 1 of the trial ran from 1 November 2011 to 29 February 2012 inclusive. It investigated the impacts of the three sets of measures continuously throughput the period. The first two are termed **reactive measures**, in that they are activated in response to a trigger condition being met (see section 1.2.2):

- operating arrivals on the designated departures runway – a dual arrival runway operation (so-called tactically enhanced arrivals measures applied after 07:00 hours (**TEAM***))

- operating departures on the designated arrivals runway – a dual departure runway operation (so-called tactically enhanced departures measures (**TED**)).

The first phase of the trial also included a number of **proactive tests** involving:

- landing Airbus A380 flights on the runway closest to their destination stand

- landing small aircraft on the designated departure runway

- use of the southern runway for Terminal 4 (T4) arrivals and departures.

These proactive tests were restricted to two four week periods during the first phase of the trial. These were between 28 November 2011 and 25 December 2011 inclusive, and between 16 January 2012 and 12 February 2012 inclusive.

Phase 2 of the trial also tested three sets of Operational Freedoms, refined from those applied in Phase 1 based on the experience gained. The first two were reactive measures activated in response to the same trigger conditions as applied during Phase 1, being met. These were:

- operating arrivals on the designated departures runway, or **TEAM*** after 07:00 hours local time. This freedom was applied from 1 July 2012 to 31 December 2012 inclusive

- early vectoring of departing aircraft from set departure routes (Noise Preferential Routes NPRs) termed **Operational Freedom (OF) vectors**. This freedom was applied from 1 July 2012 to 31 January 2013 inclusive. Note that the freedom to allow early vectoring in dual departures mode was not tested during the Trial (see www.heathrowairport.com/noise/noise-in-your-area/operational-freedoms-trial/phase-2 for further information).

In addition, there were three types of proactive test concerning arrivals[1] each of one month in length:

- moving A380 landing aircraft out of the arrival stream to land on the departures runway **and/or** moving the aircraft in front of or behind the A380 out of the arrival stream to land on the departures runway

[1] Given the potential overlap of the three types of proactive Operational Freedoms, it is not possible to differentiate between them and they are, therefore, analysed collectively as proactive tests

- moving light/small wake vortex category aircraft out of the arrival stream and landing them on the departure runway.
- landing Terminal 4 (T4) traffic on the southern runway when the designated landing runway is the northern runway.

The first Phase 2 proactive test ran between 16 July and 15 August 2012. The second ran from 1 October to 31 October 2012. The third ran from 1 February and ended on 28 February 2013. February 2013 was used solely for proactive tests.

A fourth planned freedom, to land inbound aircraft without holding between 05:30 - 06:00 hours in return for a reduction in the number of flights between 04:30-05:00 hours, was not enacted. Detailed work and discussions with the industry found that it was not possible to implement this measure during the trial due to operational factors.

The schedule used for testing each of the Phase 2 Operational Freedoms is summarised in the following figure.

Operational Freedom	Month								
	J	J	A	S	O	N	D	J	F
Arrivals on the designated departure runway (TEAM*)		■	■	■	■	■	■		
Proactive tests		■			■				■
Redirect departures in segregated mode (OF vectors)		■	■	■	■	■	■	■	

Figure 1: Schedule for testing Operational Freedoms during Phase 2 of the trial

A full explanation of these Operational Freedoms is provided by the explanatory document that can be found at:

www.heathrowairport.com/static/Heathrow_Noise/Downloads/PDF/LHR_noise-Operational_Freedoms_trial-Phase_2-explanatory_document.pdf.

1.2.2 Safeguards and triggers

A number of safeguards were agreed by the Department for Transport (DfT) and the Civil Aviation Authority) CAA to ensure that the trial was bounded. These were as follows:

- There was to be no increase in the annual number of flights at Heathrow, which will remain capped at 480000
- There was to be no increase in the hourly scheduled capacity of the Airport
- There was to be no “mixed mode” operation i.e. the scheduled use of both runways for arrivals and departures at the same time.

Reactive measures could only be deployed when specific trigger conditions were met as follows:

- an anticipated arrival or departure delay of ten minutes or more
- a headwind on approach to Heathrow forecast to be greater than 20 knots at 3000 feet
- an arrival or departure flight schedule anticipated to run later than 30 minutes or 30% of flights are running outside of the 15 minute punctuality target

- following a period of disruption to facilitate recovery.

For more detailed descriptions of safeguards applying to individual freedoms see http://www.heathrowairport.com/noise/noise-in-your-area/operational-freedoms-trial/phase-2.

It is important to note that the Operational Freedoms trial only applied to operations between 0700 hours local time and the last scheduled departure.

1.2.3 Reporting

As part of the overall trial programme, Heathrow produced factual monthly reports summarising the data gathered and highlighting the key performance parameters for the Airport (the monthly reports for July 2012 to February 2013 are annexed to this report). These monthly reports were augmented by two additional progress reports:

- the Phase 1 report describing the trial during the months November 2011 to February 2012 inclusive
- the end-of-season report for summer 2012 describing the trial during the months July to October 2012 inclusive.

This report is the final end-of-trial report aggregating the data and outcomes of Phases 1 and 2 of the trial, albeit weighted more heavily to Phase 2 as this was built on lessons learnt from Phase 1. It is the objective that this report informs the Operational Freedoms strategic framework originally proposed by the South East Airports Taskforce. This report makes quantitative assessments of the outcomes of the use of the Operational Freedoms and draws conclusions concerning the impacts of the trial.

1.2.4 Implementation of the trial

Heathrow airport is a complex system affected by multiple factors, often outside the control of the Airport operators and stakeholders. As such, in designing and implementing the Operational Freedoms trial, it was not possible to isolate external factors not under the scope of the trial and evaluate the effects of a freedom or a group of freedoms on an event to event basis. As a result, the trial saw during Phase 2, as with Phase 1, the application of Operational Freedoms, both in terms of the reactive and proactive tests, on an as needed basis following the demands of the operations on the day, rather than following a schedule of tests which may or may not have been possible to implement on the day.

1.2.5 Addressing CAA recommendations from Phase 1

At the end of Phase 1 of the trial, the CAA made a series of recommendations for Phase 2. These recommendations are summarised in the table below along with a description of the actions taken to address them.

	Recommendation	Action
1	That the technical discussions on the impact of the trial continue to be facilitated through Heathrow's existing Noise and Track-Keeping Working Group and that there is greater involvement of local authority experts in the detail of the data collection and analysis at an earlier stage for Phase 2. This should help to reduce the number of queries from various parties around different data sources and conflicting information, which it has taken considerable effort and time to resolve.	The Noise and Track-Keeping Working Group (NTKWG) was closely involved throughout Phase 2 of the trial providing review and feedback on all aspects of the trial, in particular relating to data presentation and the format and contents of reporting on the trial. The number of queries on data fell considerably compared to Phase 1.

	Recommendation	Action
2	CAA agrees with Heathrow that a different approach to awareness-raising should be adopted ahead of and during Phase 2. In particular, more effort should be given to informing local communities affected by the trial through appropriate local .media (for example, radio, local newspapers).	An extensive awareness campaign was adopted prior to Phase 2 and community engagement activities was undertaken throughout Phase 2. See Section 7.
3	Fewer issues with data accuracy are expected in Phase 2, but we believe it would be of help to those with an interest in the operation of the trial if Heathrow can correct or at least notify users of inaccuracies in published information as soon as possible throughout the period of Phase 2.	A data steering group was established to oversee data collection and integrity, including the main stakeholders. Data issues were raised through this steering group and were also reported to the NTKWG. There were far fewer data accuracy issues in Phase 2 than in Phase 1.
4	We would suggest that Heathrow seeks to establish a way of capturing how often the trigger conditions are being met but the freedoms are not being used. This would be useful information to add to that collected in Phase 2 of the trial.	Trigger conditions, when they were used and when they were not used even if available were captured and reported in monthly reports. These are summarized in this report
5	We agree with the view expressed by Cambridge University IfM ECS Unit that Heathrow should engage with them and the CAA to establish a more robust experimental design for Phase 2 ahead of commencement. V2.0 May 2012 20	The CAA and Cambridge University IfM ECS Unit were actively involved in the Phase 2 trial design
6	Given that operating conditions during Phase 2 of the trial are likely to be heavily affected by the Olympics and in light of the difficulties faced during Phase 1 in terms of drawing robust conclusions from the data generated, we recommend that the duration of Phase 2 be extended to encompass the 2012/13 winter scheduling season.	Phase 2 of the trial ran to end of February 2013.
7	We would recommend that more detailed regression analysis is undertaken on the Phase 1 data as well as the future Phase 2 results so as to provide a better foundation for any future decisions on the application of the Operational Freedoms tested.	Phase 2 data was analysed using a detailed regression analysis (see this report). It was not, however, possible, to re-analyse the Phase 1 data using the same techniques because data were not captured with sufficient granularity in Phase 1 to apply the techniques developed for and during Phase 2, specifically trigger data, flight-by-flight cataloguing of aircraft to which Operational Freedoms were applied and weather data.
8	That Heathrow gives consideration to whether Phase 2 of the trial would benefit from further work to understand the value placed on respite by residents.	The work on value of respite is described in section 6 of this report.
9	As the findings from the analysis undertaken so far leave unanswered the question of how many of the complaints generated relate specifically to direct experience of nuisance generated by flights utilising Operational Freedoms, we recommend that further analysis of complaints data, from both Phase 1 and 2 of the trial, should be undertaken to clarify the nature of the relationship.	More comprehensive analysis of complaints data was undertaken. This is described in Section 6 of this report.
10	The report on Phase 2 of the trial should include greater consideration of the resource impact on the Airport, NATS and airlines.	The resource implications of the trial itself as it was executed were minimal.

Table 1: Summary of CAA recommendations and responses

1.3 Traffic volume

Figure 2 and Figure 3 show the daily volume of arrival traffic during the winter and summer trial periods respectively. The figures illustrate when specific disruptive events where large numbers of cancellations occurred (e.g. late May and early June 2010, corresponding to a strike at British

Airways) and December 2010 when there were major snow events but also show that the general profile and level of the traffic is broadly similar in the trial period to the other periods.

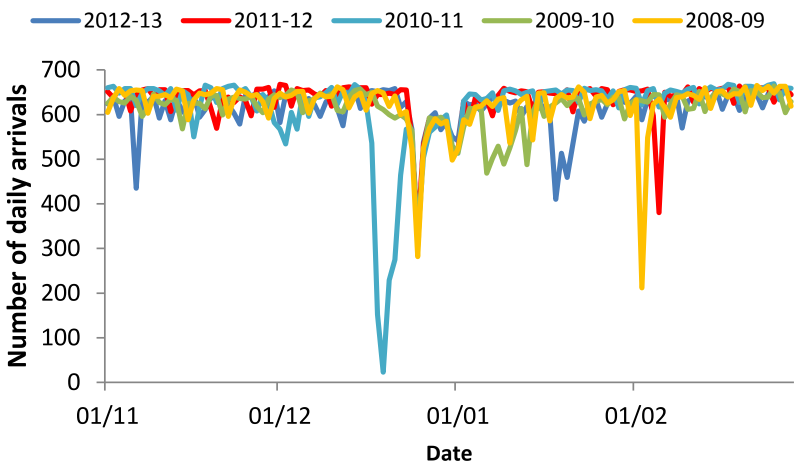


Figure 2: Arrival traffic profile during the winter trial periods

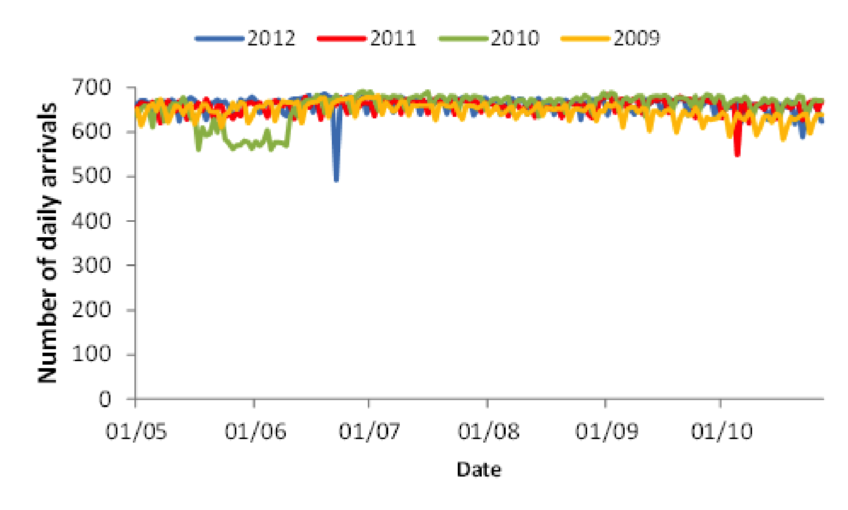


Figure 3: Arrival traffic profile during the summer trial period

Table 2 and Table 3 show the average daily arrival and departure volumes for the winter and summer trial period and associated baseline periods respectively. The tables indicate that:

- traffic during the Phase 1 period was higher than the corresponding traffic levels during the previous three winter periods
- traffic during the winter part of Phase 2 of the trial had fallen back to 2009-10 and 2010-11 levels and was considerably lower than 2008-09 and Phase 1 of the trial
- traffic during the summer part of Phase 2 of the trial was similar to the immediately preceding period of the summer of 2012 as well as summer 2011. It was considerably higher than traffic during 2009 but lower than traffic during 2010.

	2008-09 (Nov-Feb)	2009-10 (Nov-Feb)	2010-11 (Nov-Feb)	2011-12 (Nov-Feb)	2012-13 (Nov-Feb)
Average daily arrivals	621	613	615	**634**	**614**
Average daily departures	622	614	615	**634**	**613**

Table 2: Average daily traffic volumes during the winter trial and associated baseline periods

	2009 (May-Oct)	2010 (excluding strike days)	2011 (May-Oct)	2012 (May-Oct)	2012 (trial period)
Average daily arrivals	652	666	659	663	**661**
Average daily departures	652	666	659	663	**661**

Table 3: Average daily traffic volumes during the summer trial and associated baseline periods

1.4 East/west split

Figure 4, Figure 5 and Figure 6 show the daily east/west split of traffic, derived from arrivals, for the three trial periods. The figures illustrate the tendency for bunching of days of easterly operations.

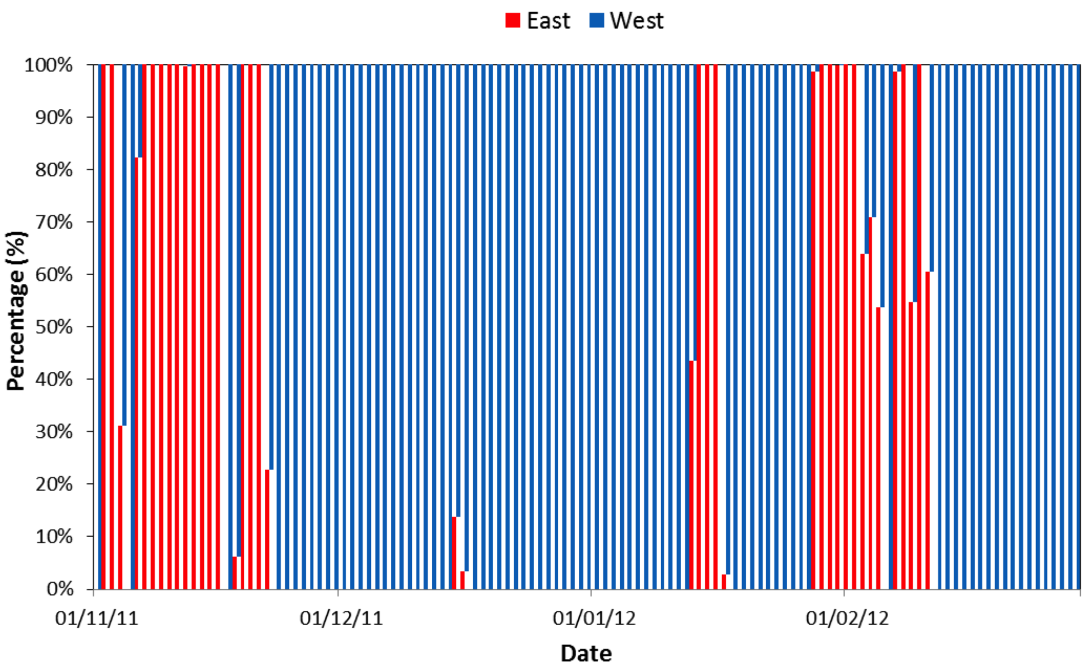


Figure 4: East-west traffic split for Phase 1 of the trial

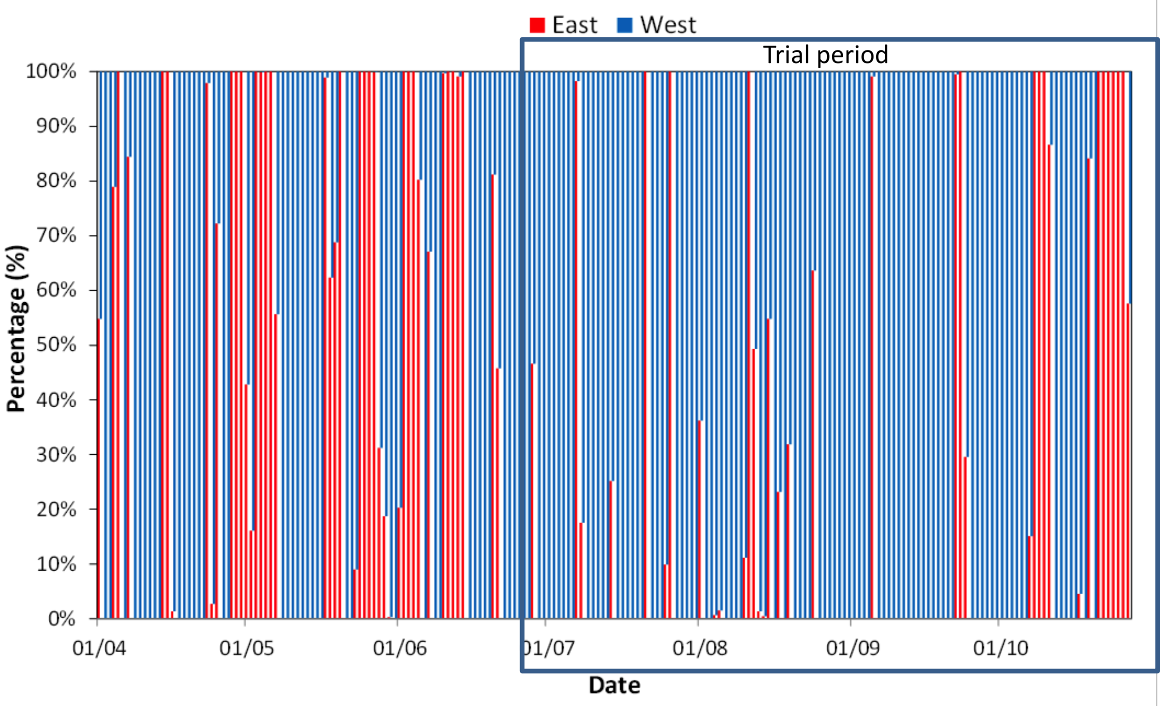


Figure 5: East-west traffic split for the summer 2012 PART OF Phase 2 of the trial

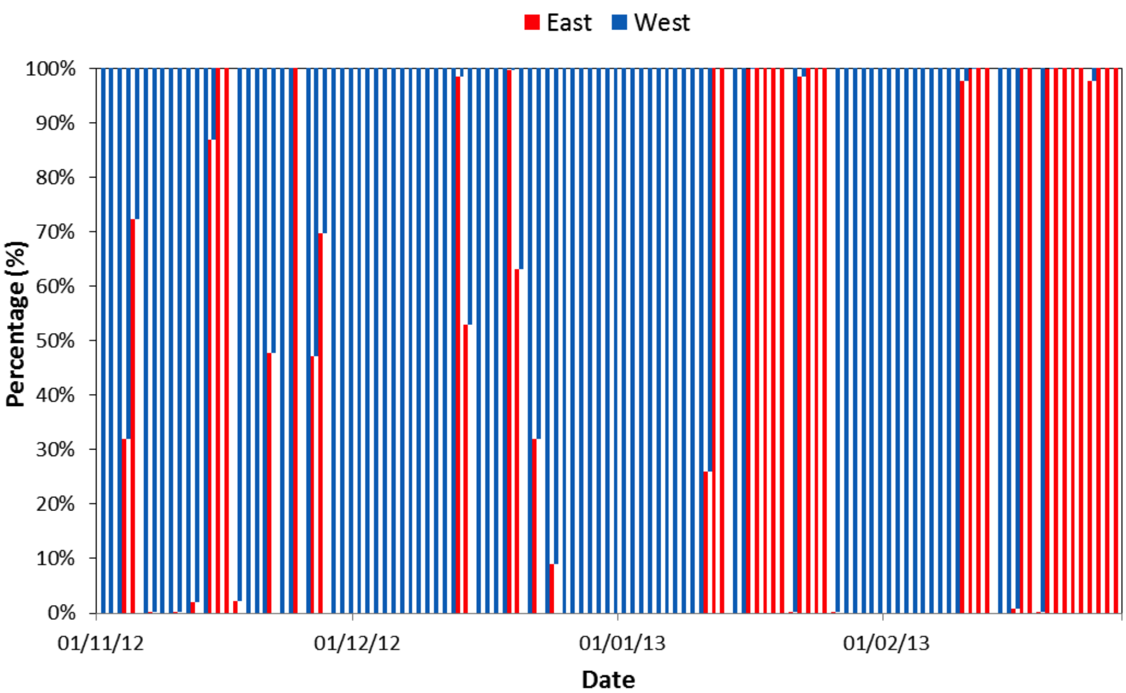


Figure 6: East-west traffic split for the winter part of Phase 2 of the trial

The overall proportion of easterly operations by movement for each of the trial and baseline periods was as follows:

Period	Description	Proportion of easterly operations by movement
1 November 2011 to 29 February 2012	**Phase 1 trial period**	**27%**
1 November 2012 to 28 February 2013	**Phase 2 winter trial period**	**30%**
1 November 2008 to 28 February 2009	Winter baseline period	28%
1 November 2009 to 28 February 2010	Winter baseline period	27%
1 November 2010 to 28 February 2011	Winter baseline period	33%

Period	Description	Proportion of easterly operations by movement
1 April to 27 October 2012	Whole summer season	27%
1 April to 30 June 2012	Pre-trial period	38%
1 July to 27 October 2012	**Phase 2 summer trial period**	**18%**
Summer 2009	Whole summer season	28%
Summer 2010	Whole summer season	27%
Summer 2011	Whole summer season	22%

Table 4: East/west traffic split for the trial and baseline periods

Comparing the direction of operations with the accepted long-term average east:west ratio of 25:75, suggests that:

- the Phase 1 trial period as well as the 2008-09 and 2009-10 winter baseline periods and summer 2009 and summer 2010 were fairly typical
- although summer 2012 was, on average, near to the normal ratio of easterly operations, the trial period itself was heavily dominated westerly operations, similar to summer 2011
- the Phase 2 winter season was slightly more biased towards easterly operations than the norm as was the winter 2010-11 baseline period.

1.5 Major events occurring during the trial

1.5.1 Events

There were two major events that affected the Airport during summer 2012:

- the London 2012 Olympics during the second half of the month, with high volumes of traffic, restructured airspace and restrictions on ad hoc slots at the Airport
- the Farnborough Airshow, which took place during the week commencing 9 July and meant that airspace restrictions were in place on 14 and 15 July.

The Airport was also affected by a number of weather and other events during the trial periods. These are summarised in the monthly reports, annexed to this report as annexes A to H for the months from July 2012 to February 2013 inclusive.

1.5.2 Other operational factors

There were other operational factors overlapping with Phase 2 of the Operational Freedoms trial as follows:

- the Airport has deployed its collaborative decision making (CDM) system. This was fully operational in control mode for the first part of July 2012 and has been operational in monitoring mode ever since. This has been taken into account through use of a dummy variable in the regression analysis (see section 2 for a description of the techniques used to analyse the impacts of the trial) reflecting the time periods when the different modes of CDM were deployed

- NATS ran an arrivals smoothing trial using the flow regulation process to restrict aircraft inbound to Heathrow to their scheduled 15 minute departure windows at the outstation airport starting on 5 November and running until 30 November. This was implemented by applying a flow regulation at 52 arrivals per hour between 09:00 and 12:00 hours. This did not affect delays but had the objective of smoothing inbound traffic

- there was a change of policy on the application of TEAM and TEAM* in late-October 2012: since then neither TEAM nor TEAM* has been applied if there is any departure delay. Prior to this, air traffic controllers could take a judgement on whether to apply TEAM or TEAM* with due regard to the impact on departure delay

- an additional trial was undertaken at Heathrow, from 5 November 2012 to 31 March 2013, to reduce the noise impact for specific regions during the night period. ‘Inner’ and ‘Outer’ areas were defined either side of the centreline for each runway end with the aspiration that aircraft would not be flown through these regions. The use of the inner and outer areas was alternated on a weekly basis to further amend the noise profile for arrival aircraft. These areas were active from 23:30 hours until 06:00 hours and did not, therefore, affect the Operational Freedoms trial.

1.6 Extent of the use of Operational Freedoms

This section summarizes the degree to which Operational Freedoms were applied during the trial period for arrivals and departures separately.

1.6.1 Arrivals

Figure 7, Figure 8 and Figure 9 show on a daily basis the extent of the application of TEAM* and proactive tests for arrivals during the three parts of the trial. The figures indicate the periods where proactive tests were applied. In contrast to Phase 1, for Phase 2 of the trial TEAM* and proactive tests are applied according to the same rules on westerly and easterly operations, so no distinction has been drawn between the two for the Phase 2 charts.

In summary, arrivals freedoms were applied as follows:

- in Phase 1 of the trial there were 2516 TEAM* landers (split 1639 westerly and 877 easterly) along with 158 proactive tests. These figures represent 2.3% and 0.4% of the arrivals traffic for TEAM* and proactive tests over the periods that the measures were active

- in the summer part of Phase 2 of the trial, there were 2296 TEAM* landers and 385 proactive tests, representing 2.9% and 0.9% of the arrivals traffic during the periods that the measures were active

- in the winter part of Phase 2 of the trial, there were 591 TEAM* landers and 465 proactive tests, representing 1.7% and 2.9% of arrivals traffic over the periods when the measures were active.

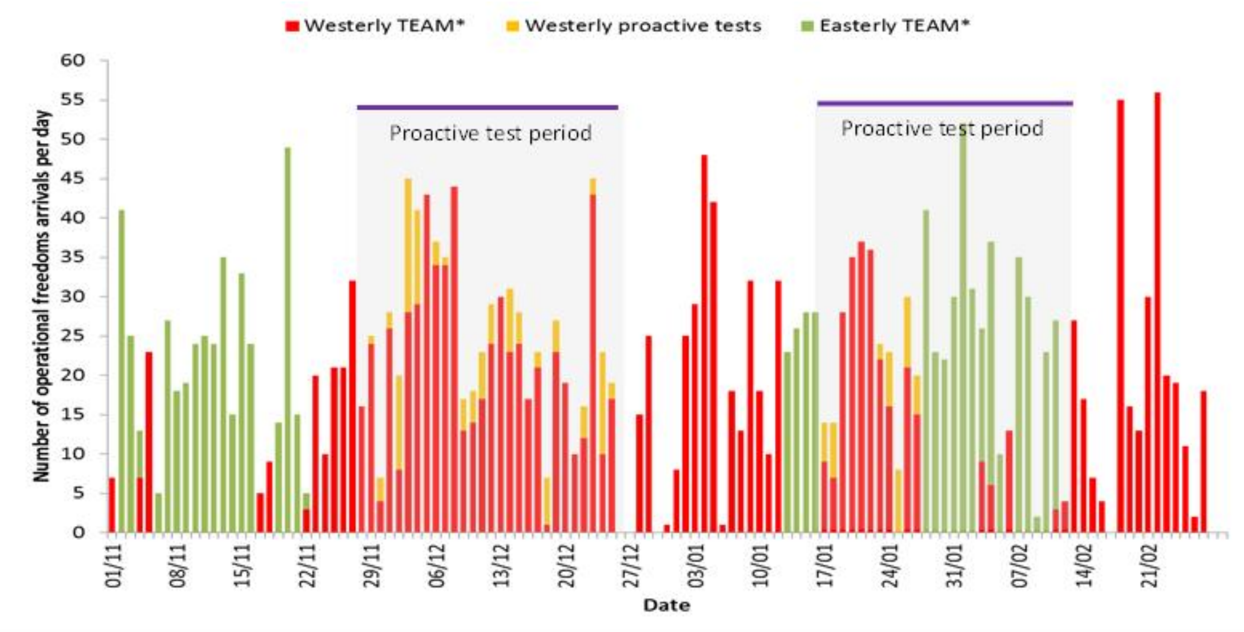


Figure 7: Application of arrivals freedoms during Phase 1 of the trial

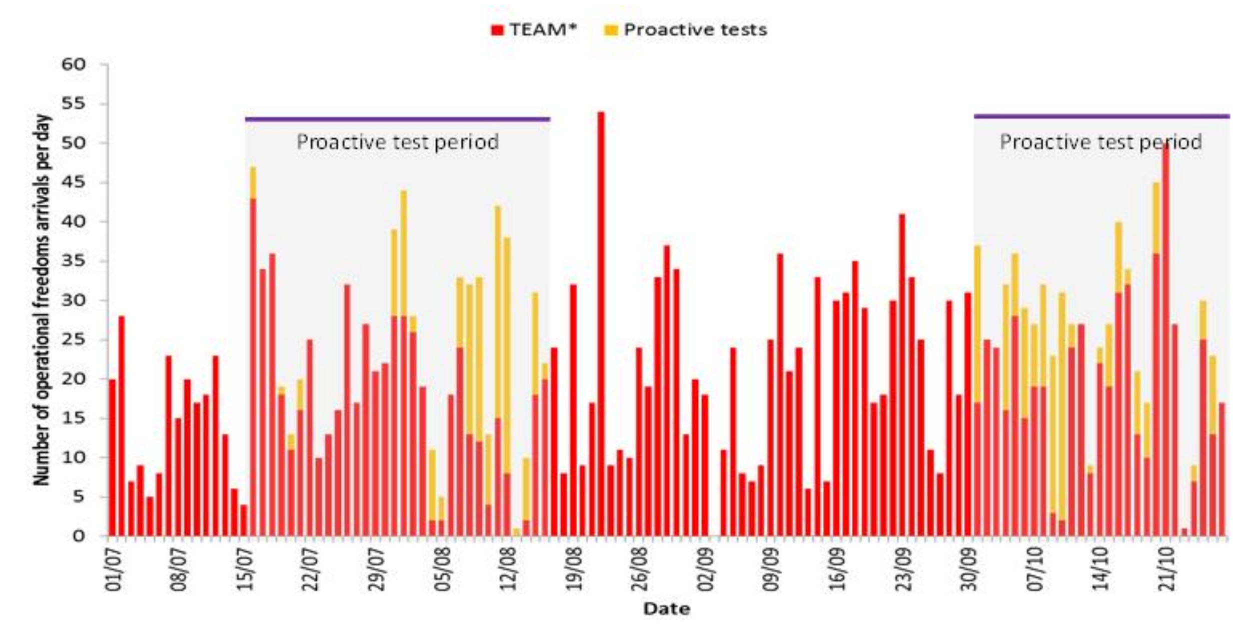


Figure 8: Application of arrivals freedoms during the summer part of Phase 2 of the trial

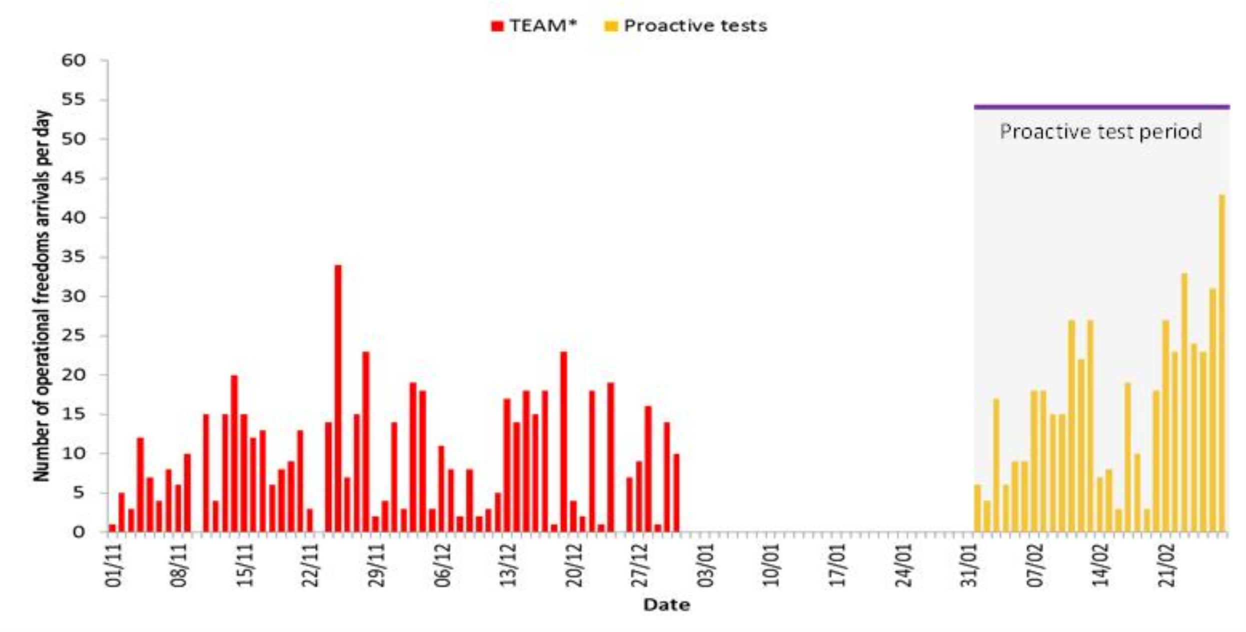


Figure 9: Application of arrivals freedoms during the winter part of Phase 2 of the trial

1.6.2 Departures

Figure 10, Figure 11 and Figure 12 show the application of departure freedoms during the three parts of the trial, TEDs during Phase 1 and OF vectors during Phase 2.

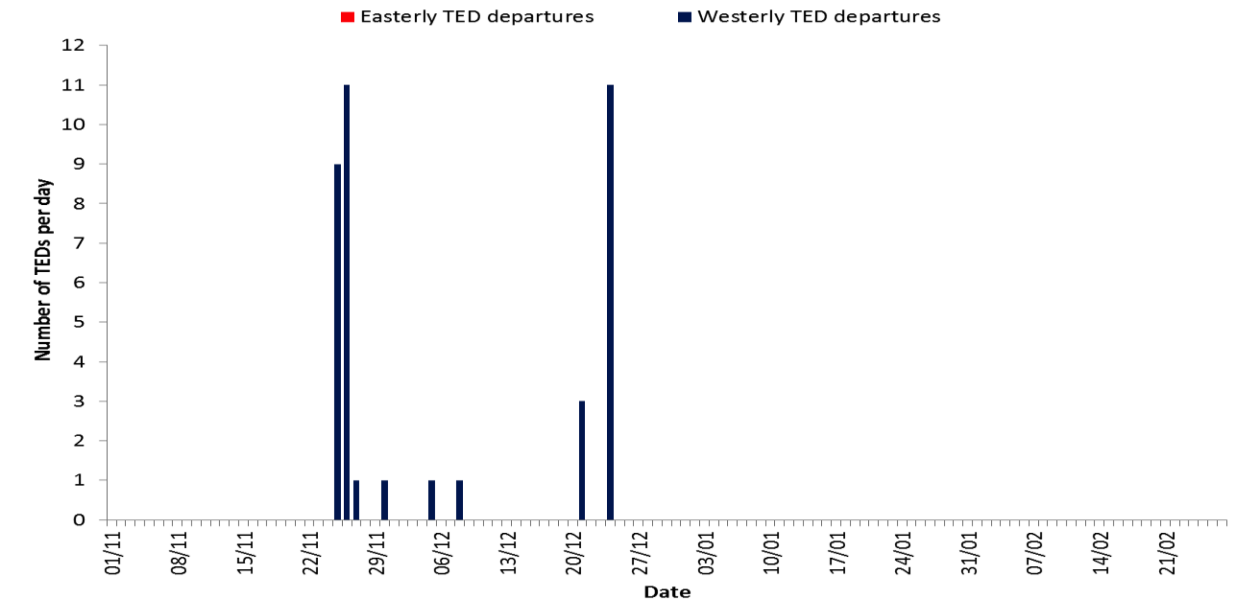


Figure 10: Application of TEDs during Phase 1 of the trial

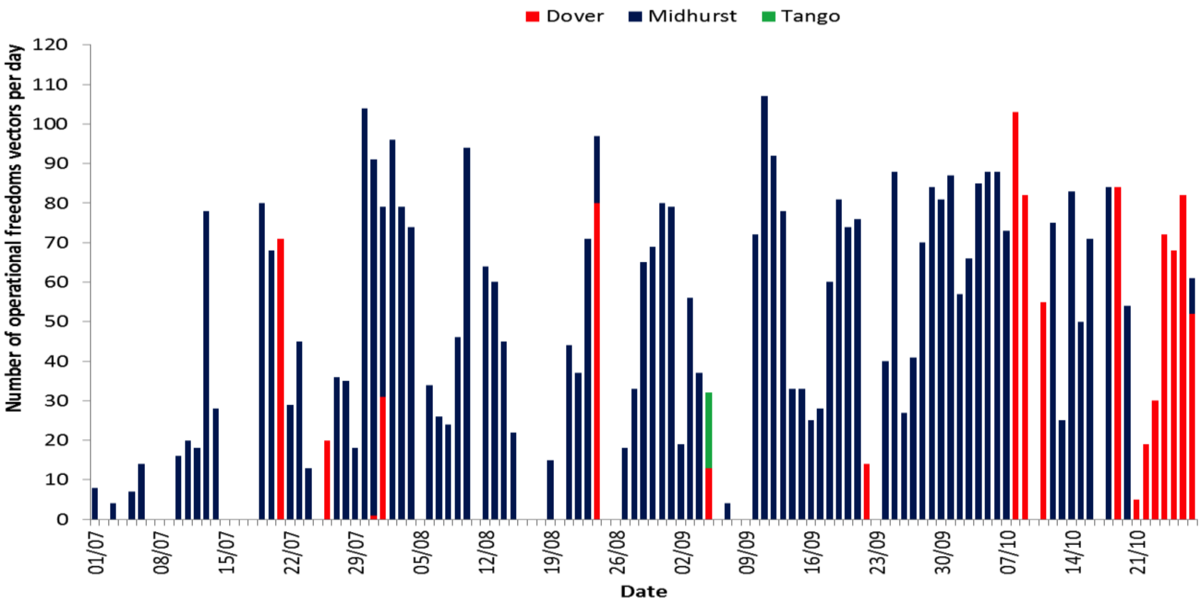


Figure 11: Application of OF vectors during the summer part of Phase 2 of the trial

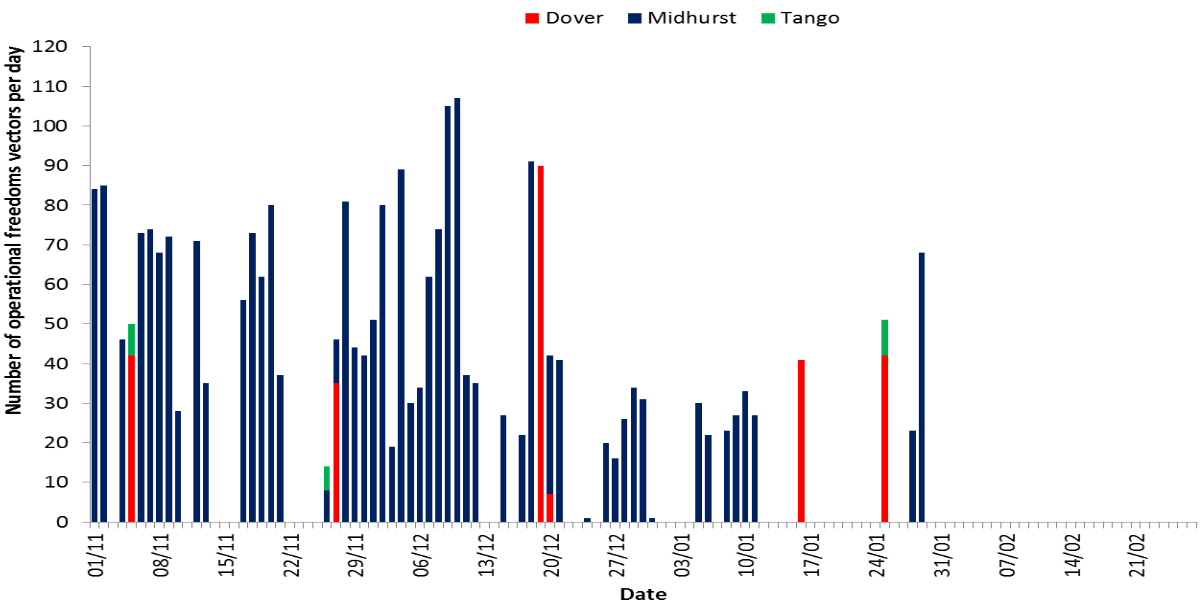


Figure 12: Application of OF vectors during the winter part of Phase 2 of the trial

In summary, the extent of application of departure freedoms was as follows:

- in Phase 1, there were 38 TEDs applied, all on westerly operations. This was insufficient to have any measurable impact
- in the summer part of Phase 2 of the trial, there were 5144 OF vectors applied representing approximately 6.5% of the total departures, split as follows:

- 884 OF vectors applied on the Dover (DVR) SID, out of a total of 3180 departures (28%) on that SID
- 19 OF vectors applied on the TANGO[2] SID
- 4250 OF vectors applied on the Midhurst (MID) SID, out of a total of 10974 departures (39%) on that SID.

• in the winter part of Phase 2 of the trial, there were 2731 OF vectors representing 4.9% of the total departure traffic split between:

- DVR with 257 OF vectors representing 8.7% of the traffic using that SID,
- TANGO with 23 OF vectors
- and MID with 2451 vectors representing 32.5% of the traffic using that SID.

1.6.3 Triggers

Figure 13 and Figure 14 show the hours per day that the arrivals triggers for TEAM* were available between 07:00 and 23:30 hours local time during the summer and winter parts of Phase 2 of the trial (detailed trigger information was not available during Phase 1). The triggers are classified as 10 minutes delay or 20 knot headwind at 3000 feet (where both apply simultaneously the 10 minute delay trigger takes precedence). None of the other triggers were recorded during the trial period.

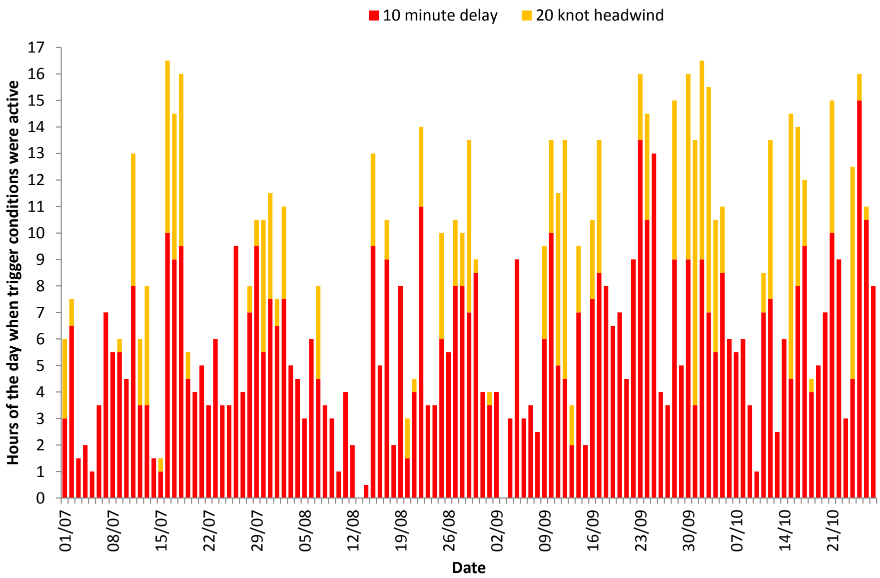


Figure 13: Availability of TEAM* triggers during the summer part of Phase 2 of the trial

2 The Southampton (SAM) SID on Easterly flies a 'loop' around the MID SID before coming back westbound. As a result of this, MID departures following SAM departure require an extra minute separation (a total of three minutes). However, for use during the Farnborough Air show, TANGO SIDs had previously been produced, that require the SAM departures to follow the same track as a MID initially.. SAM Easterly departures were to be issued with a TANGO SID so that the extra separation (above) was not required

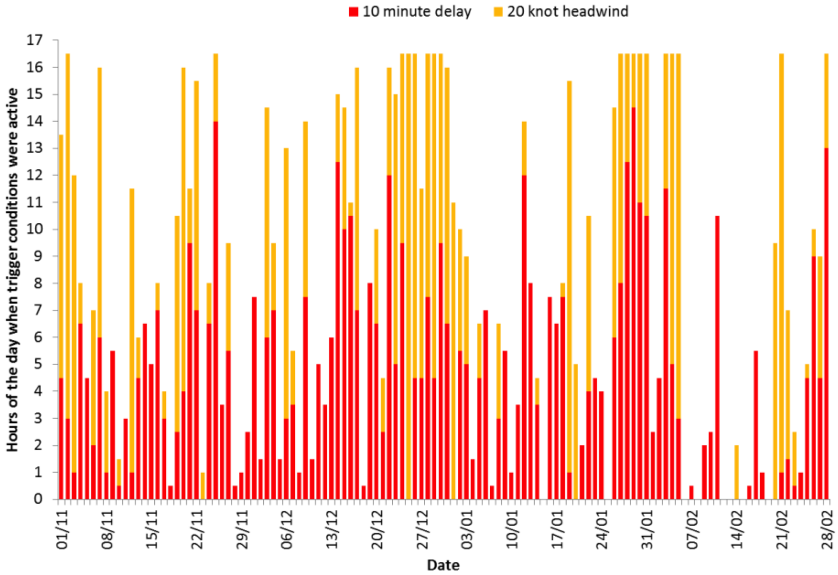


Figure 14: Availability of TEAM* triggers during the winter part of Phase 2 of the trial

The figures show that there were only a very small number of days when triggers were not available. In terms of the overall time during the operational day, arrivals triggers were available approximately 45% of the time during the summer part of Phase 2 of the trial and approximately 53% of the time during the first two months of the winter part of Phase 2 of the trial, when they were active.

Figure 15 and Figure 16 show the daily arrival trigger utilisation over the two parts of Phase 2 of the trial. This utilisation is defined as the number of hours that the triggers were used per day divided by the number of hours that they were available.

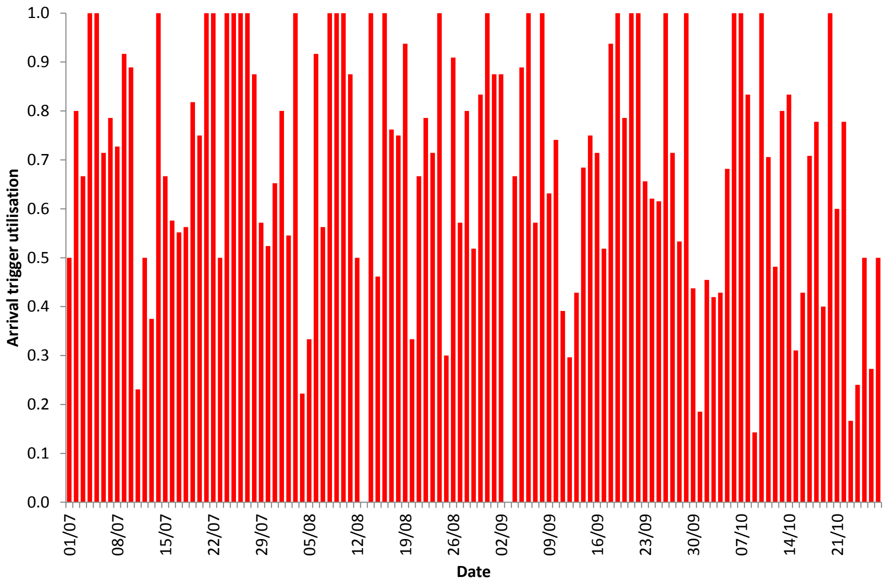


Figure 15: Arrival trigger utilisation during the summer part of Phase 2 of the trial

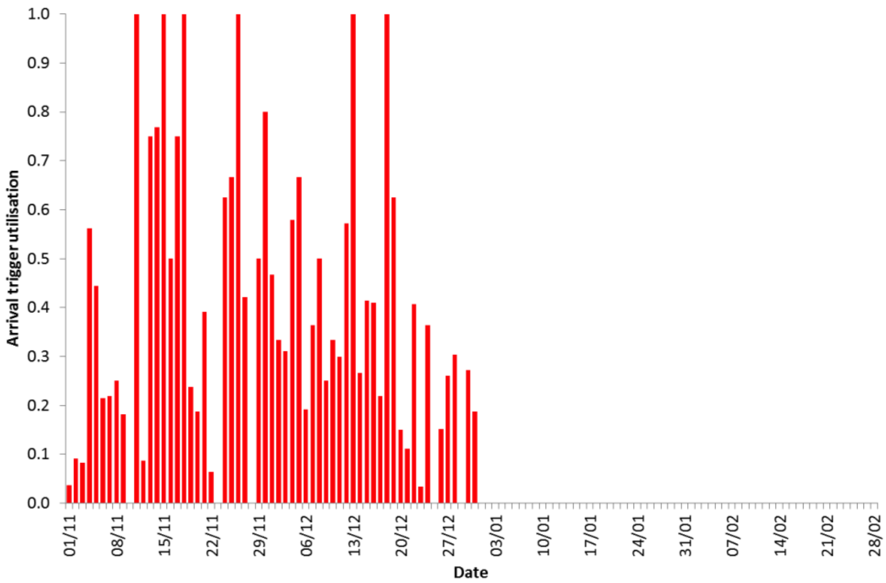


Figure 16: Arrival trigger utilisation during the winter part of Phase 2 of the trial

Comparison of the two figures suggests a lower trigger utilisation during the winter (31%) than during the summer (63%) as would be expected from the additional restriction placed on the use of TEAM* at the end of the summer season.

The principal reasons for non-use of arrivals triggers were:

- single runway operations
- build-up of departure delays, i.e. arrivals being put onto the departure runway causing a build-up of departure delays. This is then stopped by not using the arrival freedom (this was changed to the existence of any departure delay in late October 2012)
- predicted falling arrival demand
- predicted decreasing arrival delay.

Similarly, Figure 17 and Figure 18 shows the hours per day that the departure triggers for OF vectors were available between 07:00 and 23:30 hours local time during Phase 2 of the trial. Again, the triggers are classified as 10 minutes delay or 20 knot headwind at 3000 feet (where both apply simultaneously the 10 minute delay trigger takes precedence). None of the other triggers were recorded during the trial period.

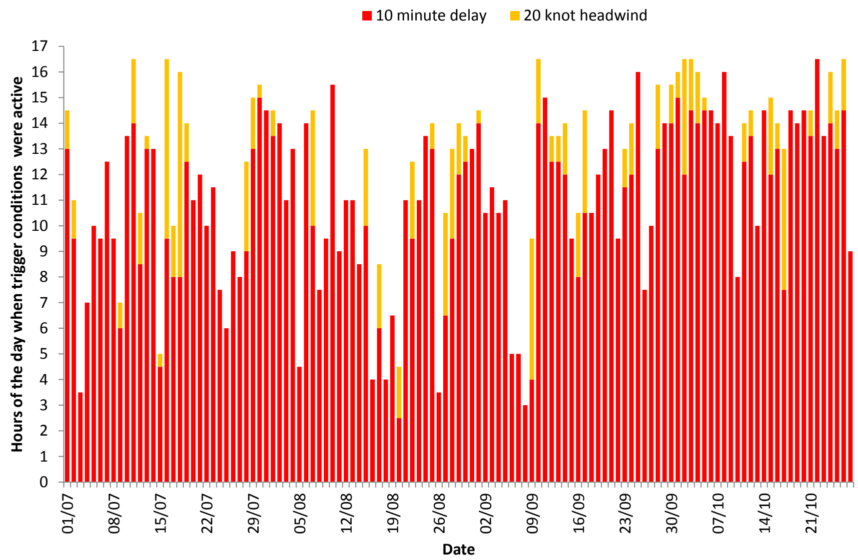


Figure 17: Availability of departure triggers during the summer part of Phase 2 of the trial

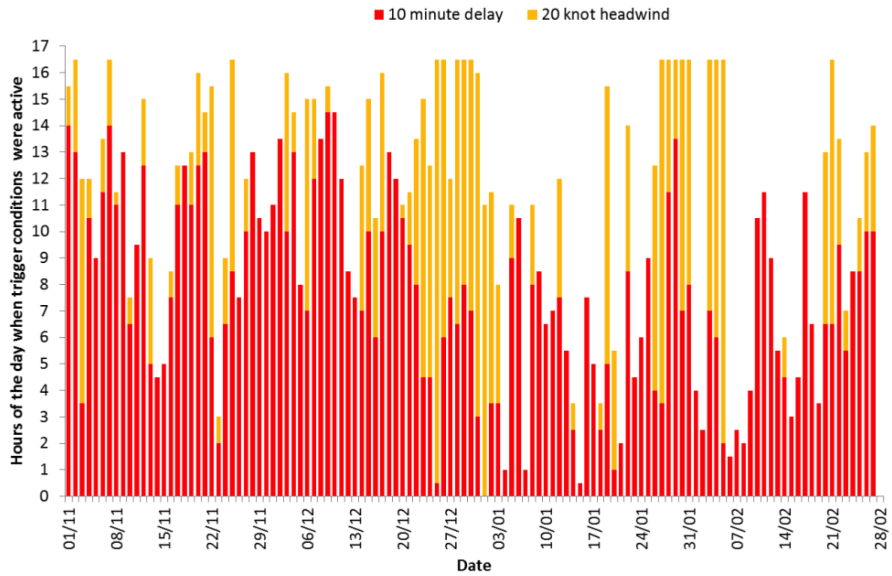


Figure 18: Availability of departure triggers during the winter part of Phase 2 of the trial

Comparison of arrival and departure trigger availability illustrates that departures triggers were more widely available during the trial period than arrivals triggers. During the summer part of Phase 2 of the trial, departure triggers were available approximately 69% of the time and during the winter part of Phase 2 of the trial, departure triggers were available approximately 67% of the time during the three months that they were active.

Figure 19 and Figure 20 show the departure trigger utilisation during the summer and winter parts of Phase 2 of the trial.

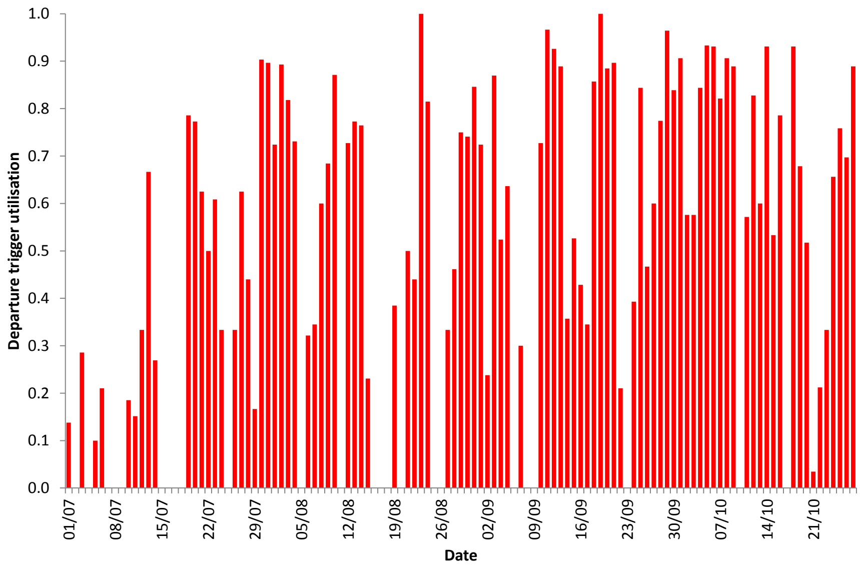


Figure 19: Departure trigger utilisation during the summer part of Phase 2 of the trial

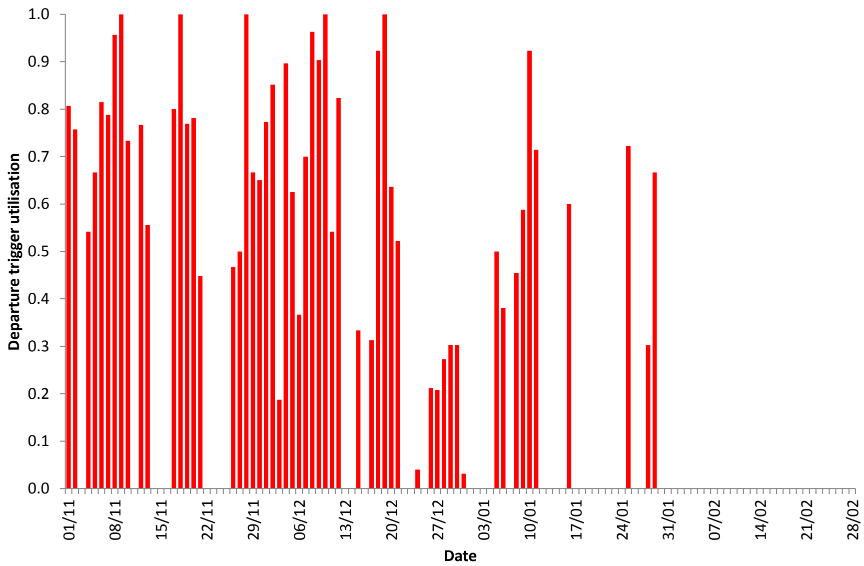


Figure 20: Departure trigger utilisation during the winter part of Phase 2 of the trial

The reasons for not applying the departures triggers were:

- predicted decreasing delay
- lack of availability of suitable aircraft (early vectoring is not applied to 4-engine aircraft)
- operations under visual separation
- unfavourable weather conditions.

1.7 Applying Operational Freedoms from the air traffic controllers perspective

1.7.1 Introduction

Air Traffic Control services at London Heathrow, as required under CAA aerodrome licencing regulations, are provided under contract by NATS Services Ltd. (NSL).

Air Traffic Control Officers (ATCOs) are based within the Air Traffic Control Tower at the Airport and via a shift based system they provide 24x7 air traffic services to aircraft arriving at and departing from Heathrow.

Heathrow's tower based ATCOs communicate directly with both flight deck aircrew and with other ATCOs based in the NATS London Terminal Control Centre at Swanwick in Hampshire, in order to effectively and safely sequence both arriving and departing aircraft in the airspace around and at Heathrow.

In order to ensure that a complete view of the operational benefits, impacts and issues observed during the trial can be considered, Heathrow Airport Ltd., asked the NATS Team at Heathrow to provide their perspectives as the primary user of the Operational Freedoms themselves.

1.7.2 Safety Observations

The Operational Freedoms Trials resulted in no safety events, although one aspect of the trials, relating to the early vectoring (or re-routing) of aircraft using the TANGO Standard Instrument Departure (SID), was the subject of a temporary suspension. This action was taken due to concerns that had been raised regarding the risk of pilot confusion due to the way in which the clearance (or "permission") to deviate from the standard routing was given. Once a revised procedure had been agreed use of this Operational Freedom was re-instated. No further concerns were raised.

1.7.3 Operational Freedom: TEAM*

The use of TEAM*, or the landing of arriving aircraft on the designated departures runway with additional triggers and an increased number of aircraft when compared to the pre-existing Tactically Enhanced Arrivals Mode (TEAM), required no change to the normal method of operation utilised by ATCOs.

The expanded triggers (as described in earlier sections of this report) allowed TEAM* to be implemented by the ATCOs at the start of the build-up of delay, rather than having to wait for significant delays to be observed.

However, there was a detrimental effect observed on the departure rate that naturally resulted from the use of TEAM*. This effect necessarily limited the use of this freedom at Heathrow where the operational demand driven by departing flights is significant throughout each day

In summary, the NATS ATCOs found TEAM* useful as the expanded triggers supported effective and increased flexibility when compared to pre-existing TEAM availability. However, the impact on departures needed careful management when using TEAM* as increasing numbers of aircraft arriving on the designated departure runway effectively meant that increasing numbers of departure movements on that runway were lost.

1.7.4 Operational Freedom: Proactive Tests

When using TEAM or TEAM* ATCOs selected the specific aircraft to be de-alternated (i.e. swapped from the currently designated arrivals runway to land on the currently designated departures runway) based upon the greatest effect on delay. However, if similar aircraft types were available they would select based upon that which would result in the greatest benefits once on the ground, e.g. landing traffic destined for a stand on Terminal 4 on the southern runway in order to reduce taxi-in times and/or runway crossings.

It was felt that use of this freedom also had a safety benefit as it reduced runway crossings.

1.7.5 Operational Freedom: Early Vectoring

For flight safety reasons all departing aircraft must to be separated by defined but differing time periods depending on the routes that they are flying. Early vectoring under Operational Freedoms allowed ATCOs to amend the outbound routing of aircraft to deviate from their planned departure route earlier thus allowing reduced time based separation between aircraft. This reduced separation could not be safely achieved if the two aircraft remained on their pre-planned, and therefore similar, departure routings (see diagram below).

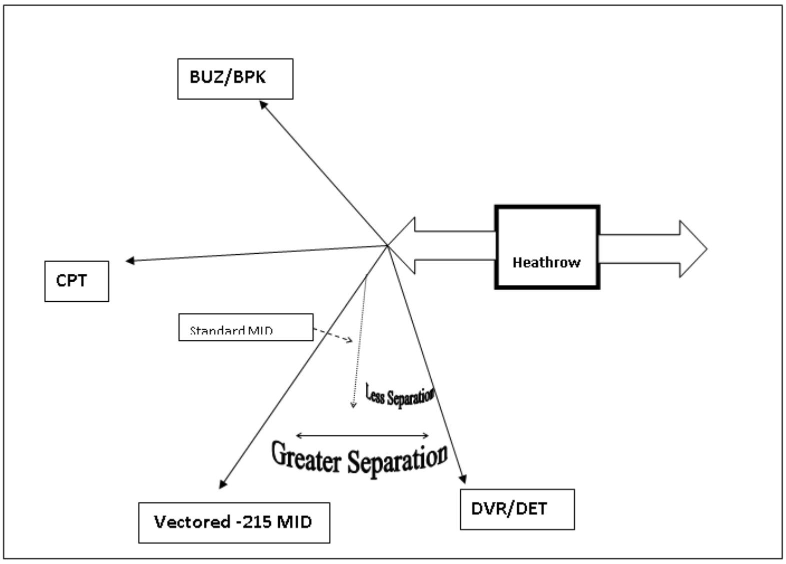


Figure 21: Illustration of departure separations achieved by early vectoring

Operational benefits were seen by ATCOs during the trial as Early Vectoring provided mitigation against delays caused by a sub-optimal mix of aircraft types. For example, at some points in the operational day excessive demand on defined departure routes, such as Dover (DVR) and Midhurst (MID), resulted in congestion and subsequent delays. Under this Operational Freedom the Midhurst MID 215 degree early vector allowed reduced separation between these two routes with an associated reduction in congestion and delay.

The method of vectoring employed during the trial required that amended clearances be given by the departures ATCO; i.e. when the aircraft was on the runway it was instructed to fly a different route. It was found that this would not be an acceptable method in the long term as it added workload to an already heavily loaded ATCO. An alternative method of issuing such amended clearances would need to be found to ensure that this freedom could be safely managed routinely in the future. It was also felt that the removal of the four engine aircraft type restriction from the MID 215 early vector routing would be beneficial in reducing controller workload.

2 Operational data and analysis

2.1 Introduction

This section outlines the objectives of the analysis of the data collected during both Phases of the trial and describes the processes used to analyse the data, specifically in terms of isolating and understanding the impacts of the trial – both reactive and proactive tests – using of a range of key performance indicators (KPIs), related to the strategic objectives of the Airport.

2.2 Objectives of the data analysis

The principal objective of the data analysis was to assess the degree to which the application of the Operational Freedoms contributed to fulfilling the strategic aims of the Airport. The framework for this is illustrated in the following figure, Figure 22: strategic aims are broken down and mapped on to specific objectives which are described by a set of performance indicators. The objective of the trial was to determine how these performance indicators are affected by the Operational Freedoms and hence trace the impact of the Operational Freedoms back through the mapping to assess the contribution to the strategic aims.

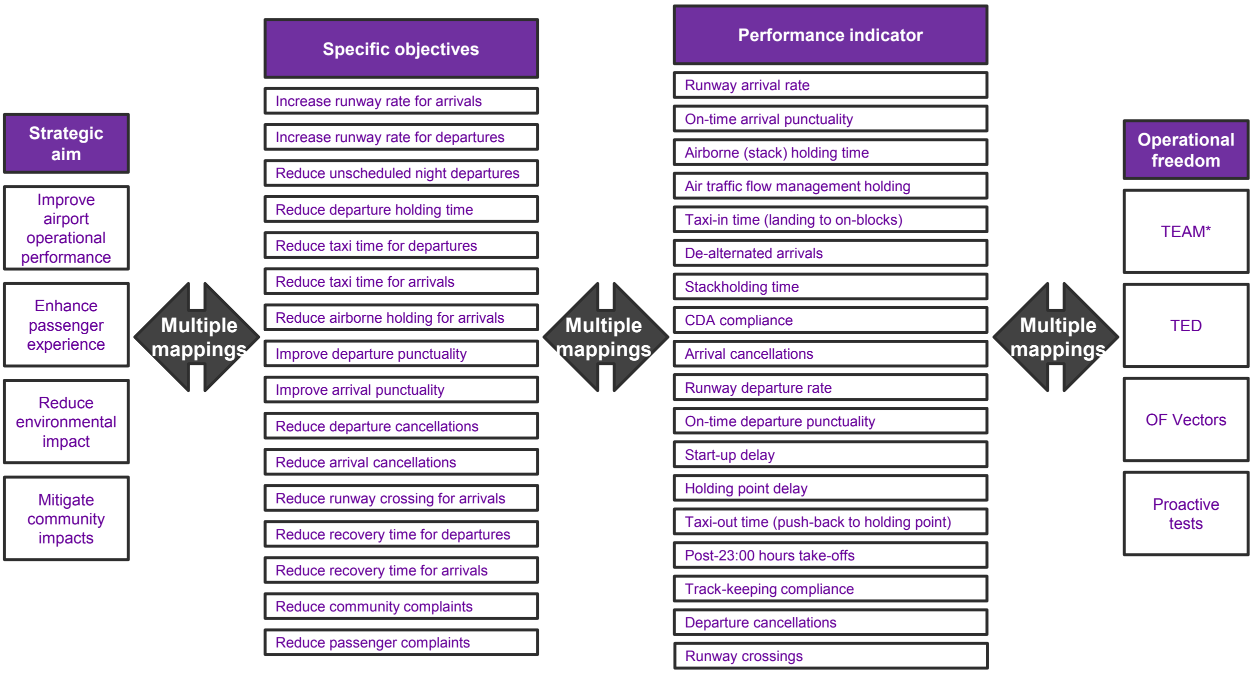


Figure 22: Framework linking Operational Freedoms to the strategic aims of the Airport

The analysis described in this report is principally concerned with assessing the impact that the Operational Freedoms have on the performance indicators.

The principal steps in the data analysis were:

- to develop and test a robust methodology that can isolate the potential impacts of the trial – reactive and proactive freedoms – on the Airport's KPIs; and
- use the methodology to determine the level association of application the freedoms with changes in the KPIs.

The methodology was built on experience gained during Phase 1 and the summer season of Phase 2 of the trial. It was then applied to the data collected during Phase 2 in total and to the data collected in Phase 1 where this was possible. The lessons learnt during Phase 1 informed the data collection and analysis procedures that were applied in Phase 2 with the result that much more detailed and granular data were collected during Phase 2 than in Phase 1. It was not possible, therefore, to analyse retrospectively the data collected in Phase 1 using the techniques developed during Phase 2. The results of Phase 1 are, therefore, based on partial analysis.

Data collection and analysis was achieved in a largely uncontrolled environment where many of the KPIs are strongly influenced by external factors, such as the weather. In addition, during the trial periods, there were other ongoing activities at the Airport, both operational and associated with infrastructure that potentially influenced the KPIs. The analysis was performed, therefore, using sophisticated statistical techniques designed to isolate as far as possible the association of the Operational Freedoms and other factors, external to the trial, with changes in the KPIs.

Ideally, this association between the Operational Freedoms and KPIs would be of a cause and effect nature but given that the trial drew principally on samples of opportunity from a periods of the Airport's operation rather than the (impossible to realize) ideal situation of a controlled experiment or very many randomized samples, drawing definitive conclusions on cause and effect was very difficult.

2.3 Overview of the operational analysis process

The overall process applied to the data analysis is illustrated in Figure 23 below. The basic steps in the analysis process were to:

- identify the appropriate key performance indicators the fulfil the criteria of: (i) contributing to one or more of the specific objectives highlighted in and (ii) being measurable and calculable using the data collected during the trial
- calculate and characterize those KPIs for the baseline period in a form suitable for statistical analysis, either based on a multivariate regression approach or quantitative comparison with similar data collected during non-trial periods
- use root cause and influence analysis to understand and characterize the impact of external factors such as traffic mix, weather and other operational and infrastructure factors on the KPIs so that these factors can be taken into account when performing statistical analyses
- generate a set of hypotheses for the impact of the trial on the set of KPIs, considering reactive freedoms and proactive tests, based on the knowledge gained throughout the trial, the knowledge gained throughout the trial and previously and the factual data as presented in the monthly reports
- consolidate the data from the diverse sets available into a single, consistent data set for analysis, covering the entire trial period and classified into half-hourly time bins
- calculate the KPIs for the trial period as well as calculating similar KPIs for previous similar periods for comparison as appropriate

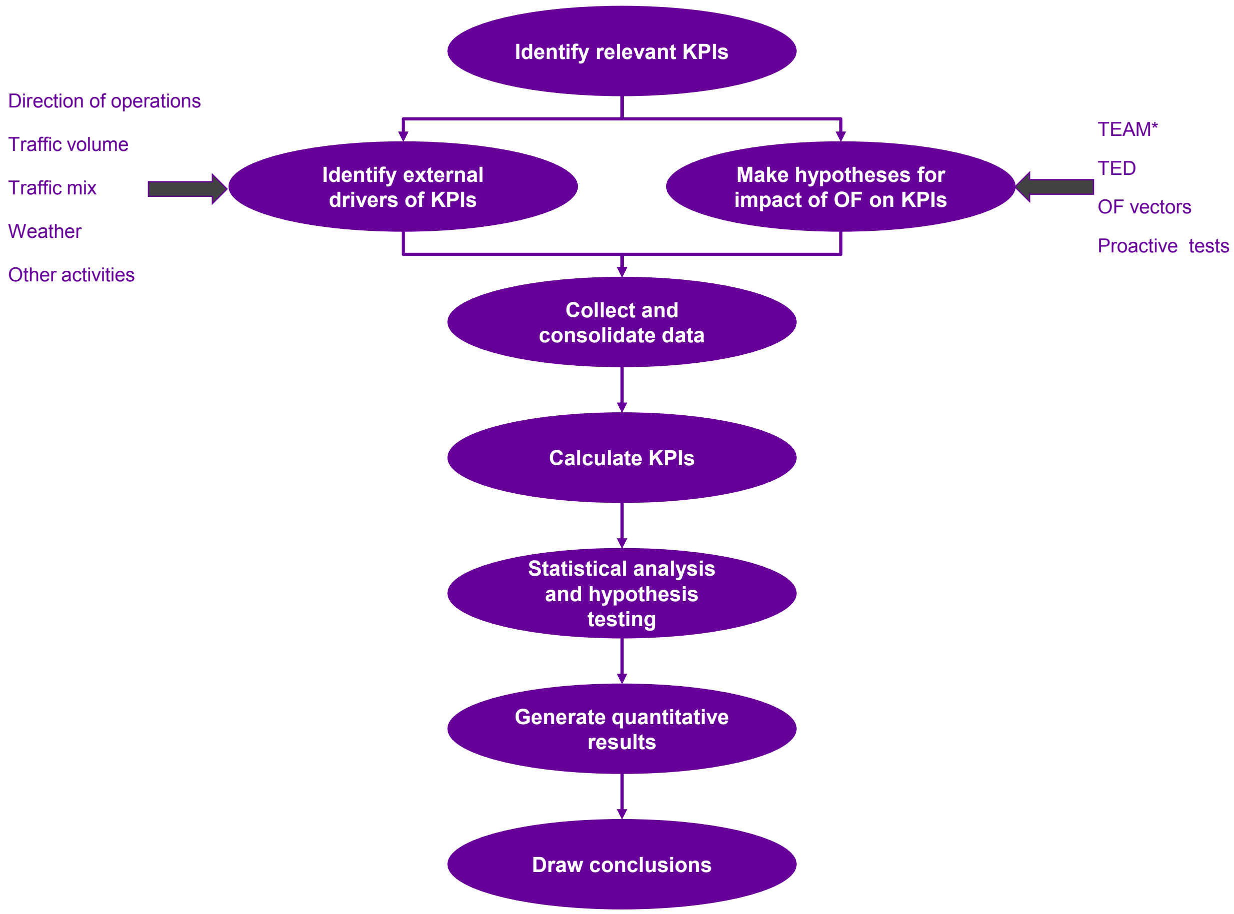


Figure 23: Overview of the data analysis process

- perform statistical analysis on the data in two principal ways:
  - for data that was available on the half hourly resolution, to undertake multivariate regression analysis using the KPI being examined as the dependent variable. The application of Operational Freedoms and the influencing factors identified from the root cause analysis are applied as independent variable to isolate individual associations with the KPI
  - for data that was only available on a daily basis (e.g. de-alternation, continuous descent approach (CDA) and track-keeping compliance), to perform statistical comparisons with the same KPI derived for previous similar periods, in the same way that the comparisons were made during the Phase 1 analysis.
- use the results of the multivariate regression analysis to estimate quantitatively, with uncertainty ranges (error bars) the likely effect that application of Operational Freedoms has had on the relevant KPIs during their application from July 2012 to February 2012
- assess the impact of the trial on the KPIs to inform the conclusions at the end of the trial process on how Operational Freedoms contributed to the Airport's strategic aims both individually and collectively; and provide feedback and lessons learnt on the analysis approach to inform subsequent analyses.

The operation of the trial during Phase 1 made distinctions between easterly and westerly operations – effectively triggers were only applied and data recorded on westerly operations for arrivals because the flexibility already exists to modify, temporarily, easterly operations as the situation dictates. However, during Phase 2, the same triggers were applied and data recorded for both easterly and westerly operations. Therefore, the data analysis for Phase 2 draws, in the main, no distinction between easterly and westerly operations because: (i) the number of easterly operations, particularly during the summer season, was very low; (ii) in practical terms, the freedoms are being applied in the same way for both easterly and westerly operations.

2.4 Key performance indicators

Based on operational experience of the Airport and the experience gained during the trial, a range of performance areas and associated KPIs were assembled for the reactive part of the trials. These represented a reduced set compared to Phase 1 – those found to have limited relevance for Operational Freedoms such as joining point compliance having been removed – and are summarized in Figure 24 for the reactive part of the trial Figure 25 on page 38 for the proactive tests.

Arrivals		Departures	
Performance area	**KPIs**	**Performance area**	**KPIs**
Runway arrival rate	• Half-hourly arrival rate	Runway departure rate	• Half-hourly departure rate
On-time arrival punctuality	• %age flights <15 minutes late • Mean delay minute per flight	On-time departure punctuality	• %age flights <15 minutes late • Mean delay minute per flight
Airborne (stack) holding time	• Mean holding time per flight	Start-up delay	• Mean start-up delay per flight
ATFM holding	• Mean ATFM delay per flight	Holding point delay	• Mean holding point delay per flight
Taxi-in time (landing to on-blocks)	• Mean taxi-in time per flight	Taxi-out time (push-back to holding point)	• Mean taxi-out time per flight
De-alternated arrivals	• Statistical distribution of daily de-alternated arrivals	Post-23:00 hours take-offs	• Statistical distribution of daily post-23:00 hours take-offs
CDA compliance	• Statistical distribution of average daily CDA compliance rate	Track-keeping compliance	• Statistical distribution of average daily track-keeping compliance rate for OF SIDs
Cancellations	• Statistical distribution of daily arrivals cancellations	Cancellations	• Statistical distribution of daily arrivals cancellations

Figure 24: Performance areas and KPIs for the reactive part of the trial

The KPIs summarised above are defined as follows for arrivals and departures.

2.4.1 Arrivals

The arrivals KPIs were:

- **runway arrival rate:** the number of aircraft landing on the runways during half-hour intervals, calculated over the period of the trial. The reference time for runway arrival rate was the actual landing time
- **on-time arrival punctuality:** the difference between the time that an aircraft was scheduled to arrive on stand and the time that is actually arrived on stand. The reference time for arrival punctuality was, therefore, the scheduled arrival time. The first measure of

arrival punctuality was defined as the proportion of flights arriving on stand less than 15 minutes behind schedule. Arrival punctuality was also defined in terms of average delay minutes averaged on a flight-by-flight basis averaged over half-hour periods. The average was calculated as the total number of delay minutes accrued in the half-hour divided by the total number of flights scheduled within that half-hour, with flights that were on-time or early contributing zero to the total delay. This parameter was calculated on a half-hourly basis throughout the trial period

- **average air traffic flow management (ATFM) holding:** the amount of time that an aircraft was held at its origin airport because of an ATFM regulation attributed to Heathrow. ATFM delays were calculated on a flight-by-flight basis and averaged over 30 minute periods throughout the trial period. The average was the sum of ATFM delays accrued by flights that would have arrived in the 30 minute period had they not been subject to ATFM delay, divided by the total number of flights (delayed and undelayed) for the period. The reference time was the time that the aircraft actually landed if not delayed or would have landed had it not been subject to ATFM delay

- **average airborne (stack) holding time:** the amount of time that an aircraft spent in a holding stack. This was averaged on a flight-by-flight basis over half-hour periods and referenced to the actual landing time of the aircraft being held. In addition, stackholding distributions were calculated for the trial period, the period immediately prior to the trial (April to June 2012) and the four month periods, July to October, for the previous three summers for comparison

- **mean taxi-in time:** the elapsed time between the aircraft touching down on the runway and arriving at its stand averaged over flights arriving in a half-hour period. The reference time was taken to be the landing time of the flight. This parameter was calculated on a half-hourly basis throughout the trial period

- **de-alternated arrivals:** defined as the number of aircraft that landed on the designated departures runway post 07:00 hours local time. This was calculated on a daily basis and the statistical distribution calculated and compared for the trial period and preceding similar periods

- **CDA compliance:** the proportion of flights that performed successful continuous descent approaches (CDAs). This was calculated on a daily basis and the statistical distribution calculated and compared for the trial period and preceding similar periods

- **cancellations:** the number of arrivals that were cancelled for operational reasons and was calculated on a daily basis and used to determine the statistical distribution over the trial period and preceding similar periods.

2.4.2 Departures

The departures KPIs are:

- **runway departure rate:** the mirror of runway arrival rate and was the number of aircraft taking-off from the runways during half-hour intervals, calculated over the period of the trial. The reference time for runway arrival rate was the actual take-off time

- **on-time departure punctuality:** the difference between the time that an aircraft was scheduled to leave its stand and the time that it actually left its stand. The reference time for departure punctuality was, therefore, the scheduled time of departure. The first measure of departure punctuality was defined as the proportion of flights leaving the stand less than 15 minutes behind schedule. Departure punctuality was also defined in terms of average delay minutes averaged on a flight-by-flight basis averaged over half-hour periods. The average was calculated as the total number of delay minutes accrued in the half-hour divided by the total number of flights scheduled within that half-hour, with flights that are on-time or early contributing zero to the total delay. This parameter was calculated on a half-hourly basis throughout the trial period

- **mean start-up delay:** defined as the mean elapsed time between the pilot requesting permission to start from air traffic control and that permission being granted as recorded in the electronic flight processing system (EFPS) system. There are many causes of start-up delay, including congestion on the airfield and congestion (not all due to Heathrow) downstream on departure routes. In addition, start-up delay is measured against a moving baseline (the time that the pilot calls) that is not always reflective of the schedule and, under certain circumstance, e.g. high delays, might incentivise perverse behaviours, e.g. early calls, to achieve a high place in the queue that necessarily lead to a snowball effect of rapidly increasing delays (which might not actually reflect reality). Start-up delay is, therefore, an imperfect performance indicator but is the best that is currently available. Start-up delay was averaged on a flight-by-flight basis over half-hour periods, using the entire sample (thus the average includes both flights that were held and flights that were not held) and referenced to the actual take-off time of the aircraft being held. This parameter was, therefore, calculated on a half-hourly basis throughout the trial period

- **mean runway holding delay:** the average time that a flight spent in the queue to use the departure runway. It was defined as the elapsed time between the holding point time and the line-up time as recorded in the EFPS system. Runway holding delay was calculated on a flight-by-flight basis and averaged over half-hour periods with the statistics covering the entire sample, including flights not subject to delay. This parameter was calculated on a half-hourly basis throughout the trial period

- **mean taxi-out time:** defined as the elapsed time between the aircraft starting to push-back from its stand and arriving at the holding point averaged over flights departing in a half-hour period. The reference time was taken to be the actual take-off time of the flight. This parameter was calculated on a half-hourly basis throughout the trial period

- **post-23:00 hour take-offs:** defined as the number of flights that take off after 23:00 hours local time. This was calculated on a daily basis and the statistical distribution calculated and compared for the trial period and preceding similar periods

- **track-keeping compliance:** the proportion of flights that complied with the requirements to stay within noise preferential routes (NPR). This was calculated on a daily basis for the standard instrument departure routes (SIDs) for which Operational Freedoms vectors were active and the statistical distribution calculated. These distributions for the trial period were compared with preceding similar periods

- **departure cancellations:** the number of departures that were cancelled for operational reasons (including those that were cancelled because of the cancellation of the linked arrival). This was calculated on a daily basis and the statistical distribution calculated and compared for the trial period and preceding similar periods.

2.4.3 Proactive tests

The KPIs most relevant to the proactive tests are summarised in Figure 25 below. These were limited to arrivals and are identical to the more general TEAM* KPIs with the exceptions of:

- **mean T4 taxi-in time**, which was limited to flights terminating at T4
- **runway crossings**, which was the number of runway crossings associated with arrivals. This was calculated on a daily basis and the statistical distribution calculated and compared for the proactive and non-proactive parts of the trial (there was no data available to allow comparisons with previous periods).

Arrivals	
Performance area	**KPIs**
Runway arrival rate	• Half-hourly arrival rate
On-time arrival punctuality	• %age flights <15 minutes late • Average delay minute per flight
Mean airborne (stack) holding time	• Mean holding time per flight
Mean T4 taxi-in time (landing to on-blocks)	• Mean taxi-in time per T4 flight
Runway crossings	• Statistical distribution of daily runway crossings

Figure 25: Performance areas and KPIs for the proactive tests

2.4.4 Interdependencies

The KPIs associated with arrivals are likely to be most strongly influenced by TEAM* and proactive tests. TED would be expected to have an impact on arrivals as it utilises the designated arrivals runway for departures. OF vectors are expected to have little, if any, impact on arrivals.

The KPIs associated with departures are likely to be most strongly influenced by OF vectors. However, as arrivals are linked to departures through the turnaround process and use of the departure runway for arrivals will impact on departures, there are likely to be linkages between some departure KPIs and arrivals freedoms that need to be taken into account in the hypotheses on the expected impact of the trial.

In the proactive case, there will be multiple linkages between the freedoms applied and the performance area and KPIs:

- landing T4 arrivals on the southern runway will likely impact all three performance areas
- landing A380s on the departures runway will likely impact on runway throughput and stack holding, both for the A380s and for those aircraft following behind, and through knock-on effects during later periods
- similarly landing small and light aircraft on the departures runway will also likely impact on runway throughput and stackholding for those aircraft and those following immediately behind, as well as further downstream.

For these reasons, and the difficulty, in some cases, in assigning a specific reason to each individual proactive landing, the analysis of proactive tests has been performed at the overall level instead of being broken down into individual causes.

In addition to the interdependencies between separate KPIs, there are likely to be interactions between KPIs at different times; for example a delay at the present time is likely to have been influenced by a delay in the past and will, likely, flow through to influence future delays. Such time lags have been taken into account in the analysis methodology.

2.5 Hypotheses

2.5.1 The reactive component of the trial

The hypotheses and underlying rationale for the impact of the reactive component of the trial on arrival performance compared to the baseline were as follows:

- **de-alternated arrivals**: it was expected that the number of de-alternated arrivals would increase on both westerly and easterly operations when TEAM* and proactive tests were applied
- **runway arrival rate**: it was expected that the application of TEAM* would increase the runway arrival rate compared to similar periods when it was not applied. It was thought that there might be a reduction in westerly runway arrival rate during Phase 1 of the trial when TED was in operation but this was expected to be minimal because air traffic controllers would not apply TED in periods of high arrival demand. Furthermore, because of the very low number of TEDs applied, it was expected that their impact would be minimal
- **airborne (stack) holding time**: it was expected that the application of TEAM* would reduce stackholding delay compared to periods, all other things being equal, when it is not applied
- **air traffic flow management (ATFM) holding**: it was expected that application of TEAM* would be associated with a reduction in ATFM holding per flight for flights that were planned to arrive when TEAM* was active
- **on-time arrival punctuality**: it was expected that the application of TEAM* would be associated with an improvement in arrival punctuality, principally due to the mitigation of stackholding and ATFM delays
- **taxi-in time (landing to on-blocks)**: it was expected that TEAM* would be associated with a reduction in average taxi-in time because, when trigger conditions were met, the air traffic controller was able select aircraft to land on the designated departure runway based on their destination terminal
- **continuous descent approach (CDA)**: it was expected that the trial would have no impact on CDA because the trial only extended the degree to which the designated departure runway could be used for arrivals but did not change operational procedures or processes
- **cancellations**: it was expected that, due to the extreme nature of the conditions that prompt cancellations, that there would be no association between Operational Freedoms and a change in the rate of arrival cancellations.

The hypotheses for the impact of Operational Freedoms vectors on departure performance were as follows:

- **runway departure rate**: it was expected that application of OF vectors would increase the runway departure rate during Phase 2 of the trial but that OF freedoms arrivals, both TEAM* and proactive tests, would decrease runway departure rate, during both Phases. Given the low number of TEDs applied during Phase 1 of the trial it was expected that it will have no measurable effect on runway departure rate

- **on-time departure punctuality**: it was expected that the application of OF vectors would be associated with an improvement in departure punctuality

- **start-up delay**: it was anticipated that the application of OF vectors would be associated with a reduction in start-up delay but, conversely, the application of TEAM* for arrivals would be associated with an increase in start-up delay

- **holding point delay**: it was expected that the application of OF vectors would be associated with decreased holding point delay, as the separation between departures was decreased, but that application of TEAM* both reactive (i.e. TEAM*) and proactive, would be associated with an increase in holding point delay, as the departure runway was used to accommodate arrivals

- **taxi-out time (push-back to holding point)**: it was expected that the trial would have no impact on taxi-out time

- **post-23:00 departures** it was expected that the trial would reduce the rate of post-23:00 hours departures when tactically enhanced departure measures (TEDs) were activated

- **track-keeping compliance**: it was expected that there would be a significant decrease in track-keeping compliance on the SIDs where Operational Freedoms vectors were applied

- **cancellations**: it was expected that, due to the extreme nature of the conditions that prompt cancellations, that there would be no association between Operational Freedoms and a change in the rate of departure cancellations.

2.5.2 Proactive tests

Reflecting the specific nature of the proactive tests, the associated hypotheses were that:

- **runway arrival rate:** application of proactive tests would be associated with an increase in runway arrival rate in the same way that TEAM* would be expected to be associated with such an increase

- **T4 taxi-in time:** during the period of the proactive tests the air traffic controller had the freedom to land T4 traffic on the southern runway and therefore this traffic would not be interspersed with other non-T4 traffic as during reactive periods of the trial. Thus during the proactive periods, T4 arrivals traffic would have shorter taxi distances and would not have to cross the southern runway. It was expected therefore that the proactive tests would be associated with a reduction in overall taxi-times but would be much more strongly associated with a reduction in T4 taxi-in times

- **runway crossings:** during the proactive tests, the number of runway crossings for arrivals would decrease compared to the remainder of the trial for the same reason as above, i.e. that T4 arrivals would not have to cross the southern runway to reach their destination. It was expected therefore that the a reduction in the number of runway crossings would be associated with periods of proactive tests

- **stackholding delay:** it was expected that the application of proactive tests would be associated with a reduction in stackholding delay as during the proactive test period, the air traffic controller had the freedom to remove small/light and A380 (or adjacent aircraft) from the arrivals stream and land them on the designated departure runway.

2.6 Introduction to multivariate regression analysis

It is well known that external factors, such as traffic demand, traffic mix (i.e. the proportion of different sizes of aircraft operating within a given time period) and weather conditions, can influence performance strongly. Ideally, this would be dealt with by comparing very large samples during the trial period with very large baseline samples to average out the effects of these external drivers. However, this was not practicable and analysis performed during the first phase of the trial showed that there were significant variations in external conditions between the trial period and baseline that might have caused differences in the measured performance masking the impact of the trial. To account for this, in the first phase of the trial, analysis was performed on periods of like-conditions to minimise the differences due to external drivers. To improve on this analysis in Phase 2, a multivariate regression analysis was applied (this was not possible in Phase 1 because of limitations in data availability) to isolate (control for) the impacts of the external drivers and to understand better the likely associations between Operational Freedoms and KPIs. The regression analysis was applied on each half-hour data bin throughout the trial period taking into account the influence of previous events by including time lags in some of the data.

In simple terms, the multivariate regression analysis used a pre-defined mathematical function that relates a number of independent variables, including the Operational Freedoms and other external effects, to the dependent variable (the KPI). Mathematically, this is expressed as follows for a simple linear regression:

$$KPI = A_0 + \sum_{i+1}^{N} \alpha_i \, x_i$$

where:

- *KPI* is the dependent variable (key performance indicator)
- x_i represents each of the *N* independent variables, describing for example, weather conditions, traffic mix and other external variable as well as the application of the Operational Freedoms themselves
- α_i is the coefficient associated with each of the N independent variables
- A_0 is the value of the KPI when all of the independent variable are zero.

The outputs of the regression are:

- the value of each of the coefficients, α_i, of the independent variables that, for the pre-defined function, that describe the magnitude of relationship between each the independent variable, x_i, and the KPI
- statistical descriptions of the degree to which the mathematical function and the independent variables selected describe the variation in the KPI, including:
  - the overall R^2 value that indicates the extent to which the regression using the function and selected independent variables provides a complete description of the

KPI, e.g. an R^2 of 0.5 indicates that the regression account for 50% of the observed variability

- the overall significance of the regression and the individual significance of each coefficient, which indicates the level of confidence to which the regression could not have arisen from a random situation, e.g. an overall significance of 5% indicates that there is a 95% probability that the real underlying value is correct within its error bounds
- the standard error of each coefficient, which is an estimate of the standard deviation of the coefficient, and is a measure of the precision with which the regression coefficient is measured
- the t-statistic, which is the ratio of the value of the coefficient to its standard error: the larger the value the lower the error bounds on the coefficient.

The two important precursors to undertaking the regression analysis were:

- selection of the independent variables
- selection of the appropriate function for undertaking the regression.

These are discussed in the following sections.

2.7 Identification of external drivers

The relevant external drivers had been identified using root cause diagrams to chart the flow of arrivals and departures, highlighting where the KPIs were measured on the flow through the diagram. These charts are provided in the following figures for arrivals and departures respectively.

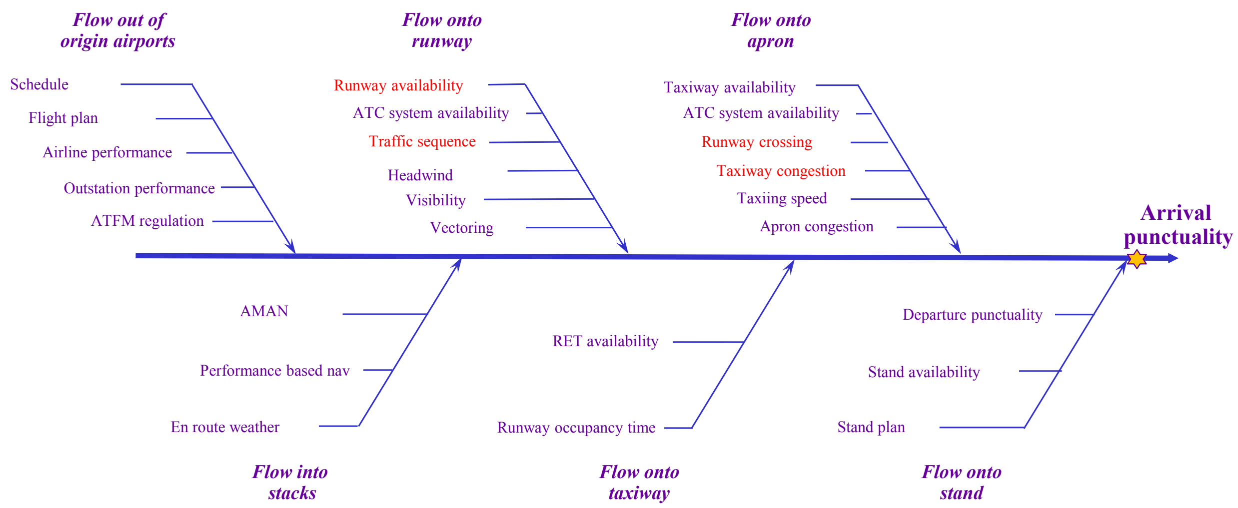


Figure 26: Root cause chart for arrivals

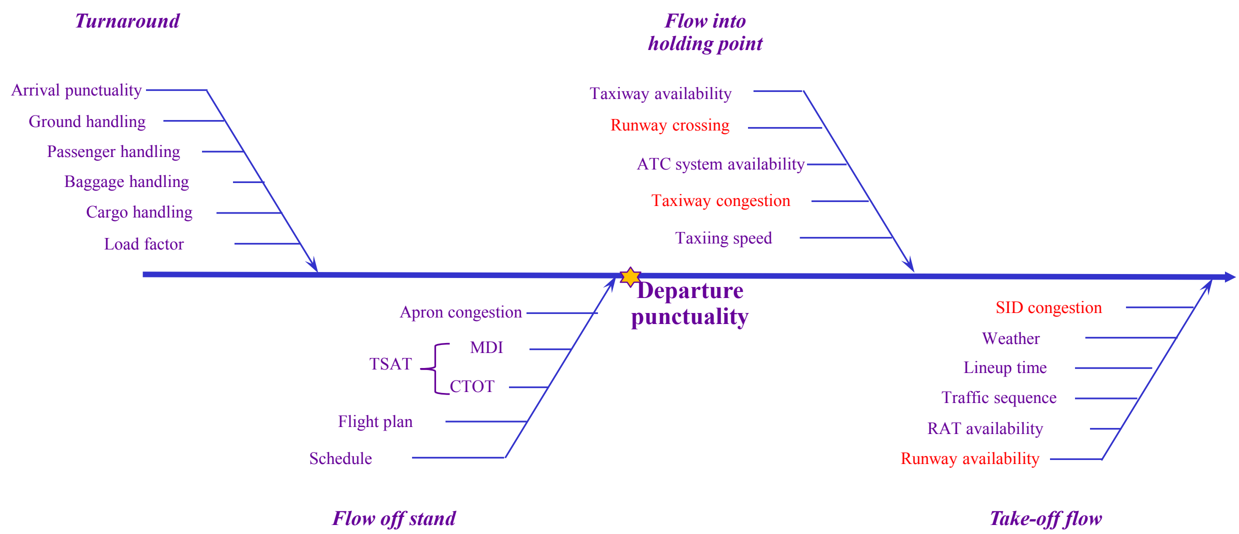


Figure 27: Root cause chart for departures

These charts were used to inform the selection of independent variables for the regression analysis. In general, the influences on the KPIs are the upstream parameters. However, because of the feedback in some of the processes, factors downstream could also influence the KPIs, particularly when the aircraft is being held on the stand. Examples of this downstream influence are:

- downstream congestion or capacity restrictions in airspace or at Heathrow that cause ATFM delays to the flight at its origin airport
- apron, taxiway, runway and/or SID congestion that result in start-up delay for departures from Heathrow.

In addition, there are many influencing factors for which reliable data is not available. The lack of this data is reflected in the R^2 values obtained from the regressions; the higher the R^2 the more complete the picture of the influencing factors.

In addition to the factors themselves, time dependent influences needed to be taken into account. For example, stackholding delay at the present time is likely to have been influenced by stackholding delay in the recent past as the effects of perturbations to operations take time to dissipate. This has been reflected in the analysis by using time lags for some of the influencing factors, such that the values of the parameter at time t_0 (the time bin being analysed), t_0-30 minutes (30 minutes ago relative to the time bin being analysed); t_0-60 minutes (60 minutes ago relative to the time bin being analysed) and t_0-90 minutes (90 minutes ago relative to the time bin being analysed) are used as independent variables in the regressions.

Based on the expected influences and the availability of data, the following tables summarise the independent variables used in the regression analysis for each of the arrivals and departures KPIs respectively. The importance of the independent variables is reflected in the significance levels and the value of the coefficients derived from the regressions (see annex E for a complete set of regression results) whereas the R^2 gives an indication of how completely the dependent variable is described by the set of independent variables used.

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
ATFM delay	Scheduled arrivals at time t_0 Scheduled arrivals at time t_0 - 30 minutes Scheduled arrivals at time t_0 + 30 minutes Actual arrivals Actual arrivals at time t_0 - 30 minutes Actual arrivals at time t_0 + 30 minutes Average stack hold per flight Average stack hold per flight at time t_0 - 30 minutes Average stack hold per flight at time t_0 - 60 minutes Humidity (%) Pressure (mbar) Temperature (°C) Occurrence of snow Surface wind speed (knots) Visibility (m) 3000ft wind speed (knots) TEAM* landers TEAM* landers at t_0 -30 minutes TEAM* landers at t_0 -60 minutes TEAM* landers at t_0 -90 minutes 06:00 TEAM landers Proactive landers Proactive landers at t_0-30 minutes Proactive landers at t_0-60 minutes Proactive landers at t_0-90 minutes

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
Runway arrival rate	Average Stackholding per Flight Average Stackholding per Flight at t0 -30 minutes Arrivals at top of stack Proportion of light category aircraft at top of stack Proportion of small category aircraft at top of stack Proportion of medium category aircraft at top of stack Proportion of heavy category aircraft at top of stack Proportion of A380 aircraft at top of stack Total arrivals at top of stack at t_0-30 minutes Proportion of light category aircraft at top of stack at t_0-30 minutes Proportion of small category aircraft at top of stack at t_0-30 minutes Proportion of medium category aircraft at top of stack at t_0-30 minutes Proportion of heavy category aircraft at top of stack at t_0-30 minutes Proportion of A380 aircraft at top of stack at t_0-30 minutes Humidity (%) Pressure (mbar) Temperature (°C) Occurrence of snow Surface wind speed (knots) Visibility (m) 3000ft wind speed (knots) TEAM* landers TEAM* landers at t_0-30 minutes TEAM* landers at t_0-60 minutes TEAM* landers at t_0-90 minutes 06:00 TEAM landers Proactive landers Proactive landers at t_0-30 minutes Proactive landers at t_0-60 minutes Proactive landers at t_0-90 minutes

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
Stackholding delay	Average stackholding per flight at time t_0-30 mins Average stackholding per flight at time t_0-60 mins Average stackholding per flight at time t_0-90 mins Total arrivals Total arrivals at time t0-30 mins Total arrivals at time t0-60 mins Proportion of light category aircraft arrivals Proportion of small category aircraft arrivals Proportion of medium category aircraft arrivals Proportion of heavy category aircraft arrivals Proportion of A380 aircraft arrivals Number of flights >15 minutes late Number of flights >15 minutes late at time t_0-30 mins Number of flights >15 minutes late at time t_0-60 mins Number of flights >15 minutes late at time t_0-90 mins LHR attributed ATFM delay per flight Other ATFM delay per flight Humidity (%) Pressure (mbar) Temperature (°C) Occurrence of snow Surface wind speed (knots) Visibility (m) 3000ft wind speed (knots) TEAM* landers TEAM* landers at t_0-30 minutes TEAM* landers at t_0-60 minutes TEAM* landers at t_0-90 minutes 06:00 TEAM Proactive landers at t_0-30 minutes Proactive landers at t_0-60 minutes Proactive landers at t_0-90 minutes

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
Taxi-in time	Taxi in Time all at time t_0 - 30 minutes Taxi in Time all at time t_0 - 60 minutes Taxi in Time all at time t_0 - 90 minutes Runway crossings -arrivals Actual Arrivals Total Actual Arrivals Total at time t_0 - 30 minutes Actual Arrivals Total at time t_0 - 60 minutes Proportion of light category aircraft arrival Proportion of small category aircraft arrival Proportion of medium category aircraft arrival Proportion of heavy category aircraft arrival Proportion of A380 aircraft arrival Humidity (%) Pressure (mbar) Temperature (°C) Occurrence of snow Surface wind speed (knots) Visibility (m) 3000ft wind speed (knots) TEAM* landers TEAM* landers at t_0 -30 minutes TEAM* landers at t_0 -60 minutes TEAM* landers at t_0 -90 minutes 06:00 TEAM landers Proactive landers Proactive landers at t_0-30 minutes Proactive landers at t_0-60 minutes Proactive landers at t_0-90 minutes
Arrival punctuality	Scheduled arrivals Cancellations Actual arrivals Average stack hold per flight Average stack hold per flight at time t_0 - 30 minutes Average stack hold per flight at time t_0 - 60 minutes Total ATFM delay per flight (minutes) Humidity (%) Pressure (mbar) Temperature (°C) Occurrence of snow Surface wind speed (knots) Visibility (m) 3000ft wind speed (knots) TEAM* landers TEAM* landers at t_0 -30 minutes TEAM* landers at t_0 -60 minutes TEAM* landers at t_0 -90 minutes 06:00 TEAM landers Proactive landers Proactive landers at t_0-30 minutes Proactive landers at t_0-60 minutes Proactive landers at t_0-90 minutes

Table 5: Influencing factors considered in the regression analyses for arrivals

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
Start delay	Average start delay per flight at time t_0 - 30 minutes Average start delay per flight at time t_0 - 60 minutes Average start delay per flight at time t_0 - 90 minutes Taxi-out time Taxi-out time at time t_0 - 30 minutes Taxi-out time at time t_0 - 60 minutes Taxi-out time at time t_0 - 90 minutes Actual Departures Proportion of light category aircraft departures Proportion of small category aircraft departures Proportion of medium category aircraft departures Proportion of heavy category aircraft departures Proportion of A380 departures ATFM delay per flight (referenced to take off time) Average holding point delay per flight Average holding point delay per flight at time t_0 - 30 minutes Humidity (%) Pressure (mbar) Temperature (°C) Surface wind speed (knots) Visibility (m) Occurrence of snow 3000ft wind speed (knots) Number of OF vectors Number of OF Vectors at time t_0 - 30 minutes Number of OF Vectors at time t_0 - 60 minutes Number of OF Vectors at time t_0 - 90 minutes Number of Wx vectors CDM flag 06:00 TEAM landers OF TEAM OF TEAM at time t_0 - 30 minutes OF TEAM at time t_0 - 60 minutes OF TEAM at time t_0 - 90 minutes

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
Departure punctuality	Arrival punctuality at time t0 Arrival punctuality at time t0 - 30 minutes Arrival punctuality at time t0 - 60 minutes Arrival punctuality at time t0 - 90 minutes Arrival punctuality at time t0 - 120 minutes Arrival punctuality at time t0 - 150 minutes Arrival punctuality at time t0 - 180 minutes Average start delay per flight ATFM delay per flight (referenced to take off time) Scheduled departures Cancellations Total Departures Proportion of light category aircraft departures Proportion of small category aircraft departures Proportion of medium category aircraft departures Proportion of heavy category aircraft departures Proportion of A380 departures Humidity (%) Pressure (mbar) Temperature (°C) Surface wind speed (knots) Visibility (m) Snow 3000ft wind speed (knots) Number of OF vectors Number of OF Vectors at time t_0 - 30 minutes Number of OF Vectors at time t_0 - 60 minutes Number of OF Vectors at time t_0 - 90 minutes Number of Wx vectors CDM flag 06:00 TEAM landers OF TEAM OF TEAM at time t_0 - 30 minutes OF TEAM at time t_0 - 60 minutes OF TEAM at time t_0 - 90 minutes

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
Holding point delay	Average holding point delay per flight at time t_0 - 30 minutes Average holding point delay per flight at time t_0 - 60 minutes Average holding point delay per flight at time t_0 - 90 minutes Number of departures (take-offs) Proportion of light category aircraft departures Proportion of small category aircraft departures Proportion of medium category aircraft departures Proportion of heavy category aircraft departures Proportion of A380 departures ATFM delay per flight Push back rate Push back rate at time t_0 - 30 minutes Taxi-out time Taxi-out time at time t_0 - 30 minutes Taxi-out time at time t_0 - 60 minutes Taxi-out time at time t_0 - 90 minutes Humidity (%) Pressure (mbar) Temperature (°C) Surface wind speed (knots) Visibility (m) Occurrence of snow 3000ft wind speed (knots) Number of OF vectors Number of OF Vectors at time t_0 - 30 minutes Number of OF Vectors at time t_0 - 60 minutes Number of OF Vectors at time t_0 - 90 minutes Number of Wx vectors CDM flag 06:00 TEAM landers OF TEAM landers OF TEAM at time t_0 - 30 minutes OF TEAM at time t_0 - 60 minutes OF TEAM at time t_0 - 90 minutes

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
Taxi-out time	Taxi-out time at time t_0 - 30 minutes Taxi-out time at time t_0 - 60 minutes Taxi-out time at time t_0 - 90 minutes Average start delay per flight Average start delay per flight at time t_0 - 30 minutes Average start delay per flight at time t_0 - 60 minutes Average start delay per flight at time t_0 - 90 minutes Average holding point delay per flight Runway crossings ATFM delay per flight Push back rate Push back rate at time t_0 - 30 minutes Actual Departures Proportion of light category aircraft departures Proportion of small category aircraft departures Proportion of medium category aircraft departures Proportion of heavy category aircraft departures Proportion of A380 departures Humidity (%) Pressure (mbar) Temperature (°C) Surface wind speed (knots) Visibility (m) Snow 3000ft wind speed (knots) Number of OF vectors Number of OF Vectors at time t_0 - 30 minutes Number of OF Vectors at time t_0 - 60 minutes Number of OF Vectors at time t_0 - 90 minutes Number of Wx vectors CDM flag

Dependent variable (KPI) at time t_0	Independent variables/influencing factors at time t_0 unless otherwise stated
Runway departure rate	Scheduled departures Scheduled departures at time t_0 - 30 minutes Cancellations Cancellations at time t_0 - 30 minutes Actual push-backs Actual push-backs at time t_0 - 30 minutes Humidity (%) Pressure (mbar) Temperature (°C) Surface wind speed (knots) Visibility (m) Snow 3000ft wind speed (knots) Number of OF vectors Number of OF Vectors at time t_0 - 30 minutes Number of OF Vectors at time t_0 - 60 minutes Number of OF Vectors at time t_0 - 90 minutes Number of Wx vectors CDM flag 06:00 TEAM landers OF TEAM landers OF TEAM at time t_0 - 30 minutes OF TEAM at time t_0 - 60 minutes OF TEAM at time t_0 - 90 minutes

Table 6: Influencing factors considered in the regression analyses for departures

As the night-time operations at the Airport are of low volume and would probably distort the results, they have been excluded from the analysis. The regression analysis has therefore been limited to the core operating day covering 06:00 hours to 23:00 hours local time for both arrivals and departures. For other analyses, e.g. night time departures, the whole 24 hours has been included.

2.8 Selection of functions for regression analysis

Clearly selection of the appropriate function for the regression analysis is important in obtaining the most accurate and reliable results. There was no theoretical description of the Airport operation available to inform the decision, which has therefore been based on empirical observations. Previous analysis reported in the Phase 2 end of summer season report based the function used in the regressions on empirical, exponential relationships between delay-related KPIs and demand based on queuing theory. KPIs that were not related to delays were assessed using a simple linear relationship. However, there were a number of issues with this approach:

- there were often low R^2 values and large standard errors associated with the regressions based on the empirical, exponential relationships which both reduce the reliability that the results of the regression can be used predictively
- there were non-normal distributions of regression residuals, caused by the technique that has been applied to deal with zero values in the exponential relationship and the results were dependent on the exact technique used to deal with the zero values

- the high sensitivity of the results to the precise form of function that is used to describe the relationship between the dependent and independent variables and contradictory results based on different functions.

To overcome these problems, a different approach was used to choose the functions for the analysis in this final report. Three basic functions relating the dependent and independent variables were trialled. These functions were:

- linear

$$KPI = A_0 + \sum_{i+1}^{N} \alpha_i \, x_i$$

- exponential

$$log(KPI) = A_0 + \sum_{i+1}^{N} \alpha_i \, x_i$$

- square root

$$\sqrt{KPI} = A_0 + \sum_{i+1}^{N} \alpha_i \, x_i$$

The three techniques were trialled and the results compared in terms of the sensitivity to the technique used to deal with zero values in the exponential approach, the resultant R^2 values and the variation of the distribution of residuals from a normal distribution. The stability and effect of varying the length of the day included in the regression analyses was also tested, with the result that the core operational day of 06:00 hours to 23:00 hours local time was selected for regression analysis. Based on these assessments, the exponential approach was abandoned. In many cases, there was little difference between the outcomes generated using the linear and square root approaches: when this was the case the linear approach was used because of the ease of interpretation of the results. The following table summarises the type of function used in each regression and annex E provides a summary of results for both linear and square root regressions.

KPI	Regression function
ATFM delays	Linear
Runway arrival rate	Linear
Stackholding delay	Square root
Taxi-in time	Linear
On-time arrival punctuality	Linear
Start-up delay	Linear
On-time departure punctuality	Linear
Taxi-out time	Linear
Holding point delay	Linear
Runway departure rate	Linear

Table 7: Type of function used for each KPI in the multivariate regression analysis

2.9 Data sources

The raw data used for the majority of the operational analysis described in this report – both for the baseline and the trial period – were derived from the Airport's operational systems as follows:

- the Airport's noise and track-keeping system known as ANOMS (Aircraft Noise and Operations and Management System). The data fields available include on a flight-by-flight basis: the flight number, the aircraft type, the scheduled arrival time, the holding stack used, the time that the flight entered the stack, the time that the flight exited from the stack, the number of stack circuits flown, the time spent in the stack, the runway used and the actual landing time

- NATS' electronic flight processing system (EFPS) which records, on a flight-by-flight basis, the passage of aircraft across the airfield for both arrivals and departures. The data fields available include: the flight number, the aircraft type, the aircraft registration, the actual time of arrival/departure, the actual time of landing/take-off, the terminal/stand used, the runway used and for departures only: the start-request and start-approved times, the push-back time, the taxi start time, the time that the aircraft reached the runway holding point and the time that the aircraft lined-up the runway. Runway crossing data is also available from EFPS for the period of the trial but long-term historical data is not

- the Airport's IDAHO system, effectively an operational database. These data cover arrivals and departures on a flight-by-flight basis. The data fields include, inter alia, the flight number, the aircraft type, the flight status (operated, cancelled or diverted), the scheduled time of arrival/departure, the actual time of arrival/departure, the actual time of touchdown/take-off, the runway used, the terminal and stand used, the aircraft registration and the number of passengers carried

- the application of freedoms themselves were recorded in NATS' Tower logs, superimposed on EFPS flight-by-flight reports and cross-checked against data derived from ANOMS

- weather data is extracted from meteorological aerodrome reports (METARs) derived from the Heathrow Weather Station and stored within the ANOMS system. These are available on a half-hourly basis. 3000 foot wind data has been extracted from NATS' operational data, also derived from METARs but only available on an hourly resolution.

Use was also made of air traffic flow management data available from the Eurocontrol Central Flow Management Unit (CFMU). Fields that are available are: the flight number, the aircraft type, the origin airport, the air traffic flow management delay, the reason for the delay and the location of the delay.

The following table summarises the sources of the data used to derive each of the KPIs for the reactive part of the trial.

Arrivals		Departures	
KPI	**Data source**	**KPI**	**Data source**
Runway arrival rate	ANOMS	Runway departure rate	ANOMS
Arrival punctuality	IDAHO	Departure punctuality	IDAHO
Airborne holding time	ANOMS	Runway holding time	EFPS
ATFM holding	CFMU	Start-up delay	EFPS
Taxi-in time	EFPS	Taxi-out time	EFPS
Runway crossings	EFPS	Runway crossings	EFPS
De-alternated arrivals	ANOMS	De-alternated departures	ANOMS
CDA compliance	ANOMS	Post-23:00 take-offs	ANOMS
Cancellations	IDAHO	Track-keeping compliance	ANOMS
		Cancellations	IDAHO

Table 8: Data sources

2.10 Data integrity and limitations

As described above the data used in the trials was derived mainly by querying databases created by recording the output of operational systems, including radar (ANOMS), the Heathrow Tower air traffic control system (EFPS) and the CFMU. IDAHO contents are derived, combined and integrated from a range of inputs and can include manual input. EFPS data can also include manual input. As with all large and complex data collection and management systems it is not possible to ensure complete and total data integrity and reliability.

The systems have the following known weaknesses for which mitigations have been applied wherever possible:

- the use of IDAHO data has been limited to the calculation of punctuality, for which no other source is available
- ANOMS is known to drop departure tracks on occasions due to problems with the radar tracker that feeds into the system. This issue is well-documented and occurs randomly on a few days (typically two to three) each month and affects typically 1 to 10% of departures on that day. Overall, therefore this fault is expected to have affected approximately 1% of flights included in the samples. Specific days on which the fault occurs are easy to identify, through discrepancies in arrival and departure numbers. Corrections have been made to these days by filling in lost departure data from EFPS
- EFPS relies on manual input by air traffic controllers to record the time at which certain events occur, such as the aircraft requesting start, it lining up for the runway, etc. At certain periods this entry is sometimes not made at the appropriate time. This can have two effects: fields are missing from the dataset or flight milestones are not recorded in sequence. The analysis process included internal consistency checking of flight milestone data and faulty data were excluded from the analysis. This mainly affects data recorded in quiet periods – late at night – but can also affect other periods. Consistency checks have been made on EFPS data records and those with missing fields excluded from the analysis (a consequence of this is that there is sometimes an inconsistency in the number of arrivals and departures recorded in EFPS)
- CFMU data is derived from an external source outside of the control of the trial participants. Therefore the use of CFMU data has been restricted to calculating ATFM delay, for which there is no other source

- there are sometimes small gaps in weather data principally due to outages at the weather station or the associated communication systems. The analysis has omitted the time periods where these small gaps occur.

Cross-checking and reconciliation of flight-by-flight data across the four systems, performed as part of a Heathrow performance monitoring project, indicated an overall consistency level of approximately 98%. This is clearly high enough to give confidence of the overall statistical analysis when large samples are used. Less confidence can be placed, however, in drill-down analysis focused on specific types of flights and has been apparent, for example, in inconsistencies between A380 and small/light arrivals and departures in monthly reports.

Identification of the specific flights to which Operational Freedoms were applied and associated triggers was recorded manually by the air traffic controllers on duty in the Heathrow Tower. There are inevitably errors in these lists when they are created initially. They were then cross-checked on a flight-by-flight basis by the Flight Performance Unit using ANOMS data as the truth for vectors and de-alternated arrivals. Data was corrected and validated with NATS as necessary before consolidation, processing and analysis.

2.11 Audit by Cambridge University, IfM ECS Unit

The Cambridge IfM ECS Unit worked closely with Heathrow and the CAA in the formation of the Operational Freedoms trial. Considerable effort went into the trial design – especially in Phase 2 - to try to control the use of the Operational Freedoms throughout the trials in order to best establish cause and effect relationships as far as feasible. Due to the complexities of operations at Heathrow and the need to ensure safe operations, it has not been possible to run freedoms independently through the trial. However considerable effort has been shown by all parties to achieve this goal.

While the trial has been conducted, the Cambridge group has had full access to all operational data and additional trial related information from both Heathrow and NATS. All parties involved have been supportive of the aims, objectives and the potential benefits that the trials were expected to bring. This has been mirrored by the efforts made by the Heathrow complaints group in providing information and feedback to the public on aspects of the trial.

Only very modest improvements in operational, environmental and economic performance were indicated by the trials and the subsequent report, but in particular the use of TEAM* under specific conditions and early vectoring freedoms indicated some improvement to operations. The independent analysis of the trial data performed by Cambridge, using the same [regression] analysis approaches, supports the report findings.

We would emphasise that the validity of the observed improvements is directly linked to the confidence in the results of the regression analysis used to evaluate operational performance. At times the results from the regression analysis of operations were found to have very low confidence levels (i.e. high error margins) and were sensitive to the selection of the underlying model chosen. With a complex operating environment such as Heathrow this is not unexpected but it does mean that it is very difficult to make strong conclusions about the overall value of the OF measures trialled. Future trials would benefit from having a narrower scope and greater control of operating conditions, helping to make cause-and-effect relationships associated with Operational Freedoms easier to observe. It is emphasised that this limitation is simply a feature of the Heathrow environment, and the Cambridge IfM ECS Unit acknowledges the significant efforts made by Heathrow and the CAA to establish consistent guidelines for regression analysis.

In conclusion, the practical inability to control the nature of many aspects of the trial made demonstrating conclusive benefits very challenging.

3 Impact of the trial on operational performance

3.1 Introduction

This section describes the results of the statistical analyses applied to assess the links between application of Operational Freedoms and the KPIs measured during the trial. This analysis has, in the main, been based on multivariate regression approach to isolate the impacts of the very many variables that can affect the KPIs (as described in Section 2.7 with the results reported in more detail in Annex E). The quality of some of the regressions is poor, with low R^2 values in some cases. Although there is a reasonable degree of confidence in the results qualitatively, there is a high degree of uncertainty in the precision associated with the quantitative outcomes of the analysis.

The multivariate regression analysis has been supplemented by statistical comparisons between KPIs observed during the trial and similar like periods from previous summers where necessary; in particular for those KPIs that are described on a daily basis, such as cancellations. Combination of the two different types of analysis increases confidence in the results. However, even with high quality results derived from this type of analysis, it is extremely difficult to draw cause and effect conclusions rather than associations between behaviours of the parameters

The remainder of the section describes the results of statistical analysis applied to the following KPIs:

- (de-)alternation for arrivals
- runway throughput during core operational hours for both arrivals and departures
- delays for arrivals, including both air traffic flow management and stack holding
- delays for departures, including both start-up delay and ground holding for the runway
- taxi-in time (from touchdown to on-blocks) for arrivals and taxi-out time (from pushback to joining the queue for the runway) for departures
- on-time punctuality for both arrivals and departures
- cancellation rates for both arrivals and departures.

3.2 Arrivals alternation

Given the nature of the Operational Freedoms, both reactive and proactive, the hypotheses to be tested associated with alternation are that de-alternation levels after 07:00 hours will have increased compared to previous like periods for westerly operations and use of 09R for arrivals will have increased for easterly operations.

Figure 28, Figure 29 and Figure 30 show the daily de-alternation levels for westerly arrivals and use of 09R for easterly arrivals across the three parts of the trial (note that the values reached for the off-scale bars are highlighted at the top of the graph). The figure shows the total of all de-alternated flights, whatever the reason for de-alternation and splits these across their main causes. De-alternated flights are, therefore, identified according to whether they occur because of:

- 06:00 hours TEAM
- TEAM*, not distinguishing between westerly and easterly operations
- proactive tests, also not distinguishing between westerly and easterly operations

- other reasons, such as emergencies, issues with infrastructure (e.g. runways, taxiways or air traffic control systems), other incidents or general de-alternation because of adverse wind conditions.

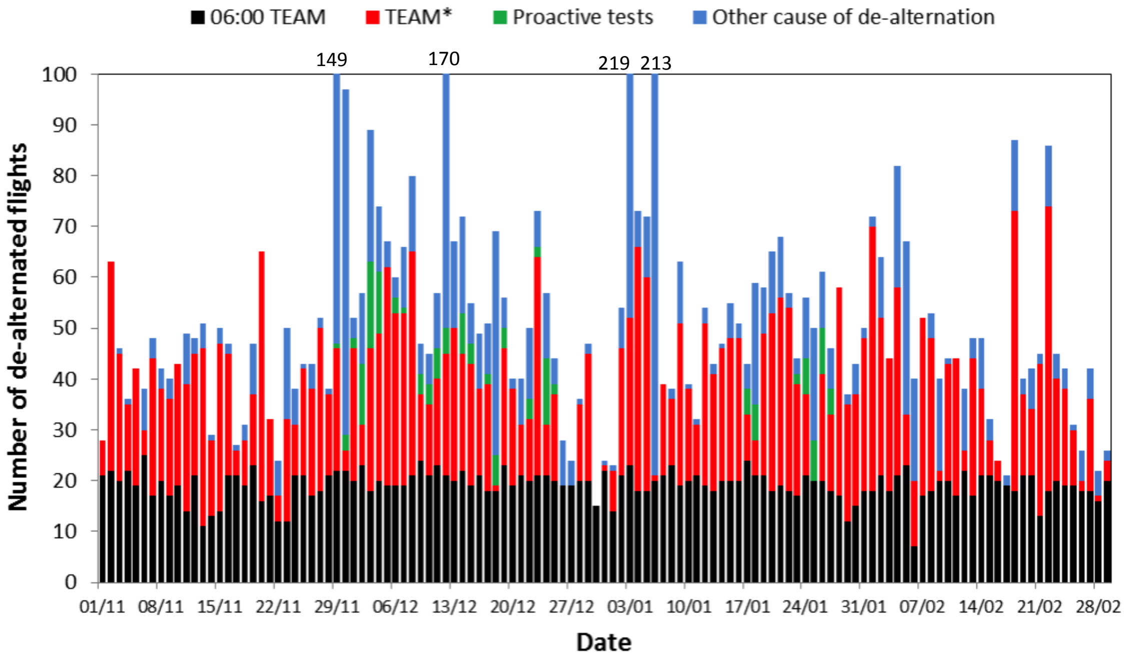


Figure 28: Occurrence and causes of arrivals de-alternation during Phase 1 of the trial (November 2011 to February 2012)

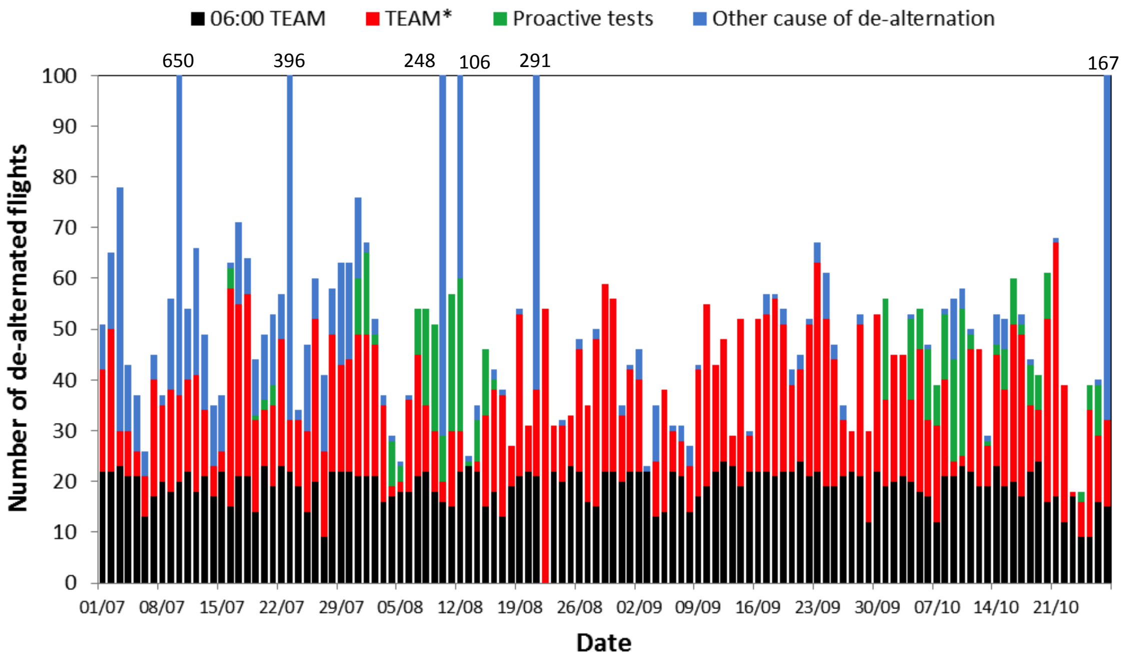


Figure 29: Occurrence and causes of arrivals de-alternation during the summer season of Phase 2 of the trial (July to October 2012)

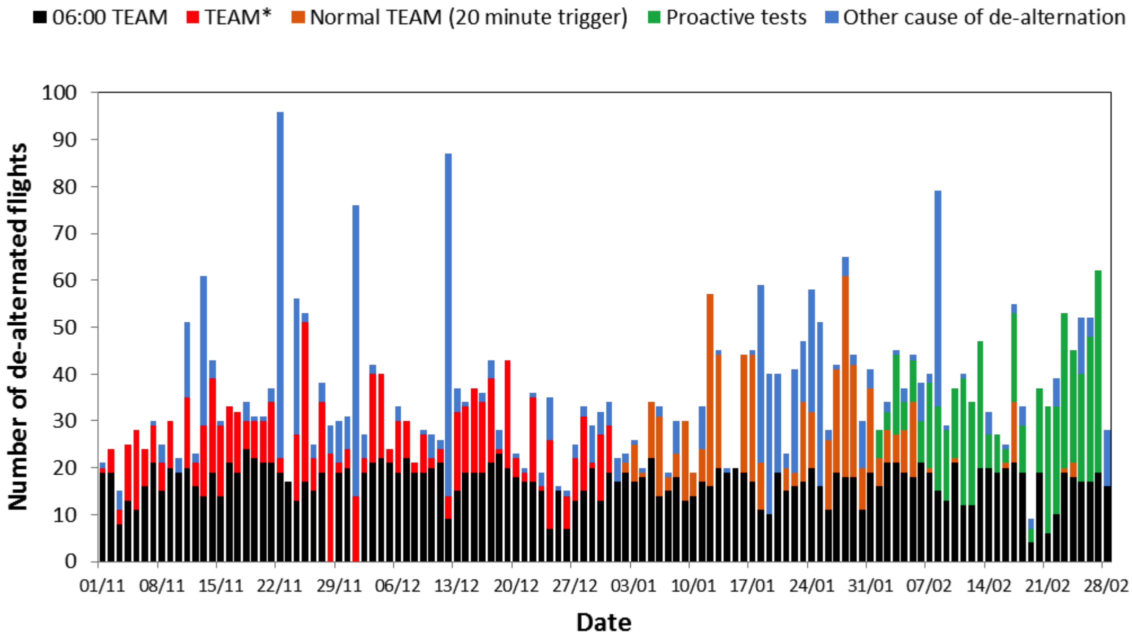


Figure 30: Occurrence and causes of arrivals de-alternation during the winter season of Phase 2 of the trial (November 2012 to February 2013)

Qualitatively the figures show:

- 06:00 hours TEAM* is a substantial and consistent component of the overall level of de-alternation and occurred on the vast majority of days during the trial period (13 August and 1 December 2012 are exceptions) during the trial
- there were ten days across the trial period where there was very large use of the designated departures runway for arrivals. These occurrences were due to issues with runway and taxiways and two major fires in the vicinity of the Airport. For Phase 2, these are described fully in the monthly reports, contained in Annexes A to H
- a reduction in the amount of TEAM* arrivals during November and December 2012, when the policy of not activating TEAM* when departure delays were occurring, was applied compared to other periods during the trial.

Figure 31 compares the average half-hourly profile of post-07:00 hours flights landing on the designated departure runway during the two winter elements of the trial, November 2011 to February 2012 and November 2012 to February 2012 respectively[3], with the equivalent data averaged over the previous three summer seasons. The figure also shows the peak level of Operational Freedoms flights in each half-hour interval across the winter 2012-13 period (data is not available at this granularity for Phase 1 of the trial and it must be stressed that these peaks did not all occur on the same day).

For Phase 1, as expected, the use of the designated departures runway for arrivals, considering all flights, is consistently higher across the day during the trial period than for the baseline (the

[3] Note that this includes a period when arrivals freedoms were not active during January 2013 but when normal TEAM with a 20 minute trigger was applied

average of the three pre-trial like-periods – winter 2008-09, winter 2009-10 and winter 2010-11) except for the short period from 12:30 hours to 15:30 hours when on average it was lower during the trial period than the baseline. For Phase 2 of the trial, however, the average level of de-alternation is consistently lower during the trial period than the baseline. This is likely due to the rule being applied that TEAM could not be activated if departure delays were occurring – this rule became active in late October 2012.

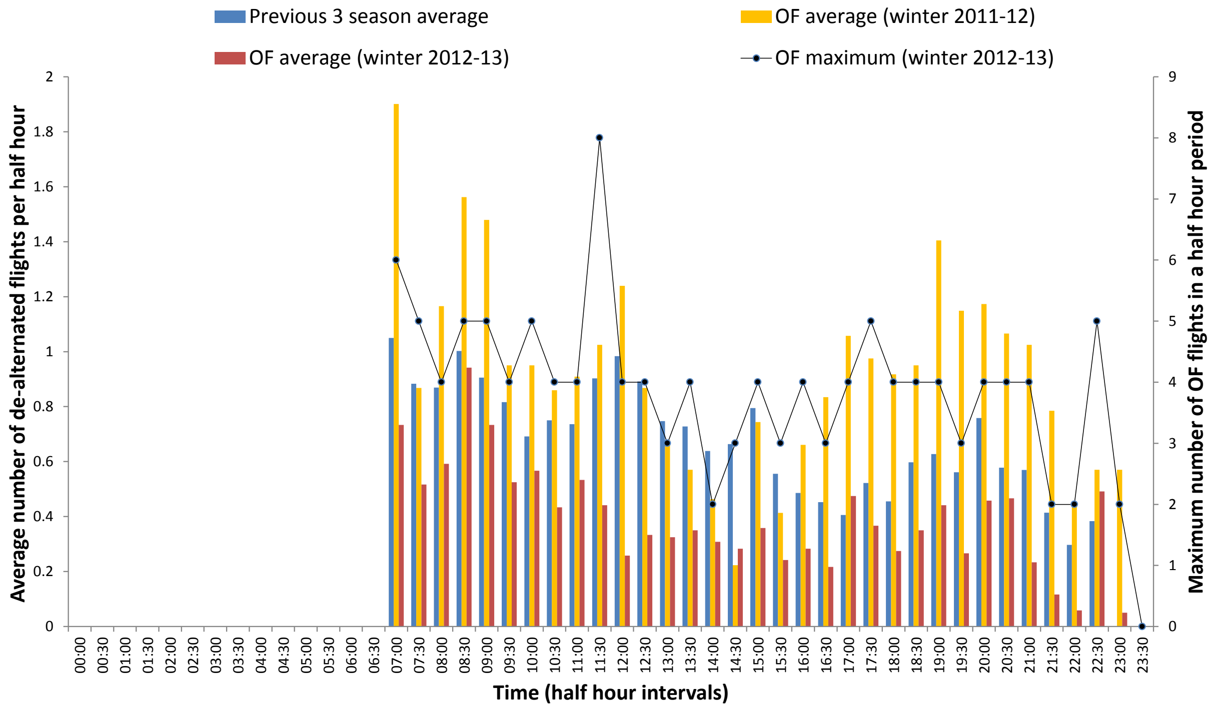


Figure 31: Comparison of OF landers in winter 2011-12 and winter 2012-13 with de-alternation levels over the last three similar periods

Figure 32 compares the average half-hourly profile of post-07:00 hours flights landing on the designated departure runway during the period from July to October 2012 with the equivalent data averaged over the previous three summer seasons. The figure also shows the peak level of Operational Freedoms flights in each half-hour interval across the trial.

As expected, the use of the designated departures runway for arrivals, considering all flights, is consistently higher across the day during the trial period except for the short period from 15:00 hours to 16:30 hours when on average it was lower during the trial period than the baseline. The application of OF landings, on average, also occurs to a greater extent in the morning than in the afternoon (ratio of 1.7:1 morning to afternoon) in contrast to the level of de-alternation over the previous three summers where the ratio morning to afternoon was 1.2:1.

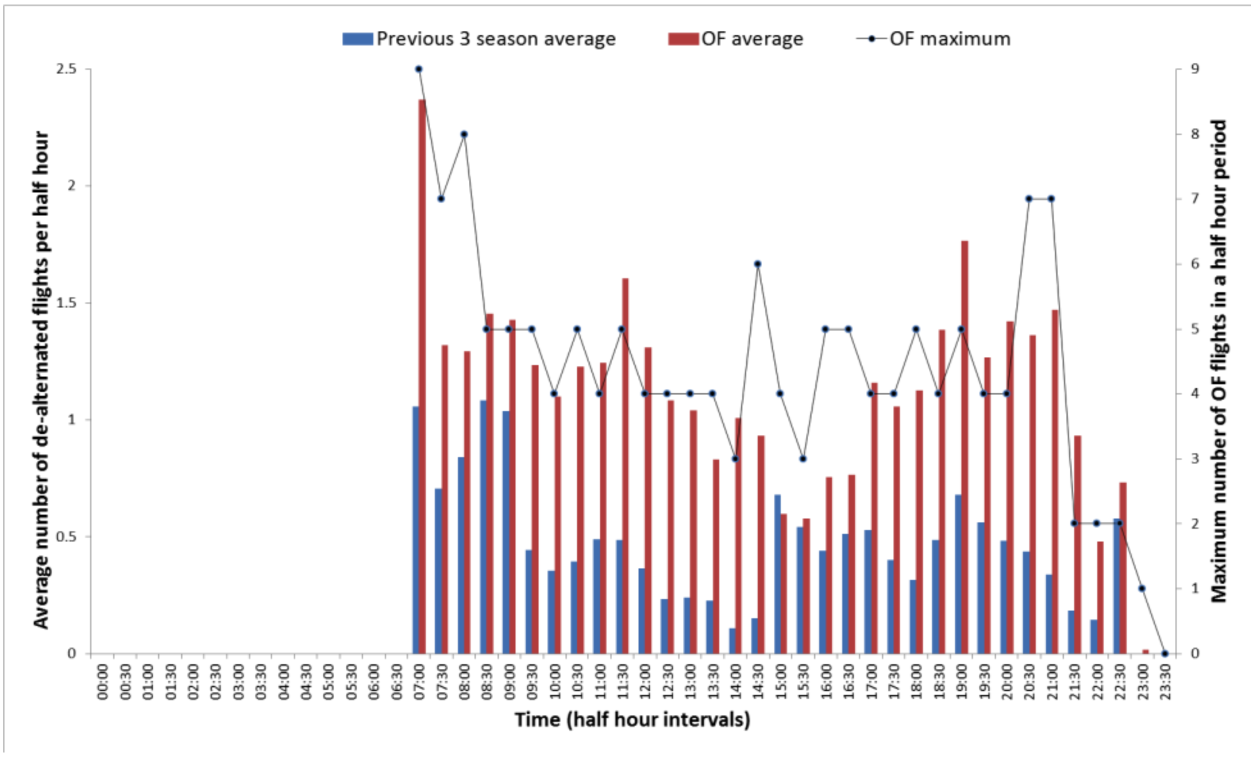


Figure 32: Comparison of OF landers in summer 2012 with de-alternation levels over the last three similar periods

Figure 33 compares the probability density functions (PDF) for the number of post 07:00 daily total de-alternated arrivals for Phase 1 of the trial and the three previous winter seasons (the winter baseline) for pure westerly and easterly operations. The westerly PDF only contains westerly and the easterly PDF only contains easterly days. All de-alternated flights compared to the published alternation pattern are included in both the trial data and that from the previous winters. Qualitatively the PDF for westerly operations during the trial has become less peaked and shifted towards higher levels of de-alternation than the baseline. The qualitative difference is less marked for easterly operations but again the PDF during the trial period appears to be shifted to higher levels of de-alternation than during the baseline and there are no easterly days when there was no de-alternation during the trial compared to approximately 2% of days with no post 07:00 easterly de-alternation during the baseline.

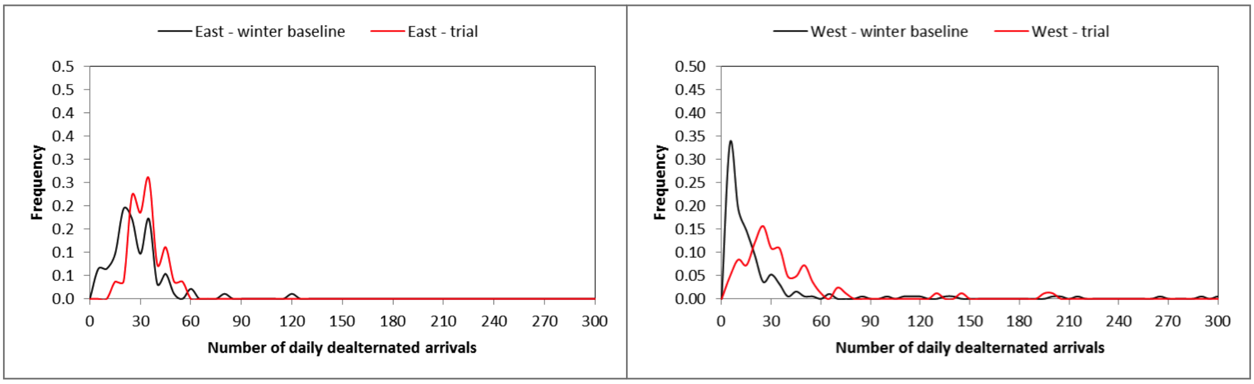


Figure 33: Comparison of the Phase 1 trial PDFs of daily arrival de-alternation with those for the baseline period for westerly and easterly operations

Figure 34 compares the probability density functions (PDF) for the number of post 07:00 daily total de-alternated arrivals for the Phase 2 summer trial period and the three previous summer seasons (the summer baseline) period for pure westerly and easterly operations. The westerly PDF only contains westerly and the easterly PDF only contains easterly days. All de-alternated flights compared to the published alternation pattern are included in both the trial data and that from the previous summers. Qualitatively the PDF for westerly operations during the trial has become less peaked and shifted towards higher levels of de-alternation than the baseline. There are also no westerly days with no post 07:00 de-alternation during the trial period. Due to the low number of easterly operations during the trial period, the associated PDF is very noisy and it is not possible to make any qualitative comparison with the previous three summers.

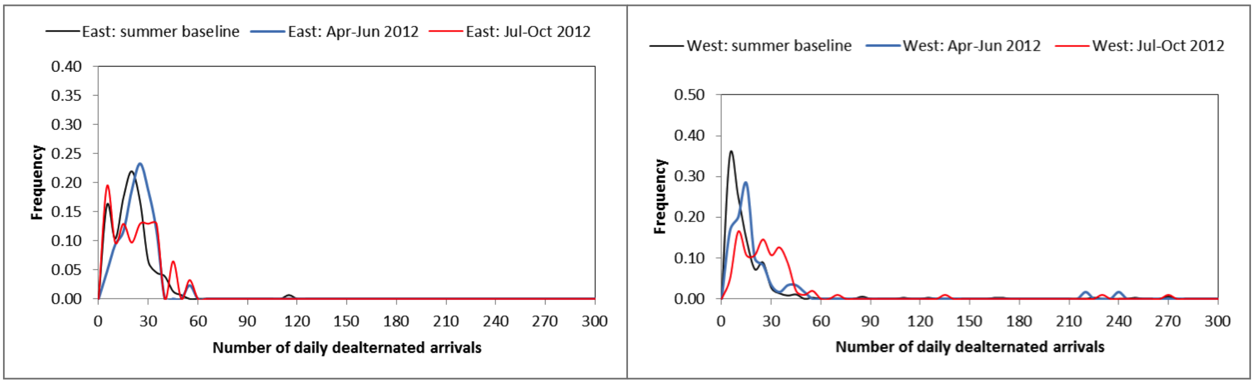


Figure 34: Comparison of the Phase 2 summer season trial PDFs of daily arrival de-alternation with those for the baseline period for westerly and easterly operations

Figure 35 compares the probability density functions (PDF) for the number of post 07:00 daily total de-alternated arrivals for the Phase 2 winter period (excluding January when no arrivals freedoms were active) and the winter baseline for pure westerly and easterly operations. There is little difference between the PDFs for the trial and baseline periods for easterly operations. For westerly operations, at low numbers of de-alternated arrivals there is again little difference between the trial and baseline PDFS: however, the trial period PDF has an additional pronounced peak at a de-alternation level of approximately 20 arrivals per day.

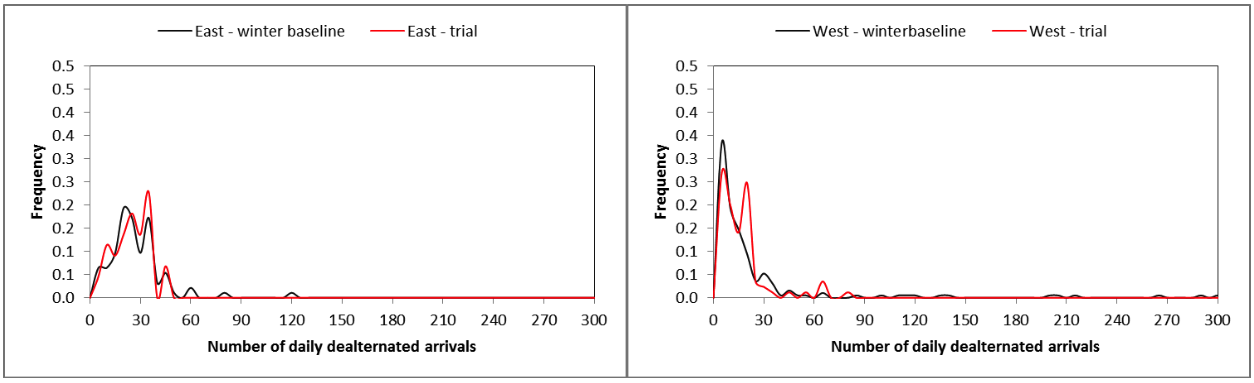


Figure 35: Comparison of the Phase 2 winter season trial PDFs of daily arrival de-alternation with those for the baseline period for westerly and easterly operations

Table 9, Table 10 and Table 11 below show the average, standard deviation and peak (as 95%ile) of the daily arrival de-alternation levels observed during the trial and baseline periods for Phase 1, Phase 2 summer and Phase 2 winter trial periods respectively.

	Winter baseline		Trial		Confidence	
	East	West	East	West	East	West
Average/day	24.96	23.14	31.30	34.43	99%	97%
Standard deviation	16.03	46.19	9.33	34.14	100%	100%
95%ile	45.00	110.00	45.00	70.00	n/a	n/a

Table 9: Comparison of arrival de-alternation statistics observed during the winter baseline and the Phase 1 trial period

	Summer baseline		Apr-Jun 2012		Trial Jul-Oct 2012		Confidence baseline - trial		Confidence Apr-Jun 2012-trial		Confidence baseline - Apr-Jun 2012	
	East	West	East	West	East	West	East	West	East	West	East	West
Average/day	17.83	15.03	21.44	22.25	20.10	37.10	60%	100%	36%	90%	96%	81%
Standard deviation	12.61	30.31	9.39	40.52	13.67	74.05	48%	100%	98%	100%	97%	100%
95%ile	35.00	30.00	30.00	40.00	40.00	65.00	n/a	n/a	n/a	n/a	n/a	n/a

Table 10: Comparison of arrival de-alternation statistics observed during the summer baseline and the Phase 2 summer trial period

	Winter baseline		Trial (excludes Jan)		Confidence	
	East	West	East	West	East	West
Average/day	24.96	23.14	22.89	14.84	84%	98%
Standard deviation	16.03	46.19	10.54	14.74	39%	100%
95%ile	45.00	110.00	40.00	50.00	n/a	n/a

Table 11: Comparison of arrival de-alternation statistics observed during the winter baseline and the Phase 2 winter trial period

The tables show:

- for the Phase 1 trial period, there are statistically significant increases in the level of de-alternation for both easterly and westerly operations compared to the baseline. On average these increases are from 24.96 to 31.30 de-alternated arrivals per day for easterlies and 23.14 to 34.43 de-alternated arrivals per day for westerlies
- similarly, for the Phase 2 summer period, there is a statistically significant increases in the level of de-alternation for westerly operations compared to the baseline. On average this increase is from 15.03 to 37.10 de-alternated arrivals per day. However, the increase in easterly de-alternated arrivals is only significant to a low level of confidence
- in contradiction, for the Phase 2 winter period, there is a statistically significant decrease in de-alternation levels compared to the baseline for westerly operations from 23.14 to 14.84 de-alternated arrivals per day. There is also an apparent reduction in easterly de-alternation levels from 24.96 to 22.89 de-alternated arrivals per day. It is very likely that this reduction is due to the change in policy on the application of TEAM that came into force in late October 2012.

The evidence from the two earlier phases of the trial suggests that the trial is associated with significantly increased westerly arrivals de-alternation but does not support the hypothesis that easterly arrivals on 09R would also increase. However, it appears that restricting TEAM to periods when there is no departure delay would decrease de-alternation levels

3.3 Runway throughput

Taking into account the balance of the trial towards applying Operational Freedoms to arrivals rather than departures, the hypotheses to be tested associated with runway throughput are:

- both OF TEAM and proactive tests will increase the arrivals runway throughput when they are applied
- both OF TEAM and proactive tests will decrease the departures runway throughput when they are applied
- OF vectors will increase the departures runway throughput when they are applied.

Runway throughputs for Phase 2 of the trial have been tested using multivariate regression as described in Section 2.

3.3.1 Arrivals

Figure 36, Figure 37 and Figure 38 compares the average runway arrival rates, defined as the average number of arrivals per hour between 07:00 and 20:00 hours, for the three trial periods with their respective baselines.

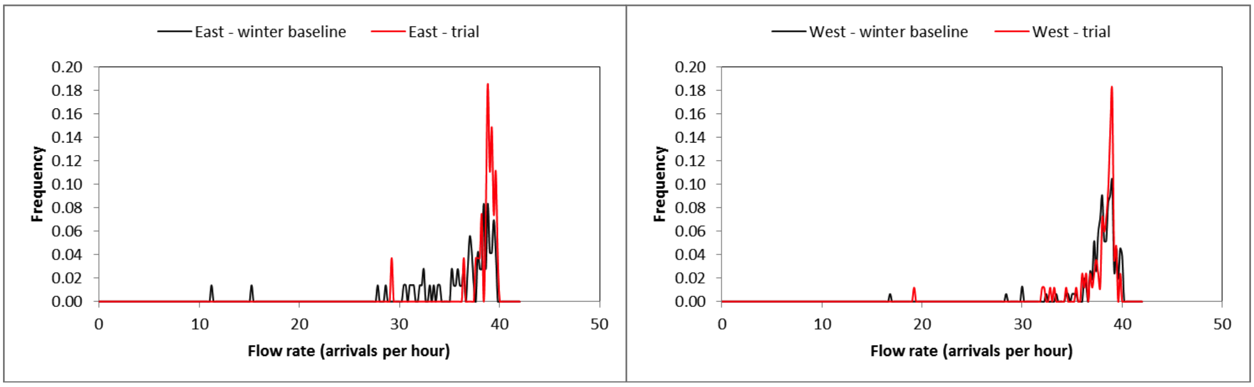


Figure 36: Comparison of the Phase 1 trial average runway arrival rate PDFs with the winter baseline westerly and easterly operations

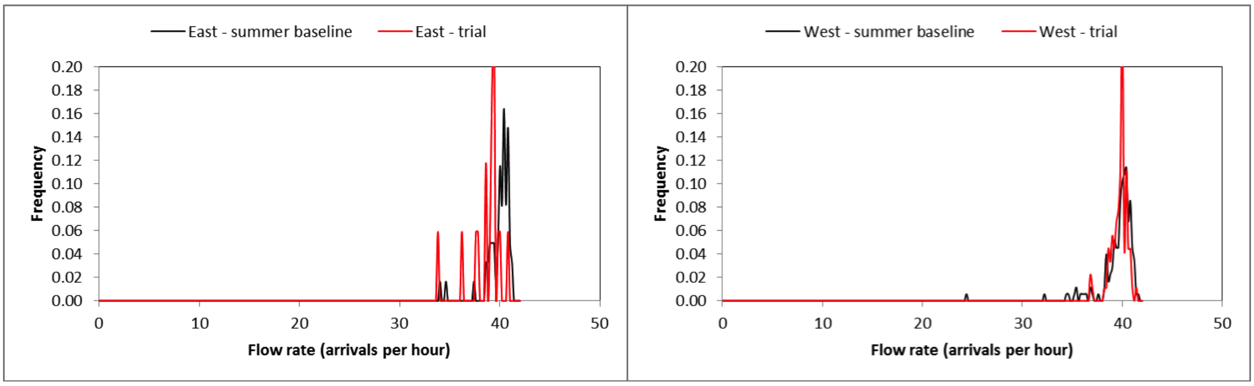


Figure 37: Comparison of the Phase 2 summer trial average runway arrival rate PDFs with the summer baseline westerly and easterly operations

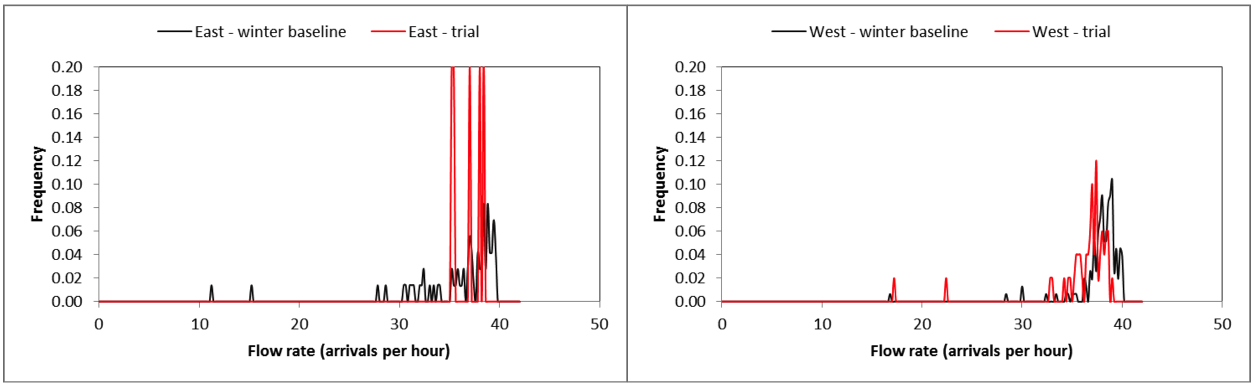


Figure 38: Comparison of the Phase 2 winter trial average runway arrival rate PDFs with the winter baseline westerly and easterly operations

Qualitatively the figures suggest that for Phase 1 and summer of Phase 2 there appears to be very little difference between the trial and the baseline for westerly operations. In these two cases, there also appears to be little difference for easterly operations but the comparison is made more difficult because of the statistical noise on the trial data caused by small sample size. However, for winter of Phase 2 the figures suggest a decrease in the average runway arrival rates for both easterly and westerly operations.

Table 12, Table 13 and Table 14 compare the runway arrival rate statistics for Phase 1, summer of Phase 2 and winter of Phase 2 of the trial with their respective baseline periods.

	Baseline		Trial		Confidence	
	East	West	East	West	East	West
Average	34.94	37.71	38.35	37.69	100%	1%
Standard deviation	7.21	2.67	1.98	2.59	100%	16%
95%ile	39.20	39.60	39.40	39.20	n/a	n/a

Table 12: Comparison of runway arrival rate statistics observed during the winter baseline and the Phase 1 winter trial period

	Baseline		Trial		Confidence	
	East	West	East	West	East	West
Average	39.63	39.59	38.59	39.63	33%	8%
Standard deviation	1.48	1.66	0.97	0.82	31%	100%
95%ile	40.80	40.80	40.60	40.60	n/a	n/a

Table 13: Comparison of runway arrival rate statistics observed during the summer baseline and the Phase 2 summer trial period

	Baseline		Trial (Nov &Dec)		Confidence	
	East	West	East	West	East	West
Average	34.94	37.71	36.65	36.05	42%	99%
Standard deviation	7.21	2.67	1.45	3.70	63%	100%
95%ile	39.20	39.60	38.20	38.40	n/a	n/a

Table 14: Comparison of runway arrival rate statistics observed during the winter baseline and the Phase 2 winter trial period

The tables show that:

- for the Phase 1 trial period, there was a statistically significant increase in average runway arrival rate on easterly operations compared to the winter baseline but no difference in average runway arrival rates on westerly operations compared to the winter baseline
- for the Phase 2 summer trial period, there was no statistically significant change in average runway arrival rate for either easterly or westerly operations compared to the summer baseline
- for the Phase 2 winter trial period, there was no statistically significant change in average runway arrival rate for easterly operations compared to the winter baseline but that there was a statistically significant reduction in average runway arrival rate on westerly operations compared to the winter baseline.

The comparisons reported above given an indication of the macro-level differences between the trial period and the selected baselines. These differences are potentially due to multiple causes, not only Operational Freedoms, and therefore might not agree with the results of the regression analysis, which isolates the effects of Operational Freedoms. These comparisons will likely be influenced by Operational Freedoms but will also be subject to other influencing factors, for example overall levels of demand (the higher the demand the higher the likely throughput of the runway). This perhaps partly explains the lower observed rates for the winter periods than the summer periods because demand is generally lower in winter than summer.

Multivariate regression has been used to isolate the specific impacts of Operational Freedoms on arrivals rates using a linear function:

$$Runwayarrival\ rate = C_0 + \sum_{i=1}^{N} \alpha_i\ A_i$$

where: C_o is a constant, α_i are the regression coefficients and A_i are the independent variables. The following table shows the simple linear correlations between all of the variables used in the regression. the change in arrival rate (Δ_{Arr}) is, therefore, given by:

$$\Delta_{Arr} = N_{OF}\alpha_{regression}$$

- N_{OF} is the number of Operational Freedoms applied per unit time
- $\alpha_{regression}$ is the coefficient derived from the regression analysis.

Three sets of analyses have been performed:

- Phase 2 summer period, including the impact of TEAM* and proactive tests
- Phase 2 winter period, November and December, only including the impacts of TEAM*
- the combined periods when proactive tests were active (July 15 to August 15 2012, November 2012 and February 2013).

Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1.

The results of these analyses are highlighted in Table 15 below and the full results are provided in Annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
TEAM* summer 2012	0.269	0.031	8.623	100%	0.75
TEAM* winter 2012	0.215	0.060	3.613	100%	0.65
Proactive tests summer 2012	0.347	0.075	4.596	100%	0.75
Proactive tests summer 2012 & winter 2012-13	0.319	0.082	3.901	100%	0.15

Table 15: Regression analysis results for runway arrival rate

The table shows there is an increase in landing rate of approximately 0.27 landings per unit time associated with each TEAM* lander in the summer period and 0.22 landings per unit time associated with each TEAM* lander in the winter period. The proactive tests performed during the summer period are associated with an increase of approximately 0.35 landings per unit with one operational freedom lander during the same unit time. All of these results are associated with a high level of confidence.

The summer and winter R^2 values are 0.75 and 0.65 respectively indicating that the indicating that the regression gives a reasonable description of the data, capturing the majority of the influencing factors. However, for the proactive test periods alone the R^2 value is only 0.15 indicating a poor description of the data.

The analysis supports the hypothesis that both OF TEAM and proactive tests increase the runway arrival rate

3.3.2 Departures

Figure 39, Figure 40 and Figure 41 compare the average runway departure rates, defined as the average number of arrivals per hour between 07:00 and 20:00 hours, for the three trial periods with their respective baselines.

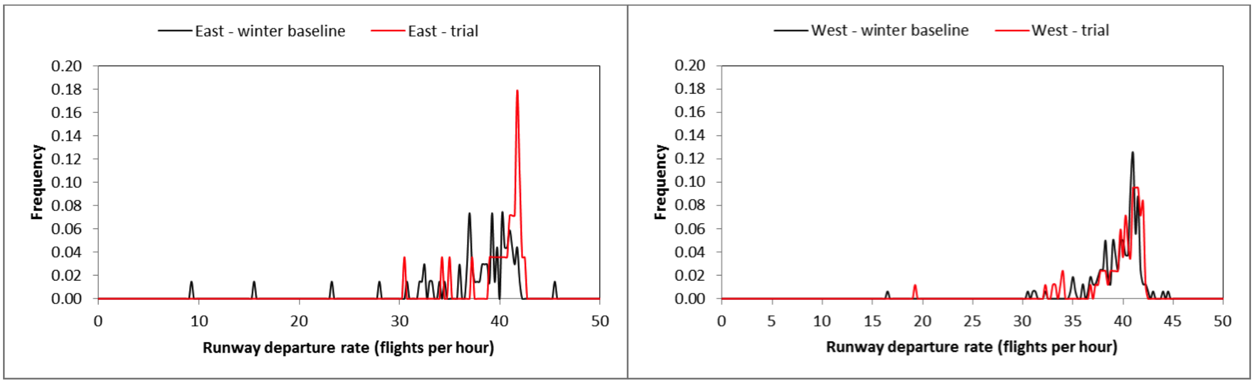


Figure 39: Comparison of the Phase 1 trial average runway departure rate PDFs with the winter baseline westerly and easterly operations

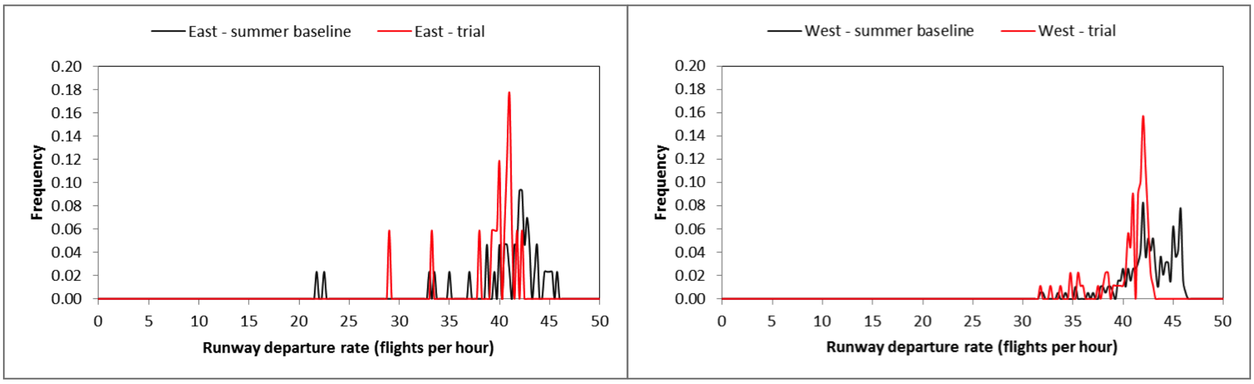


Figure 40: Comparison of the Phase 2 summer trial average runway departure rate PDFs with the summer baseline westerly and easterly operations

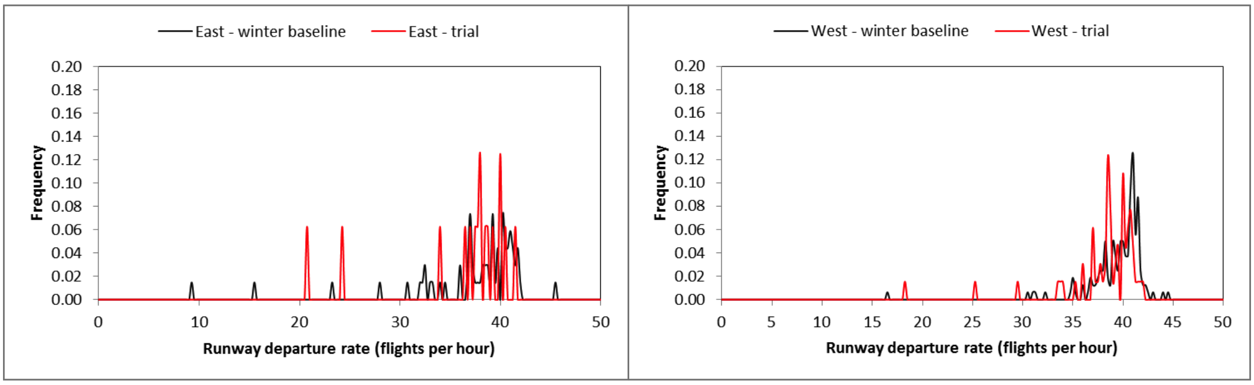


Figure 41: Comparison of the Phase 2 winter trial average runway departure rate PDFs with the winter baseline westerly and easterly operations

Qualitatively the figures suggest that for the winter components of the trial, there appears to be very little difference in average departure rates between the trial and the baseline for both easterly and westerly operations. However, for the summer period there is a marked difference at high departure rates between the trial and baseline periods. The maximum achieved average departure rate for the trial period appears to be approximately 42 departures per hour whereas for the baseline period there is an additional peak at a departure rate of approximately 45 per hour, more pronounced for westerly than easterly operations.

Table 16, Table 17 and Table 18 compare the runway departure rate statistics for Phase 1, summer of Phase 2 and winter of Phase 2 of the trial with their respective baseline periods.

	Baseline		Trial		Confidence	
	East	West	East	West	East	West
Average	36.25	39.26	39.99	39.55	100%	51%
Standard deviation	7.81	3.24	2.76	3.18	100%	13%
95%ile	41.50	41.75	42.00	41.75	n/a	n/a

Table 16: Comparison of runway departure rate statistics observed during the winter baseline and the Phase 1 winter trial period

	Summer baseline		Trial		Confidence	
	East	West	East	West	East	West
Average	40.63	42.51	39.25	40.46	83%	100%
Standard deviation	5.23	2.84	4.42	2.31	58%	72%
95%ile	44.75	45.50	42.00	42.25	n/a	n/a

Table 17: Comparison of runway departure rate statistics observed during the summer baseline and the Phase 2 summer trial period

	Winter baseline		Trial		Confidence	
	East	West	East	West	East	West
Average	36.25	39.26	36.29	38.17	84%	95%
Standard deviation	7.81	3.24	5.75	3.73	88%	96%
95%ile	41.50	41.75	41.25	41.00	n/a	n/a

Table 18: Comparison of runway arrival rate statistics observed during the winter baseline and the Phase 2 winter trial period

The tables show:

- for the Phase 1 trial period, there was a statistically significant increase in average runway departure rate on easterly operations compared to the winter baseline but no significant difference in average runway arrival rates on westerly operations compared to the winter baseline
- for the Phase 2 summer trial period, there was no statistically significant difference in average runway departure rate for easterly operations compared to the summer baseline but a statistically significant decrease in average departure rate on westerly operations compared to the baseline
- for the Phase 2 winter trial period, there was no statistically significant change in average runway arrival rate for easterly operations compared to the winter baseline but that there was a marginally significant reduction in average runway departure rate on westerly operations compared to the winter baseline.

The comparisons reported above given an indication of the macro-level differences between the trial period and the selected baselines. Multivariate regression has been used to isolate the specific impacts of Operational Freedoms on departure rates using a linear function:

$$Runwaydeparturerate = C_0 + \sum_{i=1}^{N} \alpha_i \, A_i$$

where: C_o is a constant, α_i are the regression coefficients and A_i are the independent variables. The following table shows the simple linear correlations between all of the variables used in the regression. The change in arrival rate (Δ_{Dep}) is, therefore, given by:

$$\Delta_{Dep} = N_{OF}\alpha_{regression}$$

- N_{OF} is the number of Operational Freedoms applied per unit time
- $\alpha_{regression}$ is the coefficient derived from the regression analysis.

Two sets of analyses have been performed:

- Phase 2 summer period, including the impact of OF vectors and TEAM landers (TEAM* and proactive tests combined)
- Phase 2 winter period including the impacts of TEAM landers (TEAM*, proactive tests and conventional TEAM with a 20 minute trigger in January when Operational Freedoms were not active).

Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1. In addition, during Phase 1 of the trial, there were too few TEDs applied to measure any impact on either departures or arrivals.

The results of these analyses are highlighted in Table 19 below and the full results are provided in Annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
OF vectors summer 2012	0.257	0.027	9.430	100%	0.61
OF vectors winter 2012-13	0.143	0.038	3.805	100%	0.79
TEAM landers summer 2012	-0.571	0.035	-16.321	100%	0.61
TEAM landers winter 2012-13	-0.618	0.056	-11.080	100%	0.79

Table 19: Regression analysis results for runway departure rate

The table shows that OF vectors are associated with an increase in departure rate per unit time of approximately 0.26 departures per OF vector in the summer period and of approximately 0.14 departures per OF vector in the winter period. These associations have a very high level of confidence and the summer and winter regressions have R^2 values of 0.61 and 0.79 for Phase 2 summer and winter respectively, indicating a reasonable explanation of the data by the regression.

The negative impact of TEAM landers on departure rates is strong, reducing departure rates by approximately 0.57 departures per TEAM lander in summer and 0.62 departures per TEAM lander in winter. The statistical significance of the association is again strong and the R^2 values indicate a reasonable explanation of the data by the regression. It is highly likely, but not proven, that the high level of TEAM landers is the root cause of the suppression of the very high average departure rates observed in the baseline period but not the trial period, see Figure 40.

The analysis supports the hypothesis that runway departure rates would increase if OF vectors are applied. It also supports the hypothesis that arrivals on the designated departure runway would decrease runway departure rates

3.4 Arrival delays

Arrival delays have two main components associated with Heathrow:

- air traffic flow management delays incurred at the origin airport and imposed as regulations by Eurocontrol's Central Flow Management Unit (CFMU). These delays are only incurred by flights originating from within the CFMU area, essentially Europe and may be due to capacity constraints at any point along the flight path. The ATFM regulation imposes an ATFM delay on the affected aircraft by imposing a calculated take-off time (CTOT) on the flight to ensure its passage to its destination is not impeded by capacity constraints along the way. The ATFM delay is the difference between the CTOT and the take-off time estimated in the aircraft's flight plan. Only those delays that have been classified as being caused by Heathrow are considered in this analysis

- stack holding delays. In holding stacks aircraft fly in a spiral racetrack pattern, entering at the top, descending through several levels and exiting at the bottom. Stacks are used to moderate the demand for the runway, as a buffer to allow air traffic controllers to sequence aircraft to optimise the throughput of the runway whilst maintaining separation between aircraft to ensure that the following aircraft is not affected by the preceding aircraft's wake vortex. This separation varies depending on the sequence of aircraft (heavy-heavy, heavy-light, light-heavy, etc.). In simple terms the separation for a lighter aircraft following a heavier aircraft must be greater than if the sequence were the other way round. In this report, this process is called stack holding and the time that each aircraft spends in the stack is termed the stack holding time.

Generally, air traffic control's preference is to manage arrivals flow locally using Heathrow's four holding stacks with ATFM regulations only being applied when a significant arrivals overload is predicted, usually due to some restriction on capacity at Heathrow, for example caused by bad weather.

The hypotheses to be tested concerning arrivals delays are:

- application of arrivals freedoms will be associated with a reduction in Heathrow attributed ATFM delays
- application of arrivals freedoms will be associated with a reduction in stackholding delay.

3.4.1 ATFM delays

Multivariate regression has been used to isolate the specific impacts of Operational Freedoms on average ATFM delay per flight using a linear function:

$$ATFMdelay = C_0 + \sum_{i=1}^{N} \alpha_i \ A_i$$

where: C_o is a constant, α_i are the regression coefficients and A_i are the independent variables. The following table shows the simple linear correlations between all of the variables used in the regression. The change in average ATFM delay per flight (Δ_{ATFM}) is, therefore, given by:

$$\Delta_{ATFM} = N_{OF}\alpha_{regression}$$

- N_{OF} is the number of Operational Freedoms applied per unit time
- $\alpha_{regression}$ is the coefficient derived from the regression analysis.

Two sets of analyses have been performed:

- Phase 2 summer period, assessing the impact of TEAM* and proactive tests separately
- Phase 2 winter period assessing the impact of TEAM* and proactive tests separately.

The analyses include an assessment of the impact of time lags on average ATFM delay per flight, considering four time intervals for the application of the Operational Freedoms relative to the time that the delay was experienced: 90 minutes earlier; 60 minutes earlier, 30 minutes earlier and in the same time period.

Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1. The results of these analyses are highlighted in Table 20 below and the full results are provided in Annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
TEAM* summer 2012 (time t_0)	-0.348	0.110	-3.170	99.8%	0.25
TEAM* summer 2012 (time t_0 – 30 minutes)	-0.305	0.111	-2.752	99.4%	
TEAM* summer 2012 (time t_0 – 60 minutes)	-0.156	0.110	-1.416	84.3%	
TEAM* summer 2012 (time t_0 – 90 minutes)	0.064	0.103	0.623	46.7%	
TEAM* winter 2012-13 (time t_0)	0.007	0.036	0.199	15.8%	0.30
TEAM* winter 2012-13 (time t_0 – 30 minutes)	-0.009	0.037	-0.254	20.0%	
TEAM* winter 2012-13 (time t_0 – 60 minutes)	-0.002	0.037	-0.056	4.4%	
TEAM* winter 2012-13 (time t_0 – 90 minutes)	0.028	0.035	0.810	58.0%	
Proactive tests 2012 (time t_0)	-0.185	0.154	-1.206	73.2%	0.14
Proactive tests 2012 (time t_0 - 30 minutes)	-0.160	0.152	-1.051	71.7%	
Proactive tests 2012 (time t_0 - 60 minutes)	-0.222	0.141	-1.578	88.5%	
Proactive tests 2012 (time t_0 - 90 minutes)	-0.285	0.136	-2.097	96.4%	

Table 20: Regression analysis results for ATFM delay

The table shows that:

- the association of proactive tests with ATFM delays has low confidence levels and cannot be considered to be significant for either the Phase 2 summer or winter trial periods
- similarly, the association between TEAM* and ATFM delays is of low confidence during the Phase 2 winter trial and also cannot be considered to be significant
- for the Phase 2 summer trial, TEAM* applied at the time of the delay and thirty minutes earlier has a significant negative association with ATFM delays: this means that the application of TEAM* is associated with a reduction in average ATFM delay per flight of approximately 0.3 minutes per TEAM* lander both at the time that TEAM* is applied and 30 minutes later. However, the R^2 associated with this regression is only 0.25 indicating that the analysis does not capture the majority of influencing factors and adding uncertainty to the result.

The results of the analysis are inconclusive: while there is some evidence to suggest a tentative association between the application TEAM* and proactive and a reduction in LHR attributed ATFM delays in the summer part of the trial; there is no evidence to suggest a similar association during the winter part of the trial

3.4.2 Stackholding delays

Figure 42, Figure 43 and Figure 44 show the probability distribution functions (PDFs) for Heathrow stack holding on westerly and easterly operations for the Phase 1 and the summer and winter parts of Phase 2 of the trial compared to the appropriate baselines. The PDFs are a combination of the PDFs of Heathrow's four individual stacks. The distributions show multiple peaks: one centred at zero representing aircraft that were not held in the stacks; one split-peak centred at a holding delay of approximately four minutes representing aircraft that flew one circuit of the stacks with the split indicating different sizes for each of the four stacks; one centred at approximately ten minutes representing aircraft that flew two circuits of the stacks and so on. The magnitudes of the peaks decrease as the stack holding time increases, indicating lower probabilities of flying higher numbers of circuits.

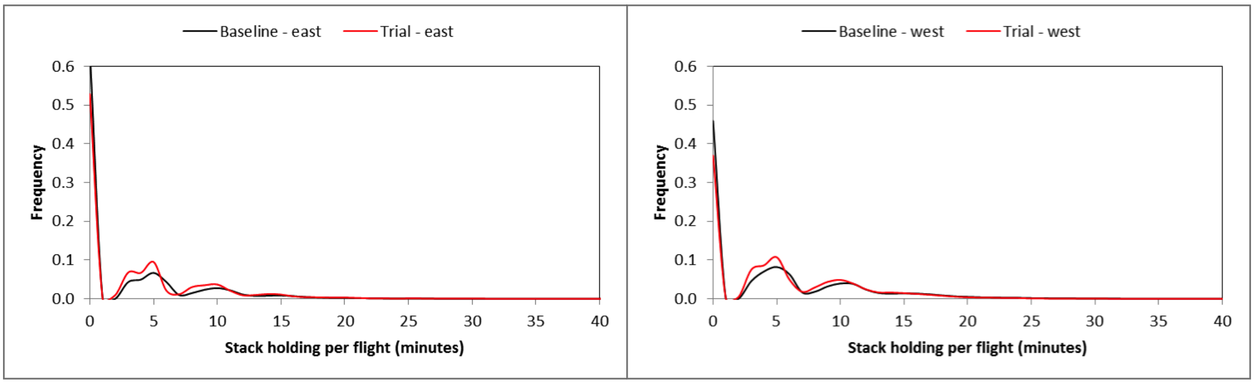


Figure 42: Comparison of the Phase 1 trial stackholding PDFs with the winter baseline for westerly and easterly operations

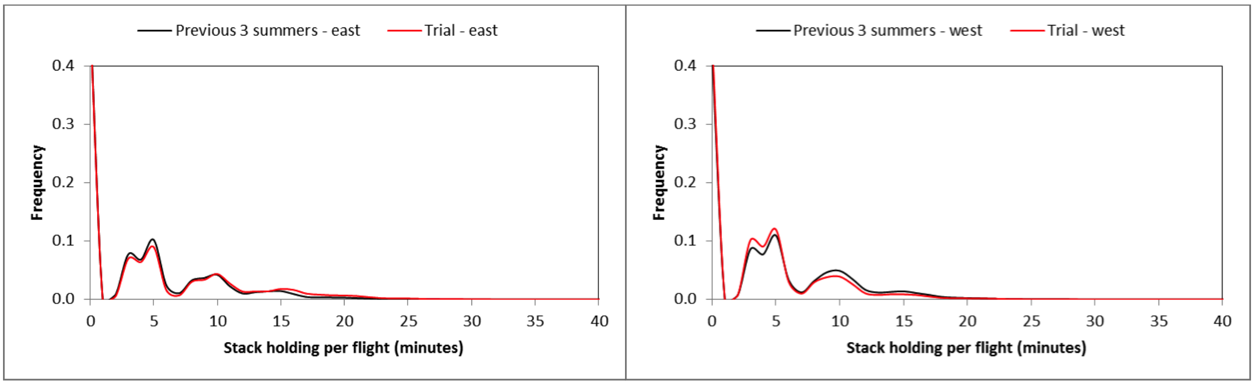


Figure 43: Comparison of the Phase 2 summer trial stackholding PDFs with the winter baseline for westerly and easterly operations

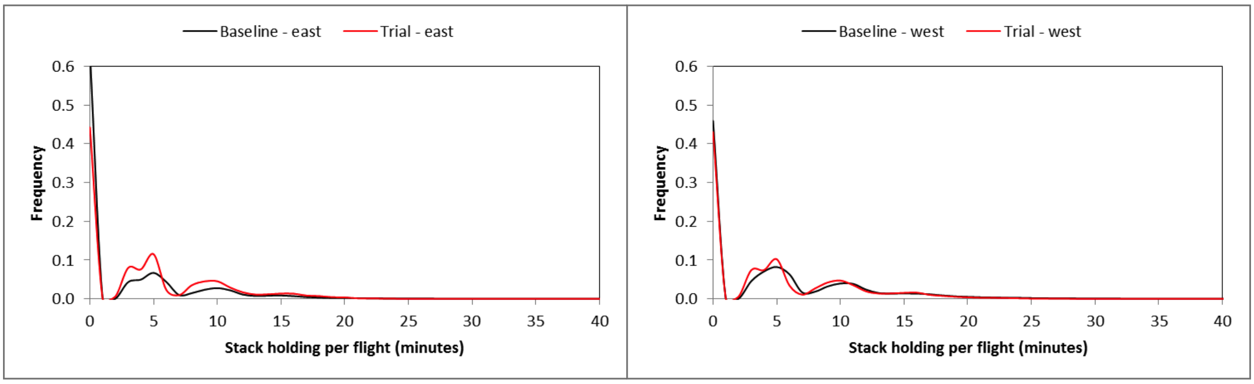


Figure 44: Comparison of the Phase 2 winter trial stackholding PDFs with the winter baseline for westerly and easterly operations

Qualitatively, comparison of the PDFs suggests:

- for Phase 1 the dual peak associated with one circuit of the stacks is more pronounced in the trial period than the baseline and there appears to be a slightly increased magnitude of the trial period PDFs indicating slightly higher stack holding
- for the Phase 2 summer period, a slight relative decrease of the proportion of the flights making one circuit and corresponding increase in the proportion of flights making three circuits in the trial period compared to the previous three summers on easterly operations, noting however, the very low proportion of easterly operations during the trial. The PDFs suggest the reverse on westerly operations where there appears to be a reduction in the proportion of flights making two circuits with a corresponding increase of the proportion making one circuit in the trial compared to the previous three summers
- for the Phase 2 winter period the dual peak associated with one circuit of the stacks is more pronounced in the trial period than the baseline, stackholding appears higher on easterlies during the trial than the baseline but the magnitudes of stackholding appear similar between trial and baseline on westerly operations.

Table 21, Table 22 and Table 23 show the average and standard deviation of Heathrow's stack holding PDFs as well as the proportion of flights not held and the peak holding time, as indicated by the 95%ile, comparing the trial and baseline periods overall on easterly and westerly operations and for both easterly and westerly operations combined (total).

	Phase 1 trial			Winter baseline			Confidence levels		
	East	West	Total	East	West	Total	East	West	Total
Average	3.6	5.1	4.7	2.8	4.8	4.2	100%	100%	100%
Standard deviation	5.2	5.6	5.5	4.8	6.0	5.7			
Proportion of flights not held	52.8%	36.9%	41.2%	63.7%	45.9%	51.5%			
95%ile	13.51	15.51	15.01	12.11	16.35	15.42			

Table 21: Comparison of stackholding statistics observed during the winter baseline and Phase 1 of the trial

	Trial			Previous 3 summers			Confidence levels		
	East	West	Total	East	West	Total	East	West	Total
Average	4.5	3.8	3.9	3.8	4.4	4.3	30%	100%	100%
Standard deviation	5.9	4.6	4.9	5.0	5.0	5.0			
Proportion of flights not held	48.4%	44.4%	45.1%	49.1%	42.0%	43.4%			
95%ile	16.25	12.37	13.53	13.74	14.01	13.95			

Table 22: Comparison of stackholding statistics observed during the summer baseline and the Phase 2 summer trial period

	Trial			Winter baseline			Confidence levels		
	East	West	Total	East	West	Total	East	West	Total
Average	4.2	4.6	4.6	2.8	4.8	4.2	100%	100%	100%
Standard deviation	5.0	5.5	5.4	4.8	6.0	5.7			
Proportion of flights not held	44.2%	43.0%	43.2%	63.7%	45.9%	51.5%			
95%ile	14.32	15.32	15.18	12.11	16.35	15.42			

Table 23: Comparison of stackholding statistics observed during the winter baseline and the Phase 2 winter trial period

The tables show that:

- for Phase 1 for westerly operations during the trial period, counter to expectations average stack holding increased to 5.1 minutes per flight compared to 4.8 minutes per flight during the baseline but for easterly operations, the difference in average stack holding per flight (3.6 minutes in the trial and 2.8 minutes per flight during the baseline) was not statistically significant

- for the summer period of Phase 2 for westerly operations during the trial period, average stack holding decreased significantly to 3.8 minutes per flight compared to 4.4 minutes per flight for the baseline. For easterly operations, the difference in average stack holding per flight (4.5 minutes per flight in the trial and 4.4 minutes per flight during the previous three summers) is not statistically significant

- for the winter period of Phase 2 for westerly operations during the trial period, average stack holding has decreased significantly to 4.6 minutes per flight compared to 4.8 minutes per flight for the baseline. For easterly operations, average stack holding per flight increased to 4.2 minutes per flight in the trial compared to 2.8 minutes per flight during the baseline: this increase is statistically significant.

Multivariate regression has been used to isolate the specific impacts of Operational Freedoms on average stackholding delay per flight using a square root transformation:

$$(Stackholding delay)^2 = C_0 + \sum_{i=1}^{N} \alpha_i \ A_i$$

where: C_o is a constant, α_i are the regression coefficients and A_i are the independent variables. The following table shows the simple linear correlations between all of the variables used in the regression. The change the average stackholding delay per flight is associated with the application of Operational Freedoms, therefore, given by:

$$(Stackholding_0)^2 - \left(Stackholding_{N_{OF}}\right)^2 = N_{OF}\alpha_{regression}$$

- $Stackholding_0$ is the stackholding without Operational Freedoms
- $Stackholding_{N_{OF}}$is the stackholding with N_{OF} being the number of Operational Freedoms applied per unit time
- $\alpha_{regression}$ is the coefficient derived from the regression analysis.

It is not straightforward, therefore

Two sets of analyses have been performed:

- Phase 2 summer period, assessing the impact of TEAM* and proactive tests separately
- Phase 2 winter period assessing the impact of TEAM* and proactive tests separately.

The analyses include an assessment of the impact of time lags on average stackholding delay per flight, considering four time intervals for the application of the Operational Freedoms relative to the time that the delay was experienced: 90 minutes earlier; 60 minutes earlier, 30 minutes earlier and in the same time period.

Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1. The results of these analyses are highlighted in Table 24 below and the full results are provided in Annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
TEAM* summer 2012 (time t_0)	0.057	0.012	4.781	100%	0.64
TEAM* summer 2012 (time t_0 – 30 minutes)	-0.002	0.012	-0.138	10.9%	
TEAM* summer 2012 (time t_0 – 60 minutes)	-0.014	0.012	-1.148	74.9%	
TEAM* summer 2012 (time t_0 – 90 minutes)	-0.002	0.011	-0.184	14.6%	
TEAM* winter 2012-13 (time t_0)	0.049	0.018	2.636	99.2%	0.69
TEAM* winter 2012-13 (time t_0 – 30 minutes)	-0.013	0.019	-0.680	50.3%	
TEAM* winter 2012-13 (time t_0 – 60 minutes)	0.008	0.019	0.436	43.7%	
TEAM* winter 2012-13 (time t_0 – 90 minutes)	0.025	0.018	1.350	86.3%	
Proactive tests 2012-13 (time t_0)	0.016	0.025	0.648	48.3%	0.62
Proactive tests 2012-13 (time t_0 - 30 minutes)	0.038	0.023	1.653	90.2%	
Proactive tests 2012-13 (time t_0 - 60 minutes)	0.015	0.022	0.683	50.6%	
Proactive tests 2012-13 (time t_0 - 90 minutes)	-	-	-	-	

Table 24: Regression analysis results for stackholding delay

For each of the regressions, the table shows an R^2 greater then 0.60, indicating that the regression captures a reasonable proportion of the significant influencing factors. However, the confidence levels are too low for the proactive tests to conclude that there is any association between proactive tests and stackholding.

For TEAM*, there is a significant association between the application of TEAM* and stackholding in the same time period. However, the sign of the association is counter-intuitive and suggests that TEAM* is associated with an increase in stackholding; whereas a decrease would have been expected.

A possible explanation of this counter-intuitive result is as follows. The simultaneous use of two runways for arrivals on westerly operations depends on a trigger condition being met or anticipated. This trigger condition is 20 minutes stackholding delay under normal circumstances reduced to 10 minutes during the Operational Freedoms trial. The trigger condition does not apply to easterly operations. Therefore it would be expected that stackholding would be higher when TEAM is being applied and two runways are being used on westerly operations because TEAM would not be triggered if the stackholding was not anticipated to meet the trigger condition. Therefore, elevated stackholding is causing the application of TEAM on westerly operations.

This hypothesis is supported by the following two charts, Figure 45 and Figure 46 that compare the average stackholding per flight experienced during one and two (TEAM) runway arrival operations over the past four years. The data is split between easterly and westerly operations and summer and winter seasons.

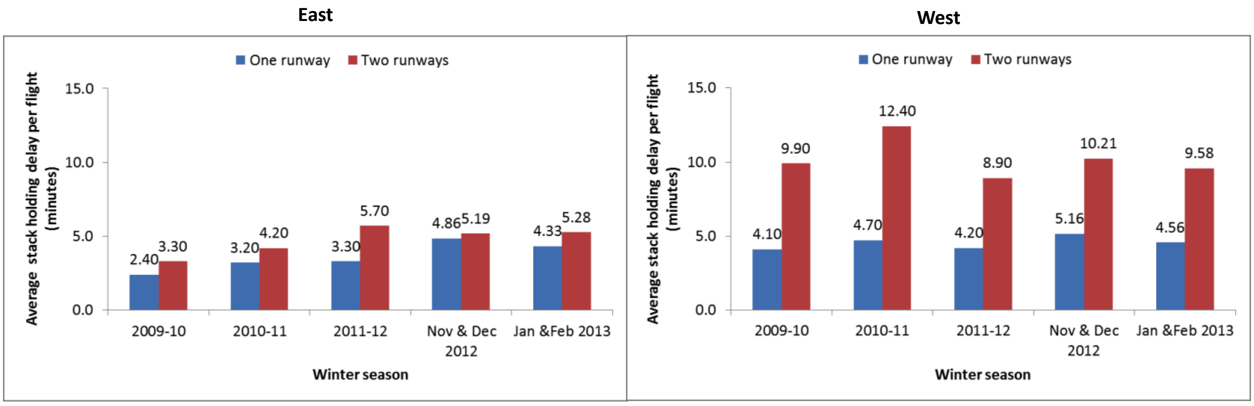


Figure 45: Comparison of stackholding for one and two runway arrival operations during winter periods

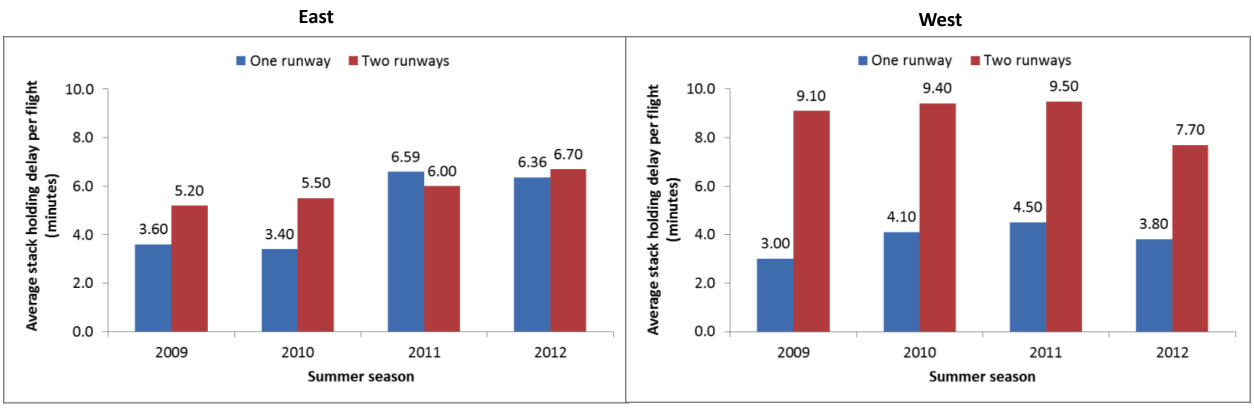


Figure 46: Comparison of stackholding for one and two runway arrival operations during summer periods

For westerly operations, the charts show much higher stackholding when two arrivals runways are being used than when one runway is in operation. For easterly operations, the difference in stackholding between one and two runway operations is much smaller than for westerly operations. One possible cause of this observation is the application of triggers on westerly operations but not on easterly operations. In addition, comparison of the two runway stackholding on westerly operations during the Phase 1 and Phase 2 summer periods, indicates that the two runway holding is lower during the trial than during previous-like periods. This might be due to the reduced trigger condition, from 20 minutes to 10 minutes. The fact that a similar reduction is not observed during the Phase 2 winter period might be due to: (i) the lower application of TEAM* during November and December due to the restriction associated with departure delays; (ii) the provision for TEAM* not being available in January and February.

In addition, multivariate regression analysis using a linear function on the rate of change of stackholding indicated a statistically significant negative association between the rate of change and the application of TEAM* with coefficient of approximately -0.4 but with a very low R^2 value (0.09). This implies that application of TEAM* decelerates stackholding, i.e. it has the intuitive effect. However, the quality of the regression was not high enough for any firm conclusions for be drawn.

The results of the analysis do not support the hypothesis of the association of TEAM* and proactive tests with a reduction in stackholding; however there is some tentative evidence that TEAM* results in a negative rate of change of stackholding from one time interval to the next

3.5 Departure delays

As a mirror of arrivals delays, departure delays also have two main components:

- start delay, which is the difference between the time that the pilot calls for start-up clearance and the time that the start-up is approved by air traffic control. There are many causes of start-up delay, including congestion on the airfield and congestion (not all due to Heathrow) downstream on departure routes. In addition, start-up delay is measured against a moving baseline (the time that the pilot calls) that is not always reflective of the schedule and, under certain circumstance, e.g. high delays, might incentivise perverse behaviours, e.g. early calls, to achieve a high place in the queue that necessarily lead to a snowball effect of rapidly increasing delays (which might not actually reflect reality). start-up delay is, therefore, an imperfect performance indicator but is the best that is currently available
- holding point delay, which is akin to holding in the stacks on arrivals, and is associated with queuing for the departure runway and sequencing, by air traffic control, to optimize tactically the throughput of the departure runway for the instantaneous fleet mix and departure routes.

The specific hypotheses to be tested concerning departure delays are:

- start delays would be reduced by the application of OF vectors but would be increased by the application of OF TEAM (both reactive and proactive) on arrivals
- holding point delays would also be reduced by the application of OF vectors but would be increased by the application of OF TEAM (both reactive and proactive) on arrivals.

3.5.1 Start delays

Multivariate regression analysis has been used to test the relationship between the application of both OF vectors and OF TEAM on arrival on start delays using a linear function.

$$Startdelay = C_0 + \sum_{i=1}^{N} \alpha_i \; A_i$$

where: C_o is a constant, α_i are the regression coefficients and A_i are the independent variables. The following table shows the simple linear correlations between all of the variables used in the regression. The change in average start delay per flight (Δ_{Start}) is, therefore, given by:

$$\Delta_{Start} = N_{OF}\alpha_{regression}$$

- N_{OF} is the number of Operational Freedoms applied per unit time
- $\alpha_{regression}$ is the coefficient derived from the regression analysis.

Two sets of analyses have been performed:

- Phase 2 summer period, assessing the impact of OF vectors and OF TEAM (TEAM* and proactive tests collectively)
- Phase 2 winter period excluding February 2013 when vectors were not available, assessing the impact of OF vectors and OF TEAM (TEAM* and proactive tests collectively).

The analyses include an assessment of the impact of time lags on average start delay per flight, considering four time intervals for the application of the Operational Freedoms relative to the time that the delay was experienced: 90 minutes earlier; 60 minutes earlier, 30 minutes earlier and in the same time period.

Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1. The results of these analyses are highlighted in Table 25 below and the full results are provided in Annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
OF vectors summer 2012 (time t_0)	0.061	0.027	2.248	97.5%	0.86
OF vectors summer 2012 (time t_0 – 30 minutes)	-0.055	0.029	-1.908	94.3%	
OF vectors summer 2012 (time t_0 – 60 minutes)	-0.102	0.029	-3.535	100.0%	
OF vectors summer 2012 (time t_0 – 90 minutes)	0.031	0.027	1.166	75.6%	
OF vectors winter 2012 (time t_0)	-0.013	0.038	-0.343	26.8%	0.80
OF vectors winter 2012 (time t_0 – 30 minutes)	-0.005	0.042	-0.123	9.8%	
OF vectors winter 2012 (time t_0 – 60 minutes)	0.027	0.042	0.643	48.0%	
OF vectors winter 2012 (time t_0 – 90 minutes)	-0.030	0.039	-0.788	56.9%	
OF TEAM summer 2012 (time t_0)	-0.058	0.037	-1.562	88.2%	0.86
OF TEAM summer 2012 (time t_0 – 30 minutes)	0.054	0.037	1.470	85.8%	
OF TEAM winter 2012 (time t_0)	-0.087	0.058	-1.515	87.0%	0.80
OF TEAM winter 2012 (time t_0 – 30 minutes)	0.118	0.060	1.968	95.1%	

Table 25: Regression analysis results for start delay

The table shows that:

- the regressions achieve high R^2 values indicating that most of the variation is explained by the selected independent variables
- the association between OF vectors and start delay in the Phase 2 winter period is not statistically significant
- similarly the association between OF TEAM and start delay is in general not significant and only marginally statistically significant for a time lag of 30 minutes during the winter part of Phase 2, where it has the impact of increasing start delay

- for the Phase 2 summer period, the application of OF vectors with a time lag of 60 minutes is associated with a small reduction in start delay with a similar marginal association for a time lag of 30 minutes. OF vectors applied in the same time interval as the start delay is incurred, have a counter-intuitive association with increase start delay – this may be due to the same type of effect as observed for stackholding – the freedom cannot be applied until a trigger is met and is therefore associated with high delay.

At best the results of the analysis are inconclusive and at worst do not support the hypothesis that start delays would be reduced by the application of OF vectors but would be increased by the application of OF TEAM (both reactive and proactive) on arrivals

3.5.2 Holding point delays

Multivariate regression analysis has been used to test the relationship between the application of both OF vectors and OF TEAM on arrival on holding point delays using a linear function.

$$Holdingpointdelay = C_0 + \sum_{i=1}^{N} \alpha_i \ A_i$$

where: C_o is a constant, α_i are the regression coefficients and A_i are the independent variables. The following table shows the simple linear correlations between all of the variables used in the regression. The change in average start delay per flight ($\Delta_{Holdingpoint}$) is, therefore, given by:

$$\Delta_{Holdingpoint} = N_{OF}\alpha_{regression}$$

- N_{OF} is the number of Operational Freedoms applied per unit time
- $\alpha_{regression}$ is the coefficient derived from the regression analysis.

Two sets of analyses have been performed:

- Phase 2 summer period, assessing the impact of OF vectors and OF TEAM (TEAM* and proactive tests collectively)
- Phase 2 winter period excluding February 2013 when vectors were not available, assessing the impact of OF vectors and OF TEAM (TEAM* and proactive tests collectively).

The analyses include an assessment of the impact of time lags on average start delay per flight, considering four time intervals for the application of the Operational Freedoms relative to the time that the delay was experienced: 90 minutes earlier; 60 minutes earlier, 30 minutes earlier and in the same time period.

Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1. The results of these analyses are highlighted in Table 26 below and the full results are provided in Annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
OF vectors summer 2012 (time t_0)	0.012	0.031	0.383	29.8%	0.56
OF vectors summer 2012 (time t_0 – 30 minutes)	-0.076	0.033	-2.317	97.9%	
OF vectors summer 2012 (time t_0 – 60 minutes)	0.043	0.033	1.328	81.6%	
OF vectors summer 2012 (time t_0 – 90 minutes)	0.032	0.030	1.044	70.4%	
OF vectors winter 2012 (time t_0)	-0.012	0.038	-0.307	14.1%	0.52
OF vectors winter 2012 (time t_0 – 30 minutes)	-0.047	0.042	-1.119	73.7%	
OF vectors winter 2012 (time t_0 – 60 minutes)	-0.014	0.043	-0.324	25.4%	
OF vectors winter 2012 (time t_0 – 90 minutes)	0.036	0.039	0.916	64.0%	
OF TEAM summer 2012 (time t_0)	0.368	0.042	8.781	100.0%	0.56
OF TEAM summer 2012 (time t_0 – 30 minutes)	0.233	0.041	5.611	100.0%	
OF TEAM winter 2012 (time t_0)	0.454	0.058	7.842	100.0%	0.52
OF TEAM winter 2012 (time t_0 – 30 minutes)	0.257	0.061	4.202	100.0%	

Table 26: Regression analysis results for holding point delay

The table shows that:

- the regressions achieve moderate R^2 values indicating that the explanation of the variation is explained by the selected independent variables is adequate
- for the Phase 2 summer period, the application of OF vectors with a time lag of 30 minutes is associated with a small reduction in holding point delay All other time lags are not significant.
- the association between OF vectors and holding point delay in the Phase 2 winter period is not statistically significant
- there is a strong and significant association between OF TEAM and an increase in holding point delay for the current time interval and a time lag of 30 minutes (this continues for both the 60 and 90 minute lags –see annex I).

The analysis does not support the hypothesis that a decrease in holding point delay will be associated to the application of OF vectors but does support the hypothesis that an increase in holding point delay is associated with the application of OF TEAM

3.6 Taxi times

Taxi-times are defined as follows:

- the taxi-in time for arrivals is the elapsed time from touchdown to when the aircraft arrives at its parking stand
- the taxi-out time for departures is the elapsed time from when the aircraft starts to pushback to when it joins the queue for the runway at the holding point.

The hypotheses concerning the impact of the trial on taxi-times compared to the baseline are:

- there is expected to be a reduction in taxi-in time in the trial associated with the application of TEAM* arising from the ability of the controller to select TEAM* landers appropriate to their final destination on the airfield
- there is expected to be reduction in T4 taxi-in time with both TEAM* and proactive tests. The association with proactive tests is expected to be stronger because of the specific objective of landing T4 arrivals on the southerly runway during proactive tests whereas TEAM* will have a weaker association as it relies on arrivals of opportunity
- taxi-out time is expected to be unchanged.

3.6.1 Arrivals

The relationship between average taxi-time per flight and the application of OF has been derived using a linear regression using the following relationship:

$$Taxiinttime = C_0 + \sum_{i=1}^{N} \alpha_i \ A_i$$

The change in taxi-in time ($\Delta_{\text{Taxi-in}}$) due to the application of OF is given by:

$$\Delta_{Taxi-in} = N_{OF} \alpha_{regression}$$

where:

- N_{OF} is the number of Operational Freedoms applied per unit time
- $\alpha_{\text{regression}}$ is the coefficient derived from the regression analysis.

An identical relationship has been used to derive associations for taxi-out time.

Three sets of analyses have been performed:

- Phase 2 summer period, assessing the TEAM* and proactive tests separately
- November and December 2012 of Phase 2 winter period assessing TEAM* alone
- the Phase 2 proactive periods combining the summer and winter tests.

The analyses include an assessment of the impact of time lags on average taxi-in time per flight, considering four time intervals for the application of the Operational Freedoms relative to the time that the delay was experienced: 90 minutes earlier; 60 minutes earlier, 30 minutes earlier and in the same time period.

Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1.

Table 27 and Table 28 show the results of the multivariate regressions for taxi-in times for arrivals to all terminals and arrivals to T4 respectively. The full results are provided in Annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
TEAM* summer 2012 (time t_0)	-0.043	0.023	-1.842	93.4%	0.22
TEAM* summer 2012 (time t_0 – 30 minutes)	-0.043	0.023	-1.846	94.5%	
TEAM* summer 2012 (time t_0 – 60 minutes)	-0.018	0.023	-0.761	55.4%	
TEAM* summer 2012 (time t_0 – 90 minutes)	0.007	0.022	0.304	23.9%	
TEAM* winter 2012-13 (time t_0)	-0.146	0.046	-3.207	99.9%	0.38
TEAM* winter 2012-13 (time t_0 – 30 minutes)	0.006	0.048	0.117	9.3%	
TEAM* winter 2012-13 (time t_0 – 60 minutes)	0.020	0.047	0.428	43.1%	
TEAM* winter 2012-13 (time t_0 – 90 minutes)	0.090	0.045	2.017	95.6%	
Proactive tests summer 2012 (time t_0)	-0.143	0.056	-2.539	98.9%	0.22
Proactive tests summer 2012 (time t_0 – 30 minutes)	-0.100	0.060	-1.666	90.4%	
Proactive tests periods 2012-13 (time t_0)	-0.164	0.049	-3.352	99.9%	0.69
Proactive tests period 2012-13 (time t_0 - 30 minutes)	-0.131	0.049	-2.694	99.3%	

Table 27: Regression analysis results for taxi-in times to all terminals

For taxi-in time to all terminals, Table 27 shows:

- low R^2 values except for the assessment of the proactive test periods where there is a reasonable R^2 value. This indicates that on the whole, the regression analysis is only partially capturing the range of important independent variables
- for the Phase 2 summer period, the results for the current time interval and a 30 minute lag are of marginal statistical significance and suggest a reduction in taxi-in time associated with the application of TEAM*. The other time lags are of low statistical significance
- for the Phase 2 winter period, the results for the current time interval appears to have statistical significance and suggests a reduction in taxi-in time associated with the application of TEAM*. The lag of 90 minutes is of marginal significance and has a very small coefficient suggesting negligible impact
- for the proactive tests performed during the Phase 2 summer period, there is a statistically significant association between the application of proactive tests and a reduced taxi-in time in the same time interval, reducing in significance as the time lag is increased
- for the proactive tests collectively, there is a statistically significant association between the application of proactive tests and reduction in taxi-in times both in the current time interval and for 30 minute lags. Subsequent time lags are not significant (see annex I).

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
TEAM* summer 2012 (time t_0)	-0.368	0.073	-5.068	100.0%	0.29
TEAM* summer 2012 (time t_0 – 30 minutes)	0.096	0.072	1.320	81.3%	
TEAM* summer 2012 (time t_0 – 60 minutes)	-0.004	0.072	-0.057	4.6%	
TEAM* summer 2012 (time t_0 – 90 minutes)	0.056	0.068	0.828	59.2%	
TEAM* winter 2012-13 (time t_0)	-0.256	0.112	-2.288	97.8%	0.38
TEAM* winter 2012-13 (time t_0 – 30 minutes)	0.014	0.117	0.122	9.7%	
TEAM* winter 2012-13 (time t_0 – 60 minutes)	0.012	0.117	0.102	8.1%	
TEAM* winter 2012-13 (time t_0 – 90 minutes)	0.051	0.110	0.467	45.9%	
Proactive tests summer 2012 (time t_0)	-0.608	0.176	-3.449	99.9%	0.29
Proactive tests summer 2012 (time t_0 – 30 minutes)	-0.019	0.188	-0.099	7.9%	
Proactive tests periods 2012-13 (time t_0)	-0.304	0.146	-2.079	96.2%	0.43
Proactive tests period 2012-13 (time t_0 - 30 minutes)	-0.174	0.145	-1.202	77.0%	

Table 28: Regression analysis results for taxi-in times to T4

For taxi-in time to T4 alone, Table 28 shows:

- low R^2 values throughout indicating that the regression analysis is only partially capturing the range of important independent variables
- for the Phase 2 summer period, the results for the current time interval suggest a reduction in taxi-in time strongly associated with the application of TEAM*. The other time lags are of low statistical significance
- similarly for the for the Phase 2 winter period, the results for the current time interval suggest a reduction in taxi-in time strongly associated with the application of TEAM*. The other time lags are of low statistical significance
- for the proactive tests performed during the Phase 2 summer period, the results for the current time interval also suggest a reduction in taxi-in time strongly associated with the application of proactive tests. The other time lags are of low statistical significance
- finally, for the proactive tests collectively, there is a statistically significant association between the application of proactive tests and reduction in T4 taxi-in times in the current time interval. Subsequent time lags are not significant (see annex I).

The regression coefficients derived for the T4 taxi-in times are larger than those derived for the taxi-in times to all terminals; implying that the T4 effect is strong and that it is diluted when average across all terminals.

There is some limited evidence to support the expectation of a reduction in taxi-in time with the application of TEAM* arising from the ability of the controller to select TEAM* landers appropriate to their final destination on the airfield. This evidence is strongest for T4 arrivals

There is stronger evidence to support the expectation of a reduction in taxi-in time with the application of proactive tests. Again this evidence is strongest for T4 arrivals

3.6.2 Departures

Table 29 shows the results from the multivariate regression analysis to investigate the impact of OF vectors on taxi-out times using an identical approach to that described for taxi-in above. Full regression results are presented in annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
OF vectors summer 2012 (time t_0)	0.001	0.001	0.560	42.5%	0.21
OF vectors summer 2012 (time t_0 – 30 minutes)	0.000	0.001	-0.002	0.1%	
OF vectors summer 2012 (time t_0 – 60 minutes)	0.000	0.001	-0.075	6.0%	
OF vectors summer 2012 (time t_0 – 90 minutes)	-0.002	0.001	-1.899	94.2%	
OF vectors winter 2012 (time t_0)	-0.006	0.028	-0.215	17.0%	0.60
OF vectors winter 2012 (time t_0 – 30 minutes)	-0.006	0.030	-0.199	15.8%	
OF vectors winter 2012 (time t_0 – 60 minutes)	0.009	0.031	0.305	14.0%	
OF vectors winter 2012 (time t_0 – 90 minutes)	0.029	0.028	1.050	70.6%	

Table 29: Regression analysis results for taxi-out times

The table shows that there is no statistically significant relationship between OF vectors and taxi-out times. Where coefficients are of reasonable confidence levels, the R^2 value is low and vice versa. Furthermore, the values of the coefficients are very small, indicating minimal levels of association.

The analysis results support the hypothesis that there is no relationship between OF vectors and taxi-out times

3.7 Punctuality

The hypotheses on both arrival and departure punctuality are that both arrivals and departures freedoms are expected to be associated with an improvement in punctuality. These hypotheses have been investigated using the standard measure of punctuality: the proportion of flights that arrive on or depart from the stand within fifteen minutes of the scheduled arrival or departure time (termed %age punctual for brevity).

3.7.1 Arrivals

Table 30 shows the association between arrival punctuality and the application of TEAM* and proactive tests, which have also been addressed separately. Full details of the results of the regression analysis are given in annex I. This relationship has been derived using a linear regression using the following relationship:

$$Arrivalpunctuality = C_0 + \sum_{i=1}^{N} \alpha_i \ A_i$$

The change in arrival punctuality (Δ_{arr_punct}) for both %age punctual and delay minutes is given by:

$$\Delta_{arr\_punct} = N_{OF}\alpha_{regression}$$

where:

- N_{OF} is the number of Operational Freedoms applied per unit time
- $\alpha_{regression}$ is the coefficient derived from the regression analysis.

Three sets of analyses have been performed:

- Phase 2 summer period, assessing the TEAM* and proactive tests separately
- November and December 2012 of Phase 2 winter period assessing TEAM* alone
- all of the Phase 2 proactive periods together combining the summer and winter tests.

The analyses include an assessment of the impact of time lags on punctuality, considering four time intervals for the application of the Operational Freedoms relative to the time that the delay was experienced: 90 minutes earlier; 60 minutes earlier, 30 minutes earlier and in the same time period. Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1. Full regression results are presented in annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
TEAM* summer 2012 (time t_0)	0.007	0.002	3.259	99.9%	0.54
TEAM* summer 2012 (time t_0 – 30 minutes)	0.008	0.002	3.631	100.0%	
TEAM* summer 2012 (time t_0 – 60 minutes)	0.008	0.002	3.858	100.0%	
TEAM* summer 2012 (time t_0 – 90 minutes)	0.008	0.002	3.997	100.0%	
TEAM* winter 2012-13 (time t_0)	0.003	0.004	0.796	57.4%	0.55
TEAM* winter 2012-13 (time t_0 – 30 minutes)	0.005	0.004	1.238	78.4%	
TEAM* winter 2012-13 (time t_0 – 60 minutes)	0.006	0.004	1.388	83.5%	
TEAM* winter 2012-13 (time t_0 – 90 minutes)	-0.003	0.004	-0.709	52.2%	
Proactive tests summer 2012 (time t_0)	0.004	0.005	0.841	60.0%	0.54
Proactive tests summer 2012 (time t_0 – 30 minutes)	0.009	0.006	1.614	89.3%	
Proactive tests periods 2012-13 (time t_0)	-0.012	0.005	-2.392	98.3%	0.42
Proactive tests period 2012-13 (time t_0 - 30 minutes)	0.000	0.005	0.066	5.3%	

Table 30: Regression analysis results for arrival punctuality

The table shows:

- for the Phase 2 summer period, there is a statistically significant association between TEAM* and an improvement in arrivals punctuality for all four time lags
- for the Phase 2 winter period, the association between TEAM* and punctuality is not significant for any of the four time lags investigated
- for the proactive tests operated during the Phase 2 summer period there is no statistically significant relationship between the proactive tests and arrival punctuality
- when all proactive periods are considered, the relationship between the proactive tests and arrivals punctuality is statistically significant for the time interval during which the proactive tests are applied but: (i) the relationship is negative – punctuality decreases as proactive tests are applied; and (ii) the R^2 value is low, indicating uncertainty in the results.

The analysis results support the hypothesis that there is an increase in arrival punctuality associated with TEAM* during the summer period but does not support the same hypothesis during the winter period

A possible explanation for this observation is that the drivers the drivers of poor punctuality are much stronger in winter than summer and beyond the capability for TEAM* to provide a counterbalance.

3.7.2 Departures

Table 31 shows outcome of the regression analysis to determine the association between OF vectors and departure punctuality. This relationship has been derived using a linear regression:

$$Departurepunctuality = C_0 + \sum_{i=1}^{N} \alpha_i \; A_i$$

where: C_o is a constant, α_i are the regression coefficients and A_i are the independent variables. The change in arrival punctuality (Δ_{dep_punct}) for both %age punctual and delay minutes is given by:

$$\Delta_{dep\_punct} = N_{OF}\alpha_{regression}$$

where:

- N_{OF} is the number of Operational Freedoms applied per unit time
- $\alpha_{regression}$ is the coefficient derived from the regression analysis.

Two sets of analyses have been performed:

- Phase 2 summer period, assessing the relationship between OF vectors and departure punctuality
- Phase 2 winter period, assessing the relationship between OF vectors and departure punctuality.

The analyses include an assessment of the impact of time lags on punctuality, considering four time intervals for the application of the Operational Freedoms relative to the time that the delay was experienced: 90 minutes earlier; 60 minutes earlier, 30 minutes earlier and in the same time period. Data with sufficient detail and granularity was not available to perform the same analysis for Phase 1. Full regression results are presented in annex I.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
OF vectors summer 2012 (time t_0)	-0.004	0.001	-2.440	98.5%	0.62
OF vectors summer 2012 (time t_0 – 30 minutes)	0.002	0.002	1.118	73.7%	
OF vectors summer 2012 (time t_0 – 60 minutes)	0.003	0.002	1.652	90.1%	
OF vectors summer 2012 (time t_0 – 90 minutes)	-0.002	0.002	-1.450	85.3%	
OF vectors winter 2012 (time t_0)	0.000	0.002	0.062	5.0%	0.63
OF vectors winter 2012 (time t_0 – 30 minutes)	0.000	0.002	-0.040	3.2%	
OF vectors winter 2012 (time t_0 – 60 minutes)	-0.002	0.002	-0.743	54.2%	
OF vectors winter 2012 (time t_0 – 90 minutes)	0.000	0.002	0.152	12.1%	

Table 31: Regression analysis results for departure punctuality

The table shows:

- a small but statistically significant decrease in departure punctuality associated with the application of OF vectors during the summer part of Phase 2 of the trial
- no statistically significant association between OF vectors and departure punctuality during the winter part of Phase 2 of the trial.

The analysis results do not support the hypothesis that there should be an increase in departure punctuality associated with the application Operational Freedoms

3.8 Cancellations

3.8.1 Arrivals

Figure 47, Figure 48 and Figure 49 compare the daily arrival cancellation PDFs for the three trial with their respective baseline periods.

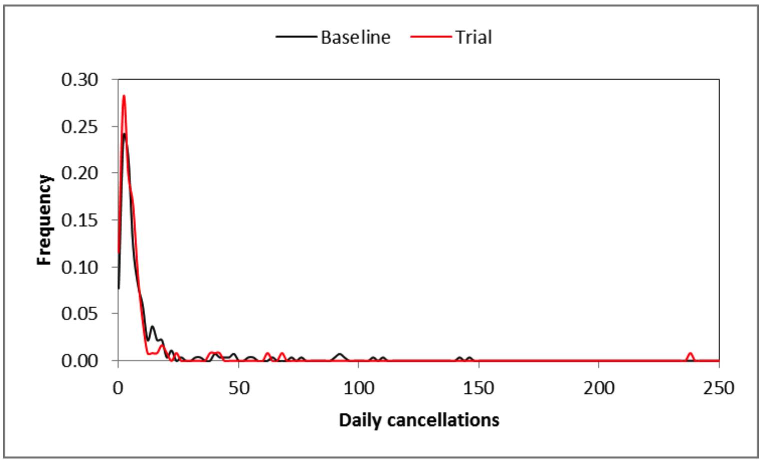


Figure 47: Comparison of the Phase 1 arrival cancellation PDFs with the winter baseline

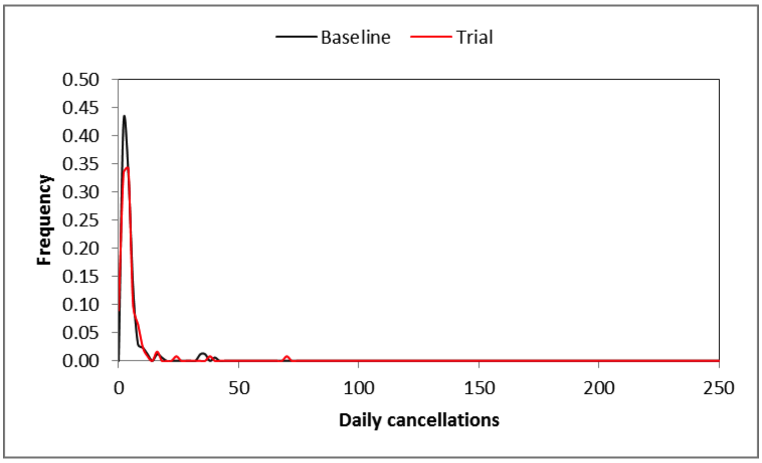


Figure 48: Comparison of the Phase 2 summer arrival cancellation PDFs with the summer baseline

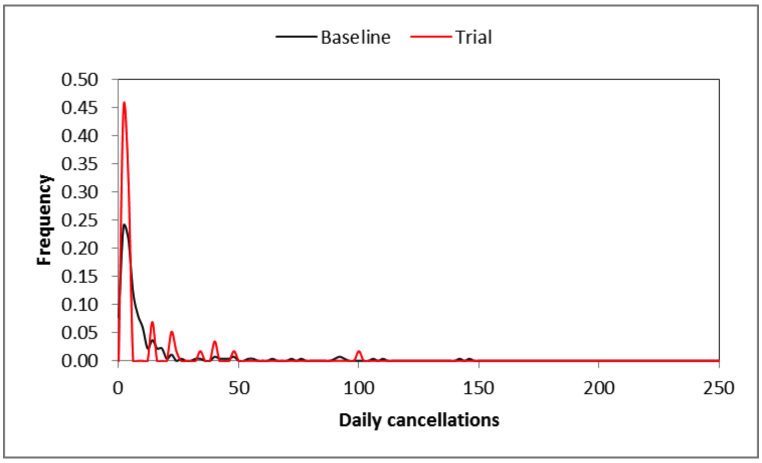


Figure 49: Comparison of the Phase 2 winter arrival cancellation PDFs with the winter baseline

Table 32, Table 33 and Table 34 compare the statistical parameters describing the arrival cancellation PDFs shown above for the three trial periods and the relevant baselines.

	Baseline	Trial	Confidence
Average	17.71	8.08	100%
Standard deviation	56.68	23.30	100%

Table 32: Comparison of arrival cancellation statistics observed during the winter baseline and the Phase 1 trial period

	Baseline	Trial	Confidence
Average	4.36	4.26	55%
Standard deviation	6.05	7.49	99%

Table 33: Comparison of arrival cancellation statistics observed during the summer baseline and the Phase 2 summer period

	Baseline	Trial	Confidence
Average	17.71	8.81	99%
Standard deviation	56.68	16.08	100%

Table 34: Comparison of arrival cancellation statistics observed during the winter baseline and the Phase 1 winter period

The statistical comparisons show that for both winter periods, arrival cancellations are significantly lower during the trial periods than during the baseline periods. Conversely for the summer period, there is no significant difference in the cancellation statistics during the trial compared to the baseline. As stated previously, this type of comparison is at the macro-level and the outcomes may be driven by many different factors, including Operational Freedoms. However, the conflicting results between the summer and winter periods, coupled with an almost identical result for the two winter periods when it is know that TEAM* was applied much less frequently during Phase 2 of the trial[4] than during Phase 1 suggests that it is not possible to conclude that Operational Freedoms were responsible for the reduction in cancellations.

The results of the analysis of arrival cancellations are inconclusive and therefore tend to support the hypothesis that Operational Freedoms are not expected to have any impact on arrival cancellations

3.8.2 Departures

Figure 50, Figure 51, and Figure 52 compare the daily departure cancellation PDFs for the three trial periods with their respective baseline periods. There is relatively little qualitative difference between each of the trial PDFs and its respective baseline, except for noise due to a small sample size for the winter period of Phase 2 of the trial.

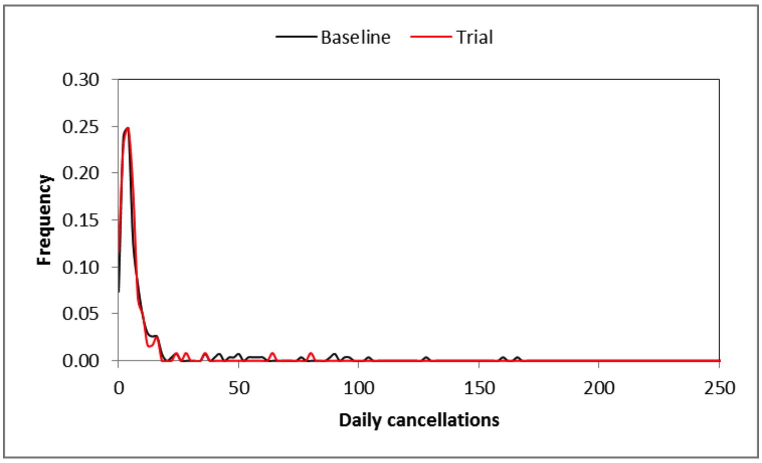


Figure 50: Comparison of the Phase 1 departure cancellation PDFs with the winter baseline

4 TEAM* was only applied for two of the four winter months during Phase 2 of the trial and was applied much less frequently during the other two months in Phase 2 than in Phase 1 due to a ban on applying the trigger condition when departure delays were occurring

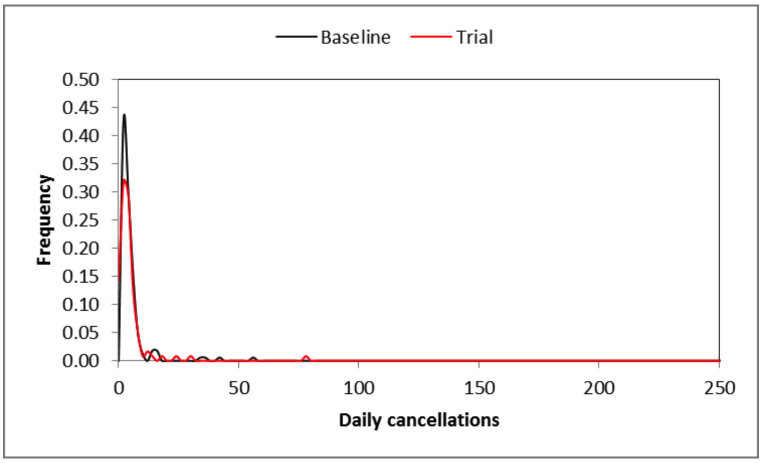


Figure 51: Comparison of the Phase 2 summer departure cancellation PDFs with the summer baseline

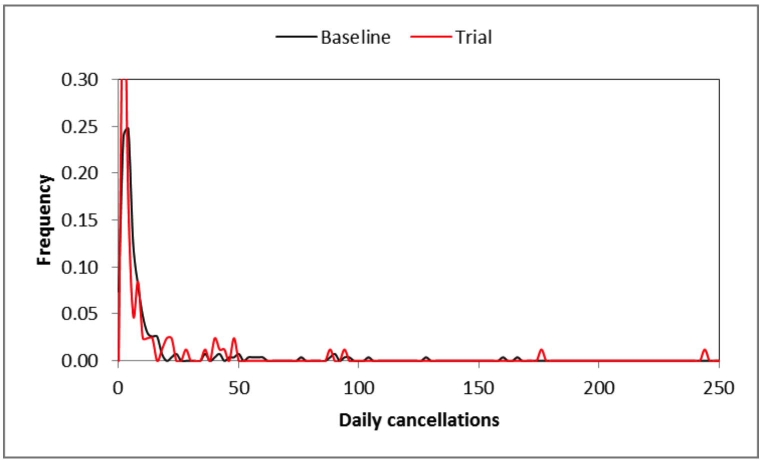


Figure 52: Comparison of the Phase 2 winter arrival cancellation PDFs with the winter baseline

Table 35, Table 36 and Table 37 compare the statistical parameters describing the departure cancellation PDFs shown above for the three trial periods and the relevant baselines.

	Baseline	Trial	Confidence
Average daily departure cancellations	17.98	8.07	99%
Standard deviation of daily departure cancellations	59.31	26.88	100%

Table 35: Comparison of departure cancellation statistics observed during the winter baseline and the Phase 1 trial period

	2011	Trial	Confidence
Average daily departure cancellations	4.43	4.17	23%
Standard deviation of daily departure cancellations	6.58	7.94	98%

Table 36: Comparison of departure cancellation statistics observed during the summer baseline and the Phase 2 summer period

	Baseline	Trial	Confidence
Average daily departure cancellations	17.98	15.23	42%
Standard deviation of daily departure cancellations	59.31	35.71	100%

Table 37: Comparison of departure cancellation statistics observed during the winter baseline and the Phase 1 winter period

The statistical comparisons highlighted in the table above show that for Phase 1 there was a statistically significant reduction in departure cancellations compared to the baseline. However, it is unlikely that this can be attributed to Operational Freedoms because: (i) departure freedoms were not applied to any significant degree during Phase 1 of the trial; (ii) it is unlikely that a reduction in departure cancellations is a direct knock-on from arrivals freedoms for the same reasons as outlined above for arrival cancellations. For both of the Phase 2 trial periods, there is no significant difference between the departure cancellations during the trial and the baselines.

The results of the analysis of departure cancellations tend to support the hypothesis that Operational Freedoms are not expected to have any impact on departure cancellations

3.9 Estimation of overall savings during the trial

The results obtained from the multivariate regression analysis outlined above describe the quantitative relationship between the application of Operational Freedoms, the other independent variables and key performance indicator (KPI) derived from observations during the trial period when Operational Freedoms were and were not applied. From the regression parameters it is possible to calculate the value of the KPI with and without Operational Freedoms being applied for a specific time period. The impact of the operational freedom, *ΔKPI(t)*, during that time period is then simply the difference between the modeled results with the operational freedom applied and the modeled results without the operational freedom being applied:

$$\Delta KPI(t) = KPI_{OF}(t) - KPI_{No\ OF}(t)$$

where:

- $KPI_{no\ OF(}(t)$ is the value of the KPI calculated from the regression had Operational Freedoms not been applied at time *t*
- $KPI_{OF}(t)$ is the value of the KPI calculated from the regression results with Operational Freedoms applied at time *t*.

The advantage of calculating the impact of the Operational Freedoms based solely on the predicted outcome using the regression results (rather than, for example, subtracting results derived from the regression from the actual observations) is that systematic errors in the regression results are minimised.

The overall saving (or cost) due to Operational Freedoms in is then simply the sum of *ΔKPI(t)* over the time period of the trial. This enables calculation of an overall savings or costs in terms of total minutes over the trial period or average minutes per flight. Uncertainties are estimated from the standard errors derived from the regression analysis.

The results are summarised in the tables below based on the trial periods of July to October 2012 inclusive for the summer period and November and December 2012 for the winter period. The latter is used as the only costs and benefits are associated with TEAM*, which was only active during those two months.

	Savings during the trial (minutes)		Average savings (minutes per flight)	
Arrival KPI	Reactive	Proactive	Reactive	Proactive
Arrival punctuality	4400 to 8400	50 to 1000	0.06 to 0.11	0.00 to 0.01
Taxi-in time (T4 only)	-3829 to 5423	-207 to 2971	-0.05 to 0.08	-0.01 to 0.08

Departure KPI	Costs during the trial (minutes)	Average cost (minutes per flight)
Holding point delay	16000 to 20000	0.20 to 0.26

Table 38: Summary of arrivals savings and departure costs calculated for the summer part of Phase 2 of the trial

	Savings during the trial (minutes)		Average savings (minutes per flight)	
Arrival KPI	Reactive	Proactive	Reactive	Proactive
Stack holding	-2067 to 3982	-	-0.06 to 0.12	-

Departure KPI	Costs during the trial (minutes)	Average cost (minutes per flight)
Holding point delay	-4856 to -269	-0.131 to -0.007

Table 39: Summary of arrivals savings and departure costs calculated for the winter part of Phase 2 of the trial

3.10 Conclusions

3.10.1 Analysis method

The multivariate regression technique has been refined since its early application to analyse the results of the summer season of Phase 2 of the trial and has improved considerably. The problem of non-normal regressions residuals has been addressed by applying different functional forms (linear and square root transformations). The results are robust, at least qualitatively, and on the whole are not sensitive to the exact functional form selected. R^2 values have been increased considerably by judicious selection of independent variable although they are still lower than desirable in several cases, casting uncertainty on some results.

During the development of the regression technique, close collaboration was maintained with the CAA, which has developed its own approach independently of the methodology described in this report. Although there are some differences in fine detail between the two methods and the associated outcomes, the broad conclusions reached are very similar.

3.10.2 Arrivals

The results of the analysis for arrivals suggest that:

- in general, a significant increase in de-alternation for westerly arrivals associated with Operational Freedoms (there is an exception during the winter part of the Phase 2 component of the trial when TEAM* was restricted to manage departure delays). There is no significant increase in 09R arrivals on easterly operations associated with the trial

- an increase in arrival rate of 0.22 to 0.27 additional arrivals associated with each TEAM* lander and 0.32 to 0.35 additional arrivals associated with each proactive lander. Although this increase is intangible in quantitative benefit terms, feedback from air traffic controllers indicates that it is advantageous in terms of operational flexibility and in reducing the need for the application of flow restrictions

- potentially a decrease in Heathrow-driven ATFM delays during the summer period but not during the winter, likely due to the increased severity of ATFM delays during the winter period, beyond the scope of Operational Freedoms to counterbalance them

- there is no reduction in stackholding associated with TEAM* or proactive tests, although a tentative indication that TEAM* decelerates stackholding that would otherwise have increase, i.e. applies a brake

- a slight reduction in taxi-in times associated with TEAM* and, more strongly with proactive tests. The impact is greater for T4 arrivals than for the average across the airfield

- an association between the application of TEAM* and improvement in arrival punctuality whether this is measured in terms of the proportion of flights arriving less than 15 minutes late

- there is no association between Operational Freedoms and arrival cancellations.

3.10.3 Departures

For departures, the results of the statistical analysis indicate:

- application of Operational Freedoms vectors appears to be associated with an increase in runway departure rate of 0.14 to 0.26 departures per vector. However, this is countered by evidence for an association of the application of OF TEAM (both TEAM* and proactive tests) with a reduction in runway departure rate of approximately 0.6 per landing on the departure runway

- there appears little of no association between the application of Operational Freedoms and changes in start delay, either positive for OF vectors or negative for OF TEAM

- there is no statistically significant association between the application of Operational Freedoms vectors and holding point delay, although there appears to be a strong negative association between the application of OF TEAM and an increase in holding point delay

- there is no statistically significant relationship between Operational Freedoms and taxi-out time

- there is no association between Operational Freedoms and an improvement in departure punctuality

- there is no significant difference between departure cancellation rates during the trial and previous periods.

3.10.4 Proactive tests

The impact of proactive tests has been investigated separately to the reactive freedoms through the regression analysis with the following conclusions:

- there is no evidence to suggest that proactive tests are associated with a reduction in stackholding. This does not therefore confirm the expected positive effect of the freedom to manage to the arrival stream around A380 arrivals
- proactive tests are associated with a reduction in both overall taxi-in times but more significantly with a reduction in T4 taxi-in times, indicating the effectiveness of applying the freedom to T4 arrivals.

4 Safety

4.1 Introduction

This section of the report includes commentary on safety aspects of the Operational Freedoms trials. There is a general commentary on safety and a specific measurement of the change in the number of runway crossings during the trial period.

4.2 General comments on safety

Prior to starting the second phase of the Operational Freedoms Trial on 1 July, NATS produced a concept of operations, operational instructions, safety assurance arguments and documentation covering both Heathrow Airport Tower and London Terminal Control operations for acceptance by the CAA. In accordance with its safety management system, NATS used the same process it would undertake for any change to a procedure or operational practice at Heathrow / Terminal Control. The CAA assessed the adequacy of the safety assurance received and the compatibility of the proposed arrangements with the existing operations. Regulatory approval was granted to NATS on the condition that any safety issues arising from components of the trial would be expeditiously evaluated, and (if appropriate) that element of the trial would be withdrawn.

As normal, NATS continuously monitored its safety performance. On a weekly basis, NATS reviewed the safety performance of the trial with Heathrow, and reported the results to the CAA.

As expected, NATS safety performance was not affected by Phase 1 of the Operational Freedoms trial. There were three events during the phase 2 trial period that were of a concern in relation to safety and which were reported to the CAA. These are described below.

4.2.1 Operation of early vectors from the MID/TANGO SID on easterlies

It was necessary to withdraw the trial procedure regarding the TANGO SID for a short time. The procedure was documented at the beginning of the phase 2 trials as follows.

Operational Freedom 2.2a

On easterlies increased separation is required between a MID following a SAM SID. An alternative departure routing already exists referred to as the Tango SID which was put in place to use during the Farnborough Airshow when route congestion was most likely to occur. The initial track mirrors a MID SID and provides a similar solution to that for Westerlies. Again there is no environmental impact as it is a Noise Preferential Route, this has associated with it height restrictions which means any aircraft type within Heathrow's fleet can fly it.

In the initial TANGO trial, operation of this early vector required the air traffic controller to pass an amended clearance (for routing purposes) to departing pilots who were already using an infrequently utilised TANGO SID. The resulting increase in workload for both aircrew and air traffic control (ATC) led NATS to temporarily withdraw the amended TANGO SID pending further review. After re-negotiation with Terminal Control the standard TANGO SID was re-introduced with the required routing issued by Terminal Control, once the aircraft was airborne.

Safety performance information for the trial was collected in accordance with the requirements of CAA CAP382 - the Mandatory Occurrence Reporting Scheme.

During Phase 2, two events were reported under the scheme that related to traffic that was operating under Operational Freedoms.

4.2.2 Error in departure clearance

On the 20th September VIR671M, an A340 was issued with a departure clearance MID heading 215. This was to vector the aircraft early off the Midhurst route. The procedure that was documented at the beginning of the trials is as follows.

Operational Freedom 2.2a

The early vectoring of these departures will not include the heaviest of the wake vortex categories such as the Airbus A380 or Boeing 747 because their climb rates compared with smaller aircraft are less and could give rise to a potential problem of separation whilst remaining within controlled airspace.

The A340 is in the "heavy" wake vortex category. This error was realised after the aircraft had departed and flown the procedure. There was no other issue with this event and no separation between aircraft was lost. A rebriefing of air traffic controllers was carried out in order that this issue should not occur again.

4.2.3 Error in track-keeping

On the 5th September 2012, UAE2 (A380) was instructed to fly straight ahead to LON 2D navigational beacon and then turn right direct to the Detling navigational beacon. This procedure was given in order that the aircraft would be vectored off the Dover SID. At LON 2D the aircraft started a right turn however due to a crew error the aircraft initially continued turning right before correcting and turning left back onto the track to DET. There was no other issue with this event and no separation between aircraft was lost during the event.

4.3 Runway crossings

Table 40, Table 41 and Table 42 summarise the statistics for runway crossings comparing the proactive and non-proactive periods for the three parts of the trial. The tables confirm that there is no statistically significant difference in runway crossings associated with arrivals between the proactive and non-proactive periods of the trial. However, there is a statistically significant difference in the standard deviation of runway crossings, i.e. the variability in crossings, observed between the proactive and non-proactive parts of Phase 1 of the trial. This difference indicates that the daily number of crossings was much more variable during the proactive test periods than during the non-proactive test periods. This increase in variability is not understood and is also not observed in Phase 2 of the trial.

Proactive period	Arrivals
Daily average runway crossings	45.23
Standard deviation of daily runway crossings	29.51

Non-proactive period	Arrivals
Daily average runway crossings	47.91
Standard deviation of daily runway crossings	18.95

Confidence level - diffence in averages	71.28%
Confidence level - difference in standard deviations	98.75%

Table 40: Comparison of runway crossing statistics for proactive and non-proactive periods of Phase 1 of the trial

Proactive period	Arrivals
Daily average runway crossings	38.9
Standard deviation of daily runway crossings	14.8

Non-proactive period	Arrivals
Daily average runway crossings	36.9
Standard deviation of daily runway crossings	12.1

Confidence level - diffence in averages	58%
Confidence level - difference in standard deviations	86%

Table 41: Comparison of runway crossing statistics for proactive and non-proactive periods of the summer part of Phase 2 of the trial

Proactive period	Arrivals
Daily average runway crossings	44.4
Standard deviation of daily runway crossings	15.0

Non-proactive period	Arrivals
Daily average runway crossings	43.4
Standard deviation of daily runway crossings	13.2

Confidence level - diffence in averages	26%
Confidence level - difference in standard deviations	61%

Table 42: Comparison of runway crossing statistics for proactive and non-proactive periods of the winter part of Phase 2 of the trial

However, multivariate regression analysis using a linear function applied to the proactive periods of the trial show the following results.

Operational freedom	Coefficient (α)	Standard error	T-statistic	Confidence	R^2
TEAM* (time t_0)	-0.239	0.034	-7.100	100.0%	0.14
TEAM* (time t_0 – 30 minutes)	-0.055	0.031	-1.768	92.3%	
TEAM* (time t_0 – 60 minutes)	0.000	0.031	-0.013	1.1%	
TEAM* (time t_0 – 90 minutes)	-0.103	0.029	-3.531	100*	
Proactive tests (time t_0)	-0.103	0.048	-2.135	96.7%	0.14
Proactive tests (time t_0 – 30 minutes)	0.080	0.048	1.680	90.7%	
Proactive tests (time t_0 – 60 minutes)	0.034	0.044	0.780	56.4%	
Proactive tests (time t_0 – 90 minutes)	0.065	0.043	1.530	87.4%	

Table 43: Regression results for runway crossings during the proactive periods

Given the caveat of low R^2 from the regressions, the table shows that both TEAM* and proactive tests are associated with a reduction in runway crossings, as would be expected given the air traffic controllers are likely to choose T4 aircraft for the southern runway when they have the opportunity. As both TEAM* and proactive test have this effect, the comparison of runway crossings between proactive and non-proactive periods of the trial is likely to give a negative result. It can be tentatively concluded therefore that both TEAM* and proactive tests are associated with a reduction in runway crossings.

5 Environmental impacts

5.1 Introduction

This section of the report discusses the environmental impacts associated with the Operational Freedom Trial in its entirety. The section covers:

- noise
- post-23:00 hour departures
- track-keeping compliance for departures
- continuous descent approaches (CDAs) for arrivals.

5.2 Noise impact

The Environmental Research Consultancy Department (ERCD) of the CAA has been commissioned by Heathrow to undertake the assessment of the noise changes associated with the Operational Freedom Trial. A full copy of their “London Heathrow Operational Freedoms Trial: Effect on noise” report is provided in Annex J of this report. This report has considered the effects of the application of landing aircraft on the designated departure runway, early-vectored departures and three different proactive Operational Freedoms during the three parts of the Operational Freedoms Trial and this section of the report provides its conclusions.

5.2.1 Landing aircraft on the designated departure runway

The analysis shows that there was a near doubling of out-of-alternation westerly arrivals during the Phase 1 and Phase 2 summer trial periods, and that there were daily averages of 10.9 and 9.9 TEAM* arrivals respectively. During the Phase 2 winter trial period, TEAM* was used to a lesser extent and, consequently, the number of out-of-alternation westerly arrivals was lower than that of the baseline.

In response to questions from stakeholders, we tested the effect of extending the Phase 2 summer season and winter season baseline periods to include 2008 and 2007. This did not materially affect the analysis which used baselines comprising the three previous years prior to the respective trial period.

For each part of the trial, the mix of out-of-alternation aircraft, in noise terms, was not significantly different during the trial period to that of the baseline.

During the trial, on any given day there were up to 53 out-of-alternation westerly arrivals. For the majority of days in the summer season, when most use was made of the freedom, there were from 6 to 35 out-of-alternation westerly arrivals. In the winter season, for the majority of days, there were up to 20 out-of-alternation westerly arrivals.

Except for the Phase 2 winter trial period, the out-of-alternation arrivals occurred at a higher frequency and over a greater number of hours compared with the baseline. Additionally, the number of hours with no out-of-alternation westerly arrivals was reduced to about half of the baseline value in the trial periods.

In all parts of the trial, the average maximum time between out-of-alternation arrivals was lower in the trial than the baseline periods, due to the higher number of out-of-alternation arrivals and/or the different approach taken towards arrivals management.

The noise contour analysis of the trial highlighted that:

- a near doubling in out-of-alternation arrivals leads to an increase in Leq noise exposure of almost 3 dB, but almost no decrease in Leq noise exposure.
- the effects of de-alternation are greatest very close to the airport (immediately east of the airport) where the benefits of alternation are greatest. The effects of de-alternation then become less apparent further away from the airport, particularly beyond approximately 15 km.
- the increase in de-alternation resulted in between one and five more noise events exceeding 70 dBA, and between 0.5 and 2 minutes more noise exposure above 70 dBA Lmax, per 8-hour respite period, but with corresponding reductions during the 8-hour non-respite period. These reductions are low in proportion to the number of noise events/noise exposure during the 8-hour non-respite period. However the corresponding increases during the alternation respite period are higher in proportion to the number of noise events/noise exposure during this period.

5.2.2 Early-vectored departures

Early-vectored departures occurred during Phase 2 of the trial only. Greater use of this freedom was made during the summer season than the winter season.

There were many more operational freedom early-vectored departures than weather-vectored departures during the trial. There were also many more westerly than easterly early-vectored departures due to there having been a predominance of days of westerly operation during the trial.

There was a large range in the numbers of daily early-vectored departures, with average numbers of easterly or westerly early-vectored departures between 35 and 47 and maximum values over 100 on some days.

The average time between early-vectored departures was around eight to ten minutes for the summer season, and around six to nine minutes for the winter season.

During the summer season, there were fewer hours in an average westerly day with no early-vectored departures than on an average easterly day. This is probably due to the fact that early vectoring was available on a different SID for westerly and easterly operations. The lower number of early-vectored departures in the winter season generally led to an increase in the average number of hours with no such departures compared with the summer season.

Operational freedom early-vectored departures on 09R DVR occurred, on an average day, during nearly eight clock-hour periods, and on 27 MID they occurred during nine clock-hour periods during the summer season. There were generally fewer one-hour periods with at least one early-vectored departure in the winter than the summer season. For the vast majority of days, once early-vectoring had begun, it continued with at least one such departure per hour until the procedure stopped for the day.

16-hour Leq noise contours representing the summer season trial and baseline were plotted for departure movements only. The differences between these were also calculated and Leq difference contours plotted to show changes in 16-hour noise exposure as a result of the operational freedom early-vectored departures.

The greatest increase in noise level (where absolute noise levels are 54 dBA $Leq_{,16h}$ or more) was +0.8 dBA. This occurred beneath the 09R DVR early vector heading. The greatest decrease of -0.6 dBA occurred beneath the 09R DVR SID from which the operational freedom early-vectored departures have been redirected.

Over 100,000 people are affected by daytime average departure noise at a level of 57 dBA $Leq_{,16h}$. Around 100 fewer people (0.1%) were exposed to at least this level of noise as a result of the operational freedom early-vectored departures.

However, over 250,000 people are affected by daytime average departure noise at a level of 54 dBA $Leq_{,16h}$. Around 700 more people (0.3%) were exposed to at least this level of noise as a result of the operational freedom early-vectored departures.

SEL footprints have been presented for the noisiest and most commonly used aircraft on each of the operational freedom early-vector mean tracks and respective SIDs for comparison. Difference contours have also been plotted which show that the greatest differences between standard SID and early-vectored departures of up to 16 dBA occur for departures on 27R MID. To put this into context, a change of 10 dBA represents a doubling or halving of loudness.

5.2.3 Proactive freedoms

The noise effects of the proactive freedoms were assessed during Phase 2 of the trial only. During Phase 2, greater use was made of these freedoms during the winter season than the summer season.

The results show that of the proactive freedoms, the Terminal 4 freedom was used most frequently, followed by the A380 freedom, and the Small/Light freedom was used the least frequently.

The analysis found that, compared with the baseline out-of-alternation arrivals, the noise energy of the average arrival associated with the A380 and Small/Light proactive arrival freedoms was lower by up to 0.4 dB and 5.9 dB, respectively. The average Terminal 4 proactive arrival was up to 0.2 dB noisier than the baseline out-of-alternation arrivals.

There were up to six A380 proactive arrivals on any given day, with the majority of days having two, three or four proactive arrivals during the winter season (zero to three in the summer season). There were up to three Small/Light proactive arrivals on any given day, with the majority of days having zero or one proactive arrival. There were relatively few days where the Terminal 4 freedom was not used; for the majority of days there were up to nine Terminal 4 proactive arrivals during the summer season, and up to 24 during the winter season.

In the summer season, despite more use having been made of the A380 freedom than the Small/Light freedom, the latter was used more intensively (but over a shorter period of time). The Terminal 4 freedom was used even more intensively. During the winter season, the Terminal 4 freedom was again used more intensively than either of the other two freedoms.

With more use having been made of the proactive freedoms in the winter season than in the summer season, their occurrence has been more spread out over an average day.

For the summer period, the A380 freedom was used about as intensively as TEAM, and the Terminal 4 freedom was used about as intensively as TEAM*. For the winter season, the A380 and Small/Light freedoms were used less intensively than either TEAM or TEAM*. The Terminal 4 freedom was used more intensively than TEAM and TEAM*.

In the summer season, each of the proactive freedoms left a greater number of hours each day free of out-of-alternation arrivals than TEAM* and even TEAM, on average. During the winter season, the A380 and Small/Light proactive freedoms left comparable numbers of daily hours free to TEAM* and TEAM, but the use of the Terminal 4 proactive freedom, by contrast, left fewer hours free.

For the times of least intensive use in the summer season, the Small/Light freedom was used more intensively than the Terminal 4 freedom. The use of the proactive freedoms was generally not spread out over a day to the same extent as for TEAM and TEAM*. During the winter season, the proactive arrivals appeared to be more spread out throughout the day than in the summer season.

5.3 Post-23:00 hours departures

Figure 53, Figure 54 and Figure 55 compare the post-23:00 departure PDFs for the three trial periods with their respective baseline periods. There is relatively little qualitative difference between each of the trial PDFs and its respective baseline, except for noise due to a small sample size for the winter period of Phase 2 of the trial.

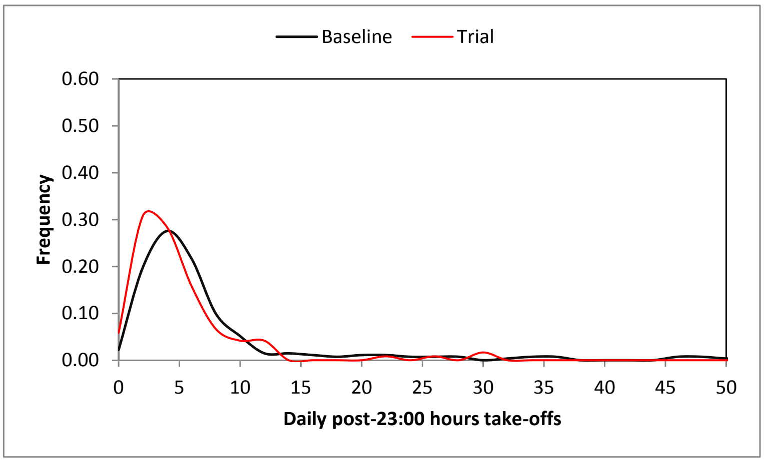


Figure 53: Comparison of the Phase 1 post-23:00 hours departure PDFs with the winter baseline

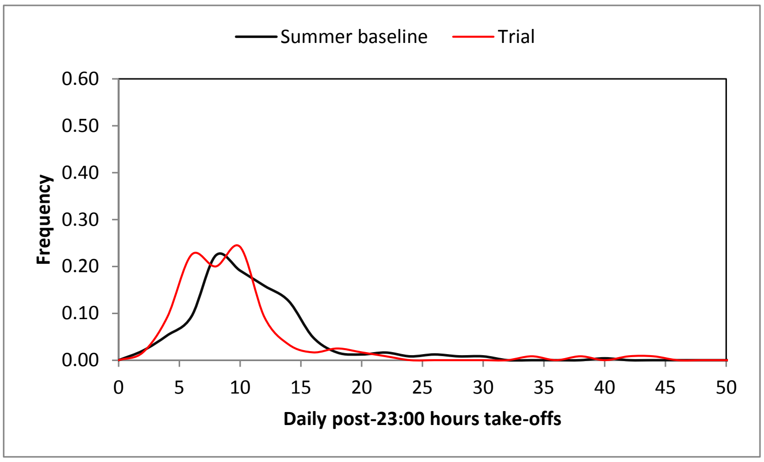


Figure 54: Comparison of the Phase 2 summer post-23:00 hours departure PDFs with the summer baseline

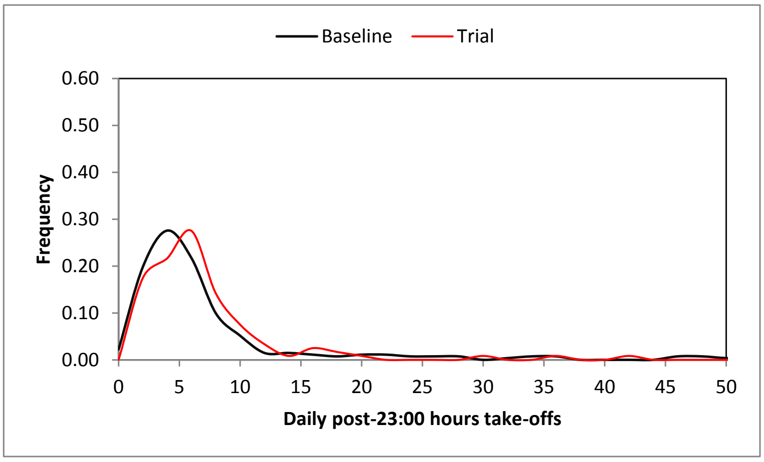


Figure 55: Comparison of the Phase 2 winter post-23:00 hours departure PDFs with the winter baseline

Table 44, Table 45 and Table 46 summarise the statistics for post-23:00 hour departures comparing the proactive and non-proactive periods for the three parts of the trial.

	Winter baseline	Trial	Confidence (baseline- trial)
Average per day	7.33	5.01	100%
Standard deviation	9.36	6.67	100%

Table 44: Comparison of post-23:00 hours departure statistics for Phase 1 of the trial and the winter baseline

	Summer baseline	Trial	Confidence (baseline- trial)
Average per day	10.52	9.38	95%
Standard deviation	5.25	6.66	100%

Table 45: Comparison of post-23:00 hours departure statistics for the summer part of Phase 2 of the trial and the summer baseline

	Winter baseline	Trial	Confidence (baseline- trial)
Average per day	7.33	6.58	85%
Standard deviation	9.36	5.93	100%

Table 46: Comparison of post-23:00 hours departure statistics for the winter part of Phase 2 of the trial and the winter baseline

The tables show that in each case there is a statistically significant reduction in post-23:00 hours departures compared to the each baseline. The trial is, therefore, associated with a significant reduction albeit small of average post-23:00 hours departures. It is not clear, however, how much of this reduction can be attributed to Operational Freedoms, particularly because the largest improvement occurred during Phase 1 of the trial when there were effectively no departure freedoms in operation.

5.4 Track-keeping

Figure 56 and Figure 57 make comparisons of the track-keeping compliance PDFs for the Dover (DVR) and Midhurst (MID) SIDs with the available baselines- these are restricted to data for the two SIDs for summer 2011 for the summer comparison and the aggregated track-keeping compliance for all SIDs split by easterly and westerly operations for the winter period. For the latter, data is available for winter seasons 2008-09, 2009-10 and 2010-11.

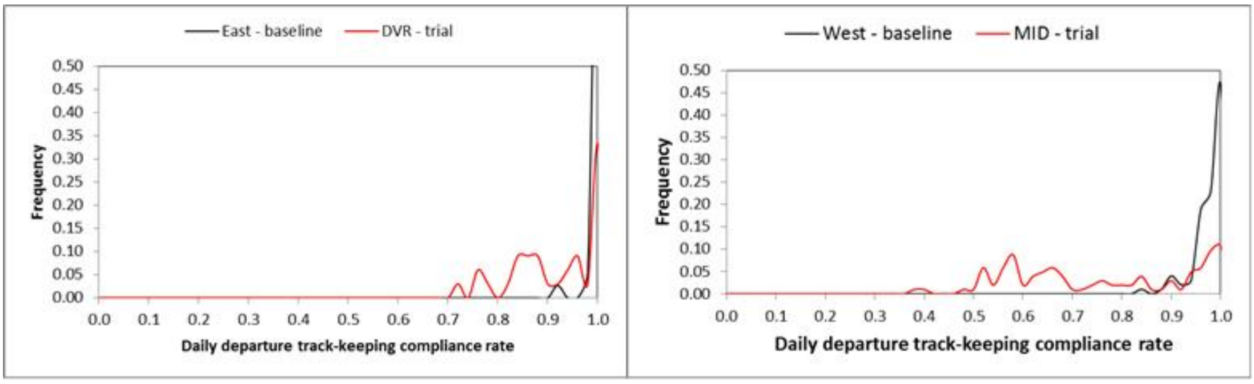


Figure 56: Comparison of the Phase 2 summer track-keeping compliance PDFs with the same period in 2011

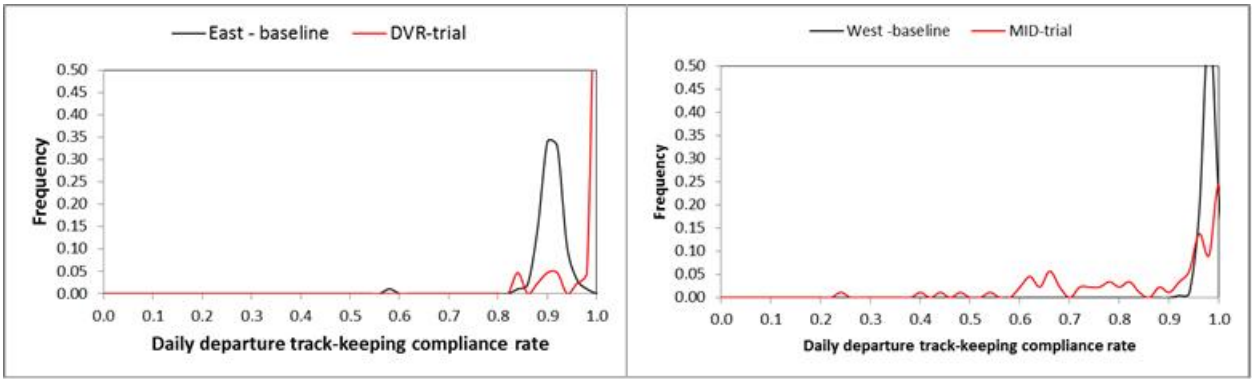


Figure 57: Comparison of the Phase 2 winter track-keeping PDFs for the DVR and MID SIDs with the easterly and westerly compliance rates for the winter baseline

The PDFs show a trend to much lower track-keeping compliance rates during the trial for all cases except DVR during the winter part of the trial.

Table 47 and Table 48 summarise the statistics associated with each of the PDFs.

	Baseline		Trial		Confidence	
	East	West	MID	DVR	MID	DVR
Average daily success rate	0.97	0.99	0.75	0.91	100%	99%
Standard deviation of daily success rate	0.03	0.02	0.17	0.08	100%	100%

Table 47: Comparison of track-keeping compliance statistics for the summer part of Phase 2 of the trial and compliance achieved during 2011

	Baseline		Trial		Confidence	
	East	West	DVR	MID	MID	DVR
Average daily success rate	0.90	0.97	0.97	0.84	100%	100%
Standard deviation of daily success rate	0.04	0.01	0.06	0.18	85%	100%

Table 48: Comparison of track-keeping compliance statistics for the winter part of Phase 2 of the trial and compliance achieved during 2011

The table show, with the exception of Dover during the winter part of the trial, a significant degradation in track-keeping compliance on the SIDs to which OF vectors are applied.

5.5 Continuous descent approach

Table 49, Table 50 and Table 51 summarise the statistics associated for CDA compliance for each of the three trial periods compared to suitable baselines. In each case the table indicates that CDA compliance was no worse or actually better than in the relevant baseline period.

	Winter baseline		Trial		Confidence	
	East	West	East	West	East	West
Average	0.76	0.83	0.80	0.84	100%	83%
Standard deviation	0.07	0.06	0.03	0.04	100%	100%

Table 49: Comparison of CDA compliance statistics for Phase 1 of the trial and the winter baseline

	Summer baseline		Trial		Confidence	
	East	West	East	West	East	West
Average	0.85	0.88	0.85	0.89	61%	98%
Standard deviation	0.05	0.05	0.08	0.04	100%	97%

Table 50: Comparison of CDA compliance statistics for the summer part of Phase 2 of the trial and the same period during 2011

	Winter baseline		Trial		Confidence	
	East	West	East	West	East	West
Average	0.76	0.83	0.80	0.85	100%	97%
Standard deviation	0.07	0.06	0.06	0.05	97%	93%

Table 51: Comparison of CDA compliance statistics for the winter part of Phase 2 of the trial and the winter baseline

It can be concluded, therefore, that the trial has had no impact on CDA compliance.

6 Community

6.1 Introduction

This section summarises Heathrow's stakeholder engagement during the trial. It also considers the community reaction to the trial. This was one of the strategic objectives set and agreed prior to the trial starting. This section includes results from the polling carried out on behalf of Heathrow in September 2012; quantitative research; and complaint statistics and analysis for Phase 2 of the trial.

6.2 Engagement

6.2.1 Introduction

In advance of the trial starting last year, the Written Ministerial Statement for the SEAT report published 15 July 2011 was clear about the engagement expected from BAA (now Heathrow). It said that we would "*engage fully and transparently with relevant local authorities, communities and other stakeholders throughout the process, particularly on the monitoring of noise impacts*".

The engagement process for Phase 1 of the trial was agreed with the CAA and DfT prior to the trial starting. The engagement activities for Phase 1 of the trial included:

- Direct mailing – A5 information leaflet to 300,000 homes
- Newspaper advertisements – placed twice in 14 newspaper titles across London and the west of Heathrow
- Community briefings/meetings
- MP/local authority briefings
- Heathrow website – details about the trial and a computer generated graphic were made available.
- Media coverage – a press release was issued and Heathrow carried out a number of media interviews in advance of the trial.

During Phase 1 of the trial, engagement activities included:

- Monthly technical working groups –set up in response to requests from local authorities and attended by local authority and industry representatives with meetings held on 8 November, 13 December, 31 January and 21 February
- Resident meetings – these were meetings at which it was requested that Heathrow attend to explain the trial and answer questions and concerns from local residents. Meetings were held in Richmond, Putney, Hammersmith, Isleworth & Brentford, Richings Park and Heston.
- Stakeholder briefings – a number of meetings were held with local MPs, councils and GLA members.
- Web site – during Phase 1 the website was amended in light of feedback. This included creating and publishing a document to explain Heathrow's runway operating procedures that existed prior to the trial, and the changes that were made to these during the trial. The document was written in conjunction with local authorities and the CAA.

- On-going media coverage and interviews
- On-line production of daily data and monthly reports.

An updated stakeholder engagement plan was agreed with the DfT and CAA in advance of the Written Ministerial Announcement on 15 May 2012 announcing details of Phase 2. The engagement during Phase 2 of the trial included

- Stakeholder briefings – we hosted two stakeholder briefings (16 May and 16 October) for local authorities and MPs around Heathrow. In addition to these a number of separate briefings were held with local authority and MPs, as well as updates to the Heathrow Airport Consultative Committee.
- Resident meetings - these were meetings at which it was requested that Heathrow representatives attend to explain the trial and answer questions and concerns from local residents. We have offered to host these in every borough and constituencies around Heathrow. We attended a meeting organised by Zac Goldsmith MP in Richmond on 21 November and the Hammersmith and Fulham Scrutiny Committee on 6 November. Meetings continued until the end of February 2013 and included a hosted tour of the Heathrow Air Traffic Control Tower
- Monthly technical working groups - these were set up in response to requests from local authorities and attended by local authority and industry representatives. Meetings were held on an approximately monthly basis.
- Media coverage and newspaper advertising – we placed newspaper advertisements in 14 local newspaper titles around Heathrow. The trial led to a number of press articles and was also covered by regional broadcast media.
- Web info /on-line animations - the website was updated with details of Phase 2 including on-line animations to explain some of the procedures being used.
- On-line production of daily and monthly data – this was provided continuously during the trial periods, including the gap between the end of Phase 1 and the start of Phase 2.

6.2.2 Resident polling

Following polling undertaken during Phase 1, Heathrow commissioned further polling by Populus Ltd to undertake quantitative research into residents' attitudes to the trial during Phase2.

A total of 1,972 telephone interviews took place with residents across three noise bands – lower (55-60 Lden), moderate (60-65 Lden) and higher (65+ Lden).

As well as gauging attitudes towards the trial, the questionnaire was used to establish general attitudes towards Heathrow and explore reasons behind people's attitudes to the Airport.

Members of the technical working group were invited to feedback comments on the proposed questionnaire, which was used to develop the final version. Comments mainly centred on the description of the trial impacts. Following the results of the polling which were issued to the group in a draft version of this report a number of further comments were registered by some members. These primarily related to the structure of the questions, the location of residents which were polled and interpretation of the results. Populus are confident in the robustness of the approach and analysis undertaken.

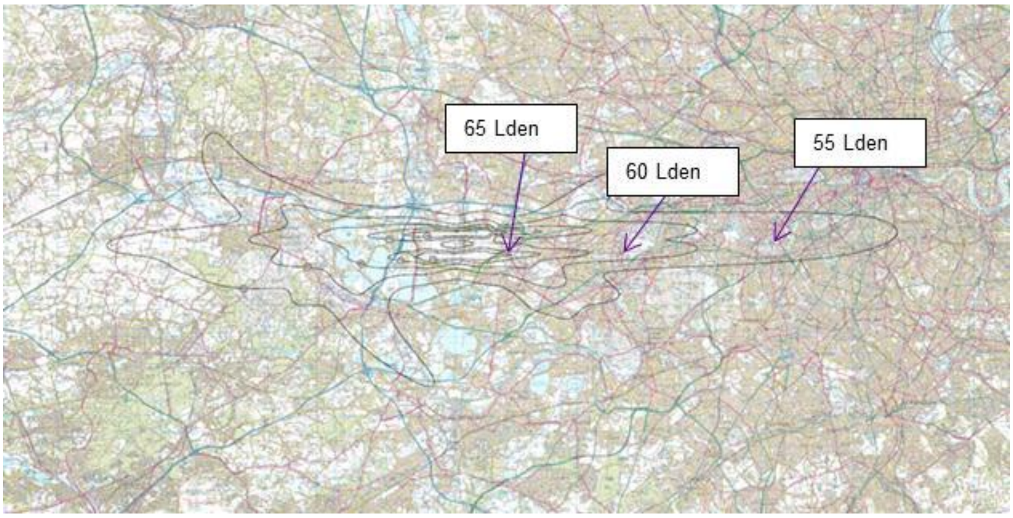


Figure 58: Lden noise contour

Annex K sets outs the questions and results related specifically to Operational Freedoms. In summary the polling found that

- 20% of residents polled were aware of changes to Heathrow's operations
- Of those that were aware, there was a range of knowledge in terms of what procedures were being used. A quarter of those that were aware of changes thought that Heathrow was no longer alternating runways.
- When told about the trial, initial responses saw 76% of respondents supportive of the trial, however this fell once told about some of the potential impacts for residents.

Overall however, support for the trial was high.

6.2.3 Qualitative research

In order to obtain more detailed insight into the impact of the trial for local residents, Heathrow commissioned some qualitative research to be undertaken. The first phase of the research was carried out in summer 2012.

The main research objectives of this research was to

- provide an initial assessment of the impact on residents of the 2nd phase of the Operational Freedom trial;
- explore the value to residents of their respite period (a recommendation from the CAA report following Phase 1)

Phase 2 of the trial was intended to provide the project team with an opportunity to obtain corroborative evidence of this positive relationship between reliable and constructive information about airport activities and residents' attitudes towards the trials and the Airport in general.

The research involved 27 in-depth interviews with residents living around Heathrow Airport. While the number of those interviewed is too small to be regarded as fully representative of the population around the Airport, the researchers felt it was sufficient to ensure that they were able to cover a full spectrum of different perspectives (both in terms of different areas affected by aircraft noise and different types of people who may, in principle, be affected by the same level of noise to different degrees).

The methodology for selecting residents as well as full findings from the research related to Operational Freedoms and respite can be found in Annex L to this report.

In summary, the research found that

- Four people were aware of the trial and this was to varying degrees.
- Once given more information about the trial, the majority of respondents were supportive of the trial objectives.
- The trial was generally seen as a positive by residents and a constructive and imaginative move by Heathrow.
- All residents were supportive of reducing the number of early morning flights and late night departures.
- Some residents felt Heathrow could have done more to communicate about the trial.
- The provision of more information during these interviews led to residents forming a more positive view of Heathrow.
- The majority of residents were unaware of defined periods of respite. Many felt that this was because they had either not been told about it or did not notice the 'quiet' periods when aircraft weren't flying overhead.

As with the polling conducted by Populus some members of the technical working group raised a number of questions in relation to the findings presented in the draft circulation of this report. The primary concern related to the information presented on the "show cards". These had been prepared to indicate the general intentions prior to the trial and were therefore not completely accurate in terms of what had actually happened. Members were concerned that this could have influenced the findings in some way. It should be noted that the show cards had no effect on the initial 'uninformed' views because they were presented in the second part of the interviews after the initial uninformed views had been obtained. The independent researchers were well aware of this potential bias to the second 'informed' part of the interviews and were careful to; a) explain that the show cards were necessarily illustrative of the general intentions of the trials rather than being a definitive explanation of what had actually happened; and b) take into account any additional effects this could have had when reporting the findings. The alternative of waiting until the trials had been completed before carrying out interviews so that it would then have been possible to describe exactly what had happened had been rejected because the interviews were also intended to provide information about the ongoing effects during the trials so that the detailed procedures could then be modified if necessary.

6.3 The value of respite

6.3.1 Methods and objectives

The main purpose of runway alternation at Heathrow is to provide scheduled noise relief, or respite, for residents underneath the westerly arrivals flight tracks to the east of the airport. This has a reciprocal effect on departures as the majority of these are constrained to use the runway not in use for arrivals; there is also a limited amount of respite in some areas underneath the westerly departures flight tracks. At present, because of the legacy of the Cranford agreement, there is no alternation and hence no scheduled relief on easterly operations. Under Operational freedoms, there was a marginal loss of noise respite caused by aircraft using the other runway from that specified under the scheduled alternation pattern. The value, to residents, of this marginal loss of noise respite was investigated using focus groups and in-home depth interviews.

Initial analysis using flight tracks and noise contours for individual take-offs and landings (provided by the CAA) showed that the geographical areas where the current alternation patterns make any significant difference to physical noise exposure are quite limited. Close to the airport, any scheduled respite provided by the current alternation pattern can be compromised by unpredictable changeover to easterly operations required by prevailing weather conditions. At increasing distances from the airport, the flight tracks to and from the north and south runways overlap and coincide, limiting the areas in which any significant physical benefits of alternation can be achieved.

It was therefore decided to select sampling areas to the east and west of the airport where the current alternation patterns produce the greatest differences in physical noise exposure. The findings of the focus groups and in-home interviews apply to these areas and might not apply to other areas where there is little or no identifiable difference in aircraft noise exposure associated with increasing Operational Freedoms.

Previous research had indicated a generally low level of either interest in or understanding of current airport operations. Achieving a sufficient degree of understanding to obtain meaningful 'informed' views about loss of respite was therefore likely to be challenging. Animated graphics supported by verbal explanations were found to be effective, using a flexible script which had to be adapted for different respondents in different areas.

Focus groups and in-home depth interviews were carried out in Datchet and Wraysbury to the west of the airport and in Isleworth and Richmond to the east of the airport. A specialist contractor recruited 75 participants, of whom around half took part in focus groups lasting around one and a half hours and the rest were interviewed by appointment in their own homes. In-home interviews were designed to take around 30 minutes, although some participants had less to say and the interviews were consequently a bit shorter and some participants took almost an hour to cover everything. All participants were given a small thank you gift and all interviews and focus groups were recorded.

6.3.2 Overview of general opinions about living near to an airport

In general, most participants were very happy with the areas in which they live. For most participants, aircraft noise can be annoying from time to time; such as when entertaining friends from out of the area at a summer barbecue or after having been woken up by early morning flights, but it is nevertheless accepted as an unavoidable feature of living near to a major airport. As in previous research, few participants had much interest in or understanding of current airport operations or remembered seeing any previous information about the Operations Freedoms trials.

6.3.3 Uninformed views on noise respite

Before being given detailed information about current airport operations, most participants were aware of variations in aircraft noise from one day to the next, but had little understanding of, or even interest in, the causes of this variation, and had no appreciation of any particular pattern to it. There was no evidence that anyone was able to plan their activities according to the alternation schedule, of which they were unaware. When given more information later, many participants were sceptical that having access to the alternation schedule would be of much benefit to them, although a minority felt that it could be of some use.

Nobody had noticed any changes in overall aircraft noise or any marginal loss of amenity during the Operational Freedoms trials through 2012 as compared to the previous year (2011) and to the current situation (2013). There was no evidence that the marginal loss of amenity associated with increased Operations Freedoms had any significant monetary value to these participants. When given more information later about the alternation schedule a few participants expressed a view that they wished they had been paying more attention in order that they might then have noticed any changes which had occurred.

6.3.4 Informed views on noise respite

All participants were then given detailed information about runway alternation, the current pattern of operations, and the Operations Freedoms trials. The detailed information had no material effect on participant's perceptions of aircraft noise, but many were impressed that, every day, over 600 arrivals and over 600 departures were handled safely and efficiently on only two runways. From various comments made, it seems likely that some at least might pay a little more attention to the different types of aircraft operations in the future, and there was absolutely no impression given that providing the detailed information had any negative effects.

All participants were presented with lists of alternative hypothetical noise management options from which to select the most important or valuable for them personally. The lists included varying amounts of hypothetical financial compensation and a range of hypothetical management options such as reducing night flights, or reducing air pollution, or more generous noise insulation schemes in addition to either retaining the current runway alternation procedures or reverting to the situation experienced as under the Operational Freedoms trial in 2012. All participants were able to trade between the alternative hypothetical noise management options, and provided rational explanations for their choices. The overall principle of alternation/respite appeared to be of some value to participants, but most of them placed higher priority on other options such as reducing night flights, reducing air pollution, or more generous noise insulation schemes.

Following receipt of detailed information, there was no evidence that the marginal loss of amenity associated with increased Operations Freedoms through 2012 had any significant monetary value for these participants.

A sub-sample was presented with hypothetical options for 'sharing' or 'alternation' by which the total number of operations on the nearest flight track could be (hypothetically) spread out with a reduced hourly frequency over the entire day (sharing), or concentrated either before or after 1500 pm with scheduled respite for the rest of the day (as in current alternation). Opinions were divided as to the benefit of these options with no consensus one way or the other.

The research demonstrated that, not-withstanding the general lack of interest in or understanding of current airport operations, the great majority of participants are able to trade between alternative hypothetical noise management options, some of which can include hypothetical financial compensation, requiring only that they have been given sufficient information to ensure that any views expressed are fully informed by factual details of which they might previously have been unaware. It was not possible in this qualitative research to obtain statistically definitive (albeit small or even negligible) monetary values for marginal loss of respite, but the research demonstrated that by using the techniques developed for this research, it would be possible to obtain statistically definitive monetary values if repeated on a much larger and more quantitative scale.

6.4 Enquiries analysis

All complaints received during the trial have been analysed and are presented in this section. A complaint will either be related to a time 'specific' event – where a particular flight has been cited - or may be a more 'general' complaint about a particular issue or range of issues (e.g. night flights, low flying aircraft etc.). Figure 59 sets out the process we have followed in the complaints received.

Heathrow classifies complaints that the Airport receives at three levels

- a **caller** which is an individual person who makes contact with Heathrow's complaint handlers by telephone, e-mail, letter or through the web-portal
- a **contact** which represents the number of times a caller contacts Heathrow
- an **enquiry** which represents the number of issues reported by the caller during a contact (e.g. low flying, noise, de-alternation, etc.)

These three levels are reported as standard by Heathrow in its monthly reports. As an example, one person that makes contact three times and each time enquires about low-flying aircraft and track keeping would count as: one caller; three contacts; and six enquiries.

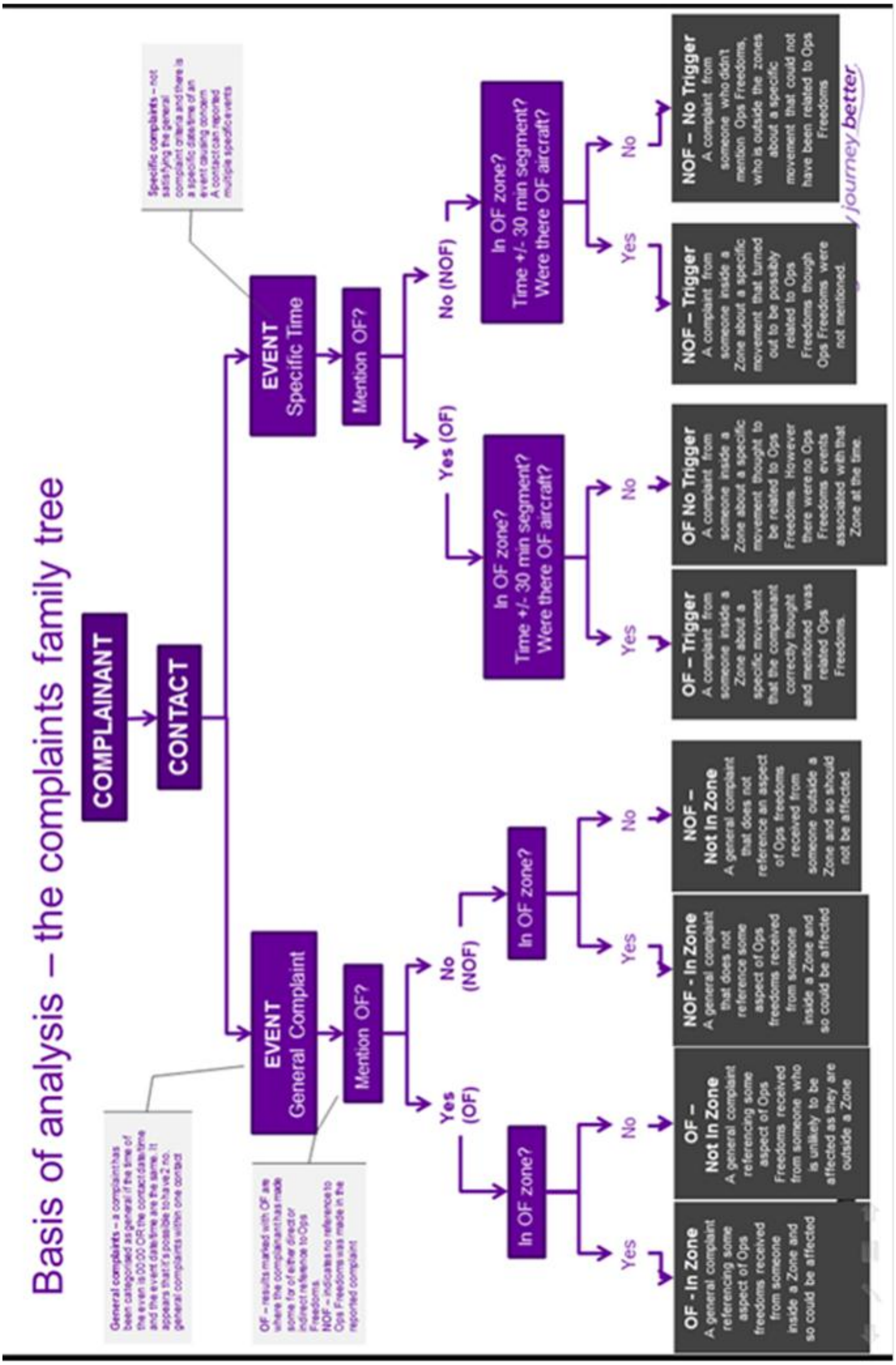


Figure 59: The complaints family tree

6.4.1 Methodology

6.4.1.1 How have the complaint figures been derived?

Complaints are received by Heathrow's community relations team via email, telephone, website and letter. Each one of them is then inputted into the complaints database. The total numbers of contacts per day were published on our website as part of the daily reporting process during the trial. It is important to note that these daily figures related to all complaints received on a particular day but which were not necessarily about that particular day. Where a specific date and time has been mentioned this will be logged in the system on the date it was received but the date to which it refers has been used in the analysis presented in this section. This may cause differences between the daily statistics presented on the website and those reported in this report.

There are a very small number of Callers who have been in contact with the Heathrow Community Relations team (who manage noise complaints) over the course of many years and routinely make contact a large number of times on a daily basis to register a complaint. In dealing with these, and in order to ensure we make best use of our resources, we have a long standing policy agreed with NTKWG to acknowledge all of the complaints but only record them under one contact. This avoids the statistics being significantly skewed by one or two callers. In the daily website report the number of contacts has not been adjusted to take account of these multiple contact callers but the analysis presented in this report has been adjusted. This will account for a large part of the differences in the total which can be derived from summing all the daily reports and the contact figures cited in this report. For transparency the total number of contacts inclusive of the multiple contact complaint is presented in Table 52 below.

Data Source	Total Contacts
Daily contacts posted on our website (inclusive of multiple contact callers)	13721
Contacts relating to general or specific contacts for the period of the trial and recorded in the database for analysis in report	10818
Sum of contacts from multi-contact repeat callers	3608

Table 52: Total number of contacts

Over the course of Phase 2 of the trial there were four multiple-contact complainants who made contact with the Heathrow Community Relations team accounting for 3,608 contacts presented above.

6.4.1.2 How have we determined whether the complaint received related to the Operational Trial?

Not everyone who has made an complaint would necessarily be aware of the Operational Freedoms trial or perhaps use those specific words when making contact. Therefore it has been necessary to develop a methodology that enables a reasonable assessment to be made as to whether the contact was related to the trial or not. In order to do this we have created a series of "zones" which are broadly located over areas which could be impacted by the trial related flights. These zones have been created using flight track plots of actual trial flights and adding a "buffer" either side of the zones. All the postcodes within each zone were then matched with the postcode of the complainants. This process is the same for both general and specific complaints. Typical arrival tracks on westerly operations (see for example

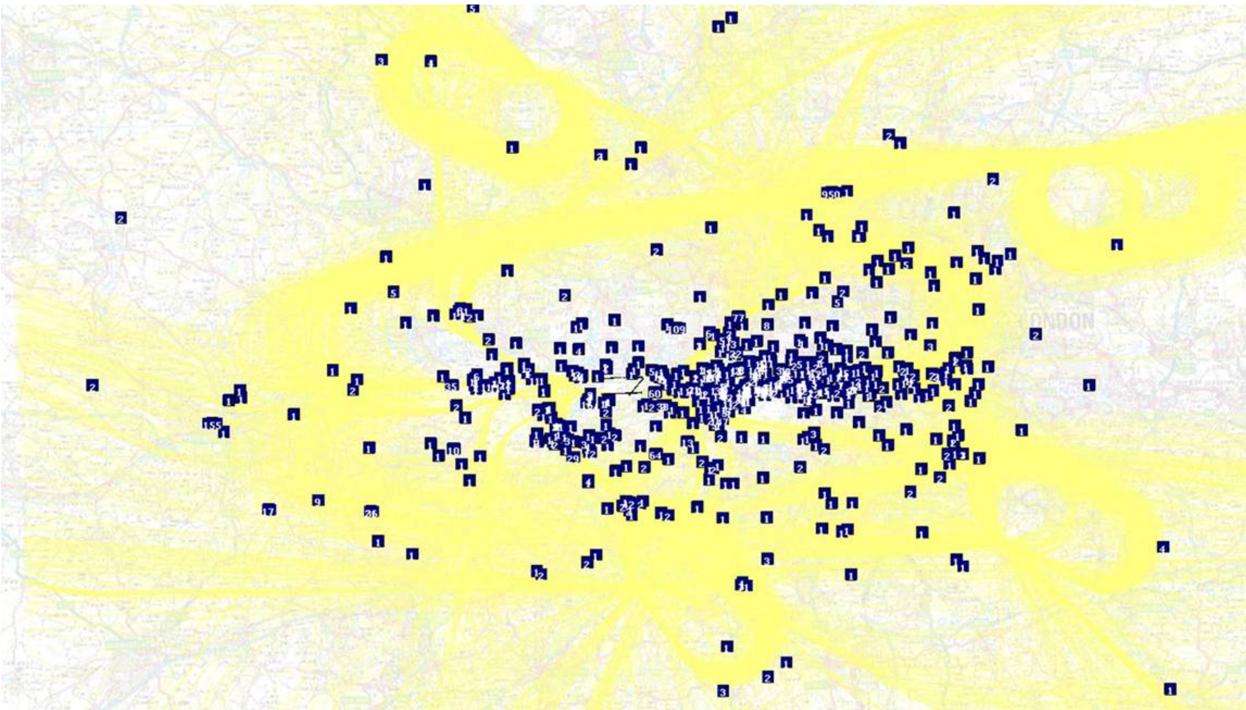


Figure 66) as well as the tracks generated by the vectored flights on 09RDVR, 27LMID and 27RMID and the monthly reports in Annexes A to D) have been used to generate the zones. Table 53 below summarises the operational freedom most likely to impact the various zones.

Zone	Operational Freedom potentially affecting the zone.
1	Early Vectors on 27RMID or 27LMID
2	TEAM* (Out of alternation) **established** arrivals on 27L or 27R
3	TEAM* (Out of alternation) **establishing** arrivals on 27L or 27R
4	Early Vectors on 09RDVR
5	Early Vectors on 27RMID or 27LMID close to the runways

Table 53: Impact of Operational Freedoms on complaint zones

For specific complaints which are within the zones regardless of whether the person complaining mentioned the Operational Freedoms trial, a further piece of investigation has been undertaken to determine whether the complaint could have related to an operational freedom flight. This involves taking the 30 minute period which contained the time stated by the caller and to this, adding 30 minutes either side the two periods either side (i.e. giving a 90 minute window). Within this time the Heathrow Team have investigated whether there were any flights operating as part of the trial affecting that zone. Where this is the case the complaint has been assumed to relate to an operational freedom flight.

Specific complaints, from areas outside the four identified zones but where the trial has been mentioned, have not been recorded as relating to flights operating as part of the Operational Freedoms Trial although the fact that the trial was mentioned has been accounted for.

Figure 60 shows the five zones that could be potentially affected by Operational Freedoms as described in the table above.

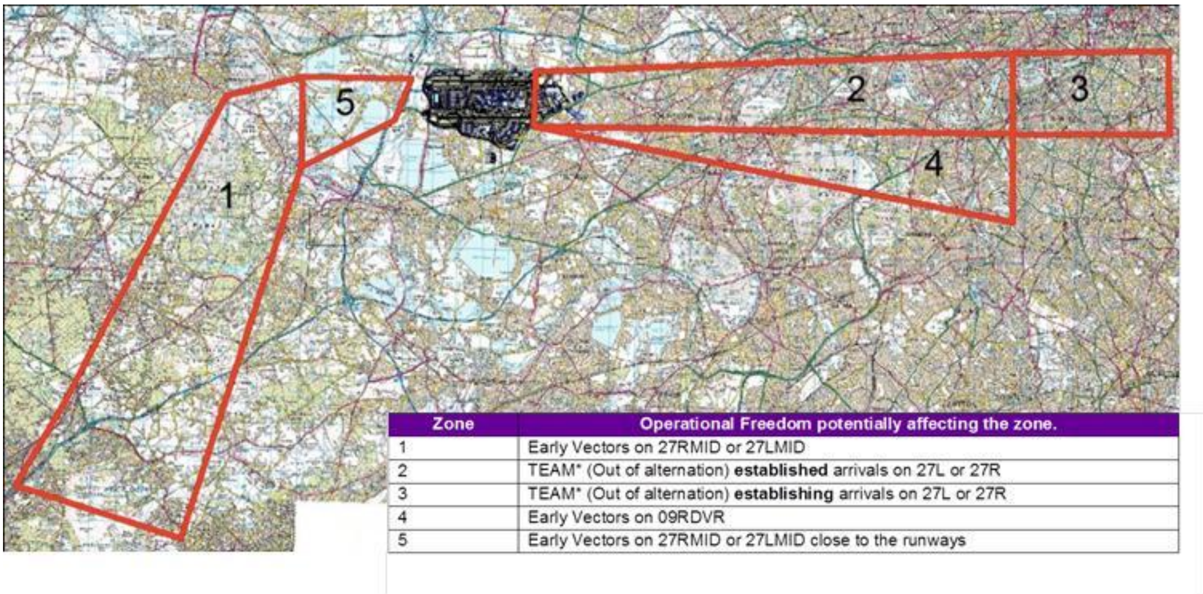


Figure 60: Zones potentially affected by Operational Freedoms

Using demographic data already held by Heathrow estimates of the households within each zone have been calculated using postcode centres. These are shown in Figure 61. It should be noted that because of the limited extent of the household data held the number quoted for zone 1 is likely to be an underestimate, whereas zones 2 to 5 should be more accurate figures.

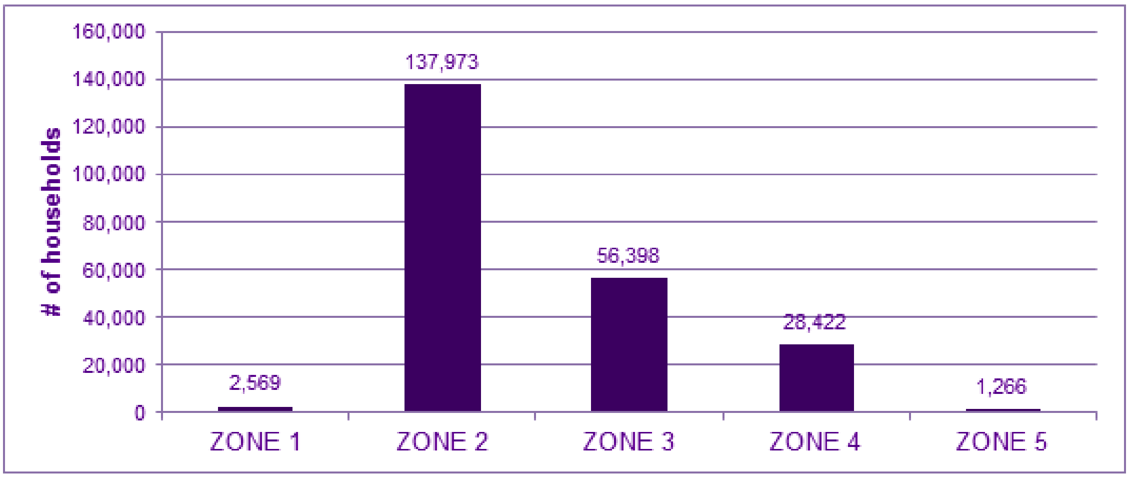


Figure 61: Number of households within each zone and within the 55 Lden contour

6.4.2 Analysis

6.4.2.1 Summary Overview

Between 1 July 2012 and 28 February 2013 we received 20,498 noise complaints from 2,844 callers. This is presented in Figure 62 below in direct comparison with data for the same period in 2011. Of the complaints received within this period, 2,993 (14.6%) were general and 17,505 (85.4%) related to a specific time. Not all of these complaints related to Operational Freedoms.

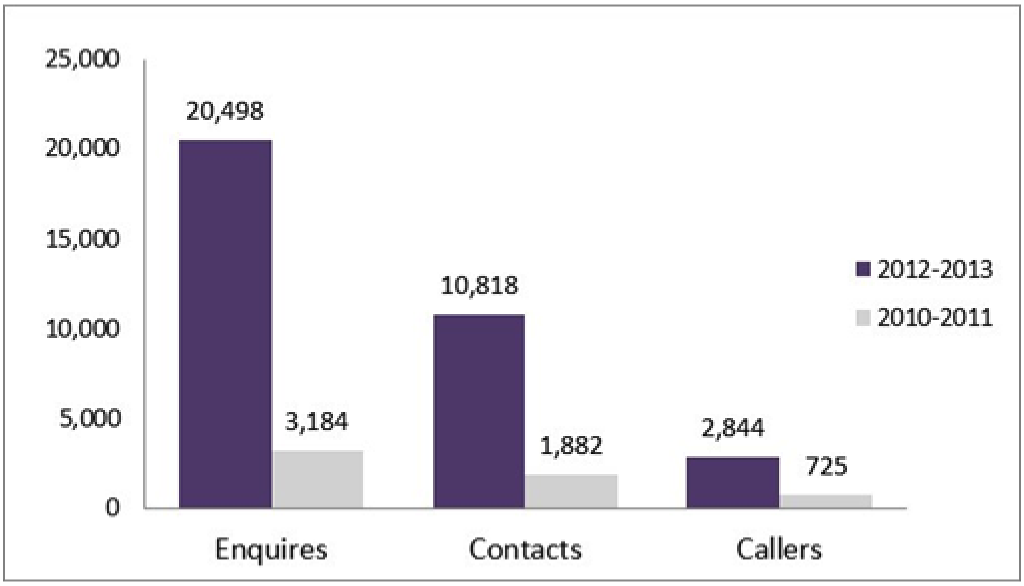


Figure 62: Overall complaints (general and specific)

Breaking down the overall complaint data by zone as shown in Figure 63 it is apparent that zone 2 accounted for around 30% of the complaints and 44% of the callers. This is the area under the final approach to Heathrow during westerly operations. As a percentage of the households within this zone the number of callers represents approximately 0.7%.

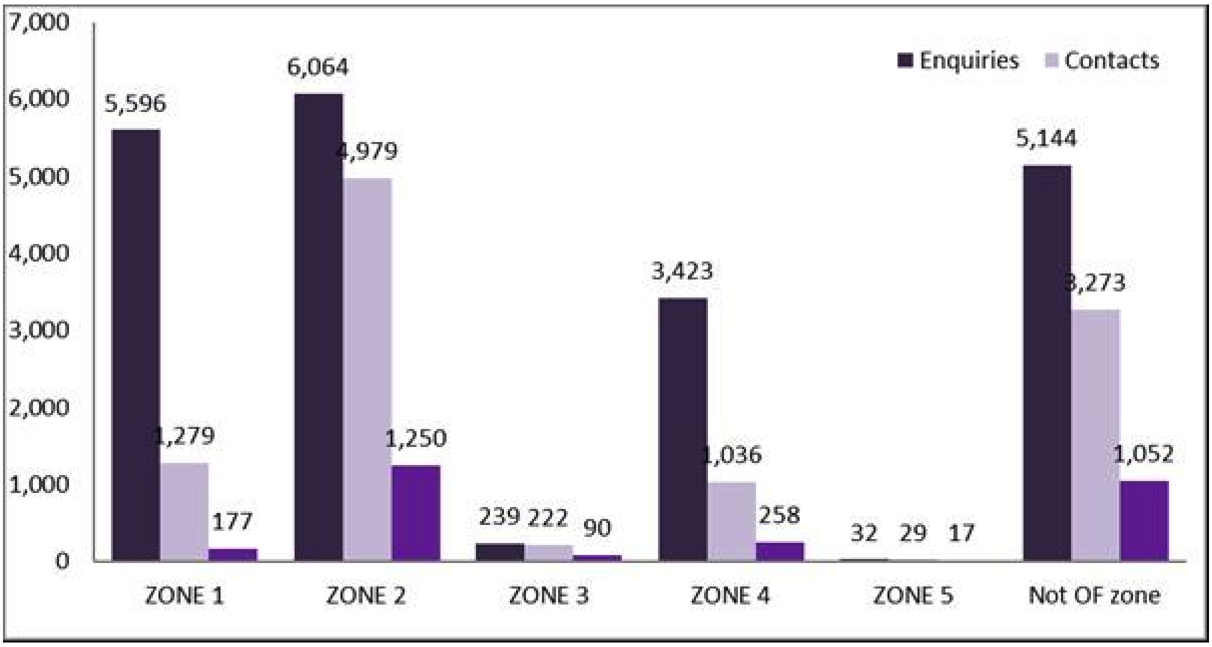


Figure 63: Breakdown of callers, contacts and complaints by zone

In Zone 2, 87% of the complaints were received from 5 post code areas as follows.

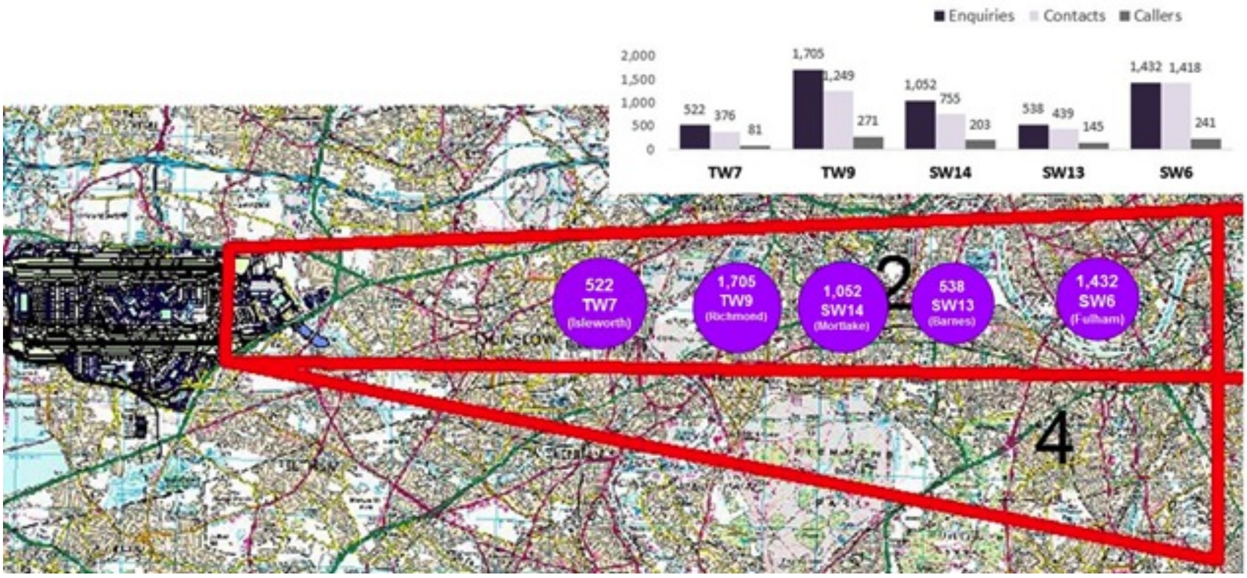


Figure 64: Breakdown of zone 2 complaints by postcode

Approximately 27% of the complaints were received from within Zone 1 and 17% within Zone 4. Zone 1 is affected by Operational Freedoms provided to departures from 27L and 27R using the Midhurst departure SID. Zone 4 is affected by vectored departures from 09R using the DVR SID.

Analysis of Zone 1 data indicates that 99% of the overall complaints were received from 2 post codes. one very close to the airport known as Ham Island (21%); and, the other, further out, near Windlesham (78%) in an area that would normally be affected by aircraft departing Heathrow. In Ham Island, the 1,193 complaints were made by approximately 165 callers (93% of total callers from this zone). However, in Windlesham the 4,391 complaints were made by 3 callers (1.7%). The approximate location of these postcodes is presented in Figure 65 below (note the full postcode has been hidden to provide anonymity).

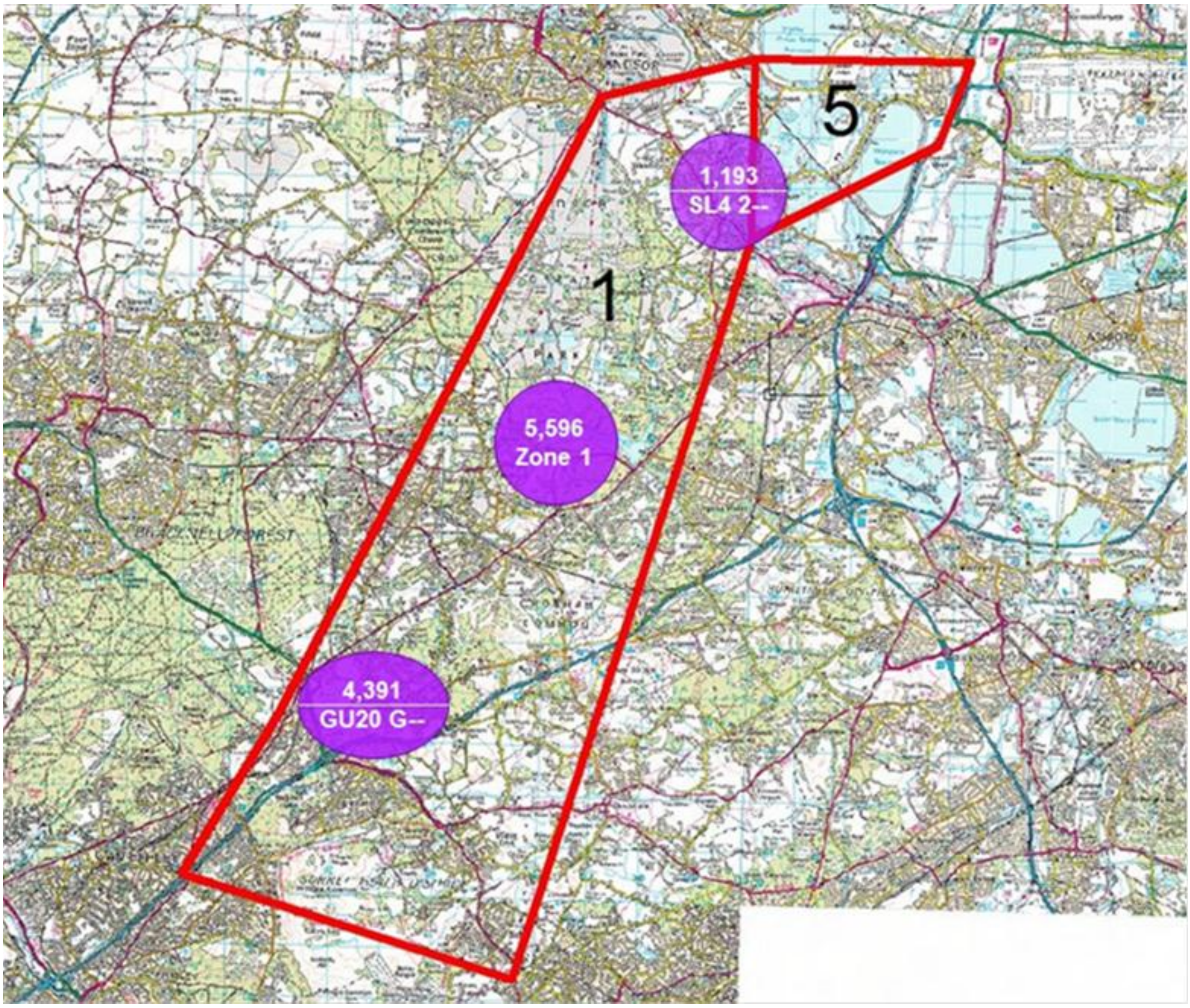


Figure 65: Location of specific event complaints received from Zone 1

Across the period, less than 32 complaints were received from Zone 5 in total. This area is one that is routinely affected by all westerly departures and easterly arrivals and therefore differences resulting from Operational Freedoms may not be noticeable to residents.

Around 37% of the Callers and 25% of the complaints were from areas outside of the Operational Freedoms analysis zones.

The location of the callers in relation to some typical aircraft tracks can be seen in

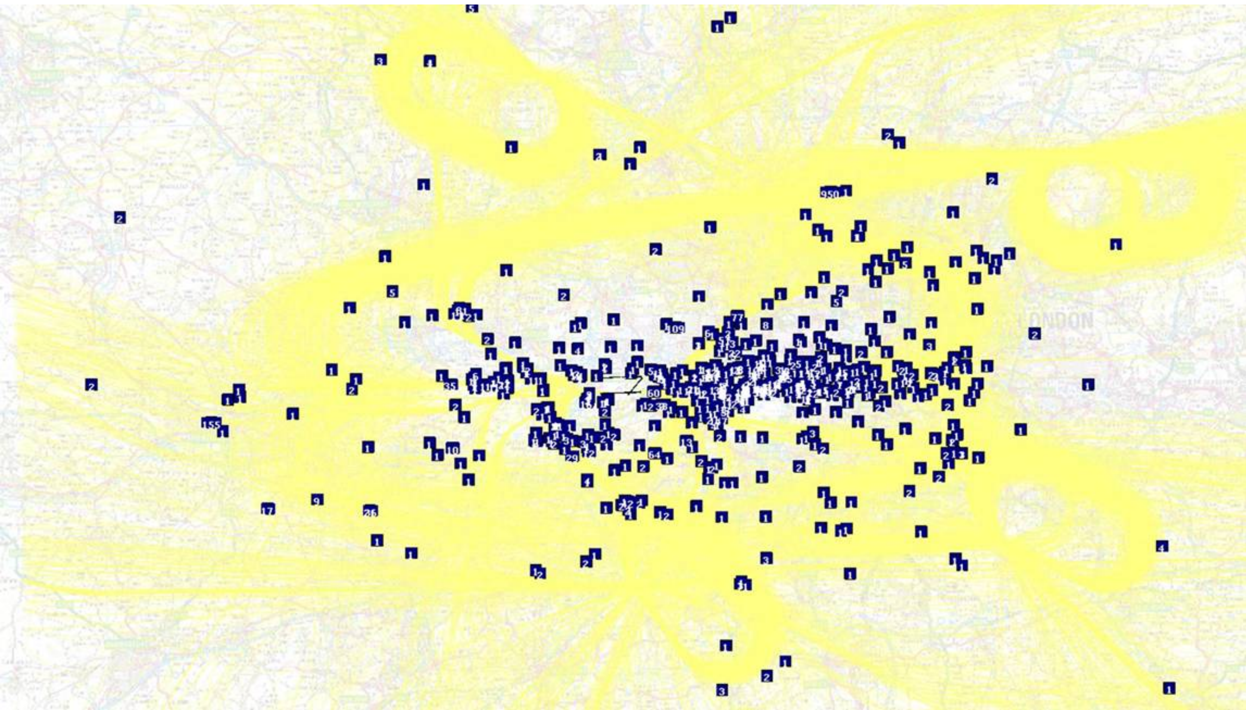


Figure 66 and

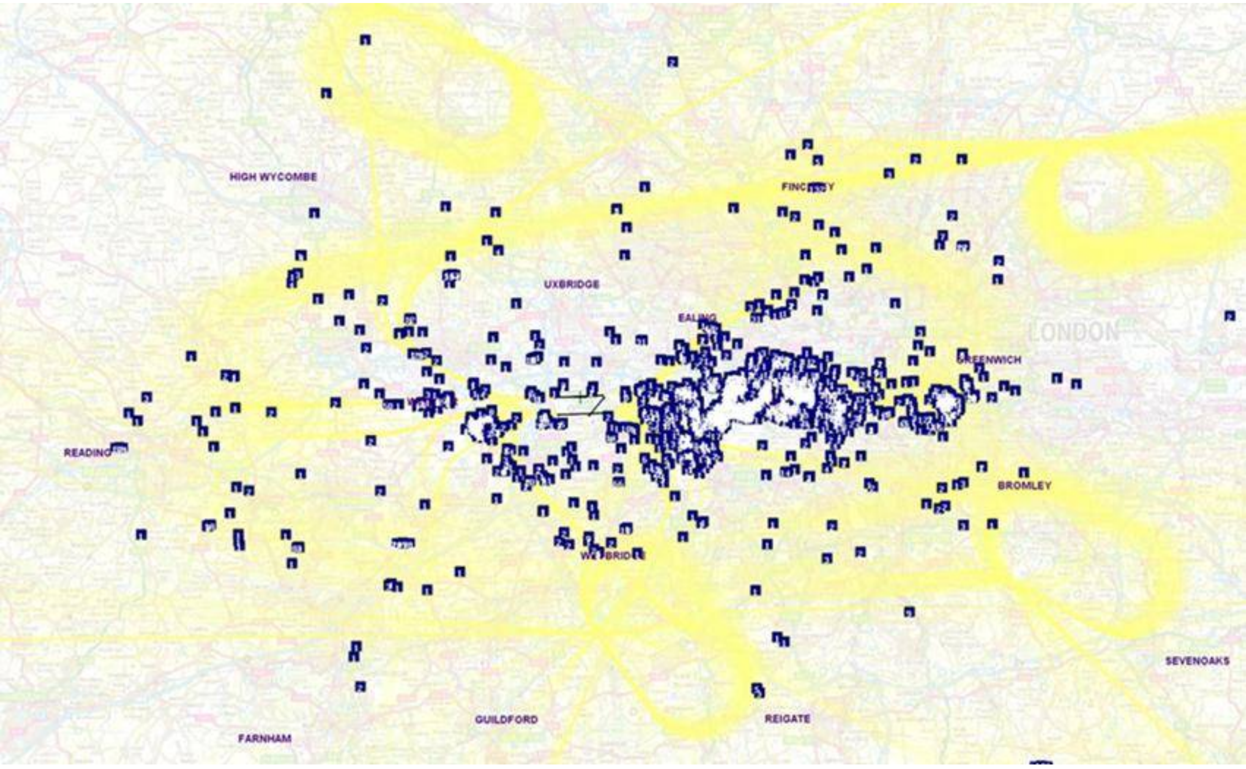


Figure 67. The general distribution of the callers is not dissimilar between the trial period and an equivalent period in 2010-11, although the number of callers during the trial is greater. An increase in caller numbers is evident, particularly in parts of west London and Old Windsor.

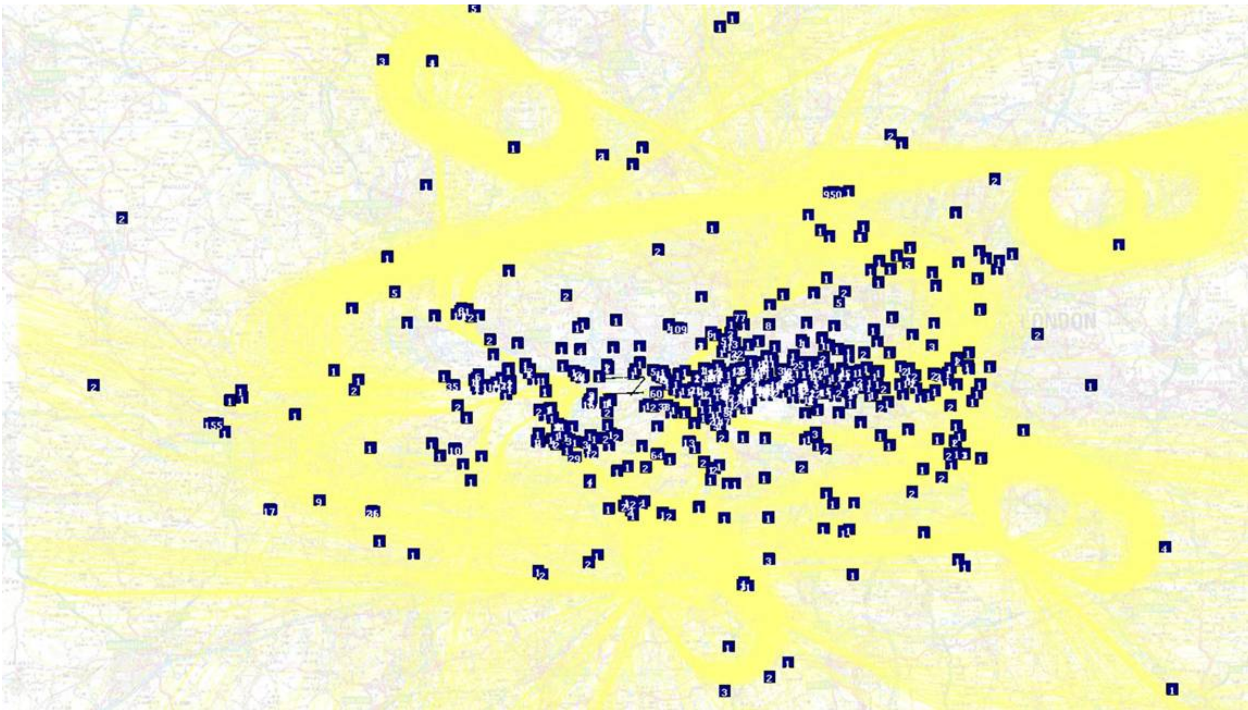


Figure 66: Caller locations 1 July 2010 – 28 February 2011

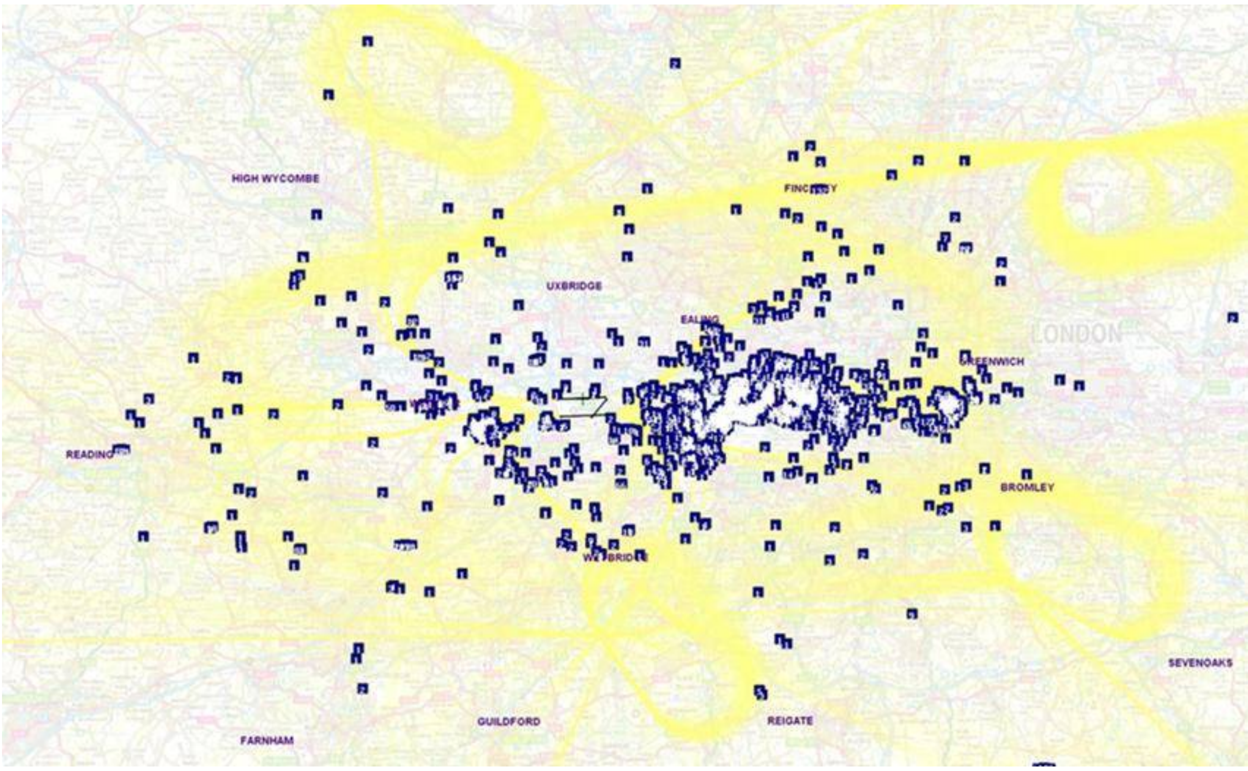


Figure 67: Caller locations during Phase 2 of the trial

6.4.2.2 General complaints

For the period of the trial, general complaints accounted for approximately 15% of the total complaints and 27% of the contacts. This contrast with the same period for the previous year (01/07/2010 to 28/02/2011), in which general complaints accounted for 41% of total enquiries and 63% of the contacts.

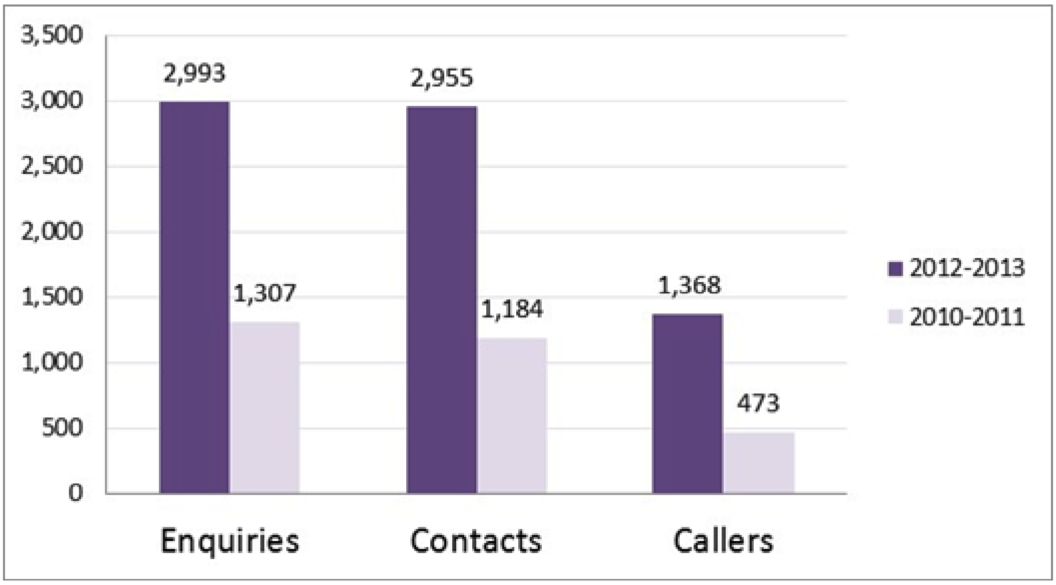


Figure 68: Summary of events, contacts and callers complainers for general complaints

For the period between 2012 and 2013, as with the overall data, Zone 2 recorded the largest proportion of general complaints and contacts with 37% in both cases. Approximately 46% of the callers came from Zone 2. There were very few complaints from Zone 5.

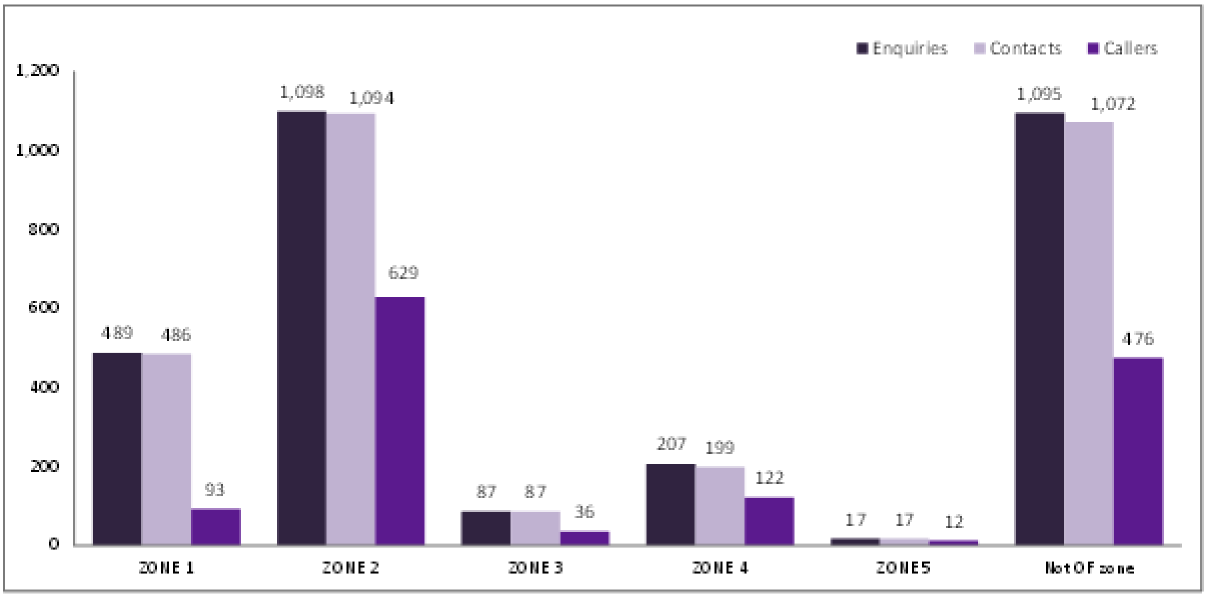
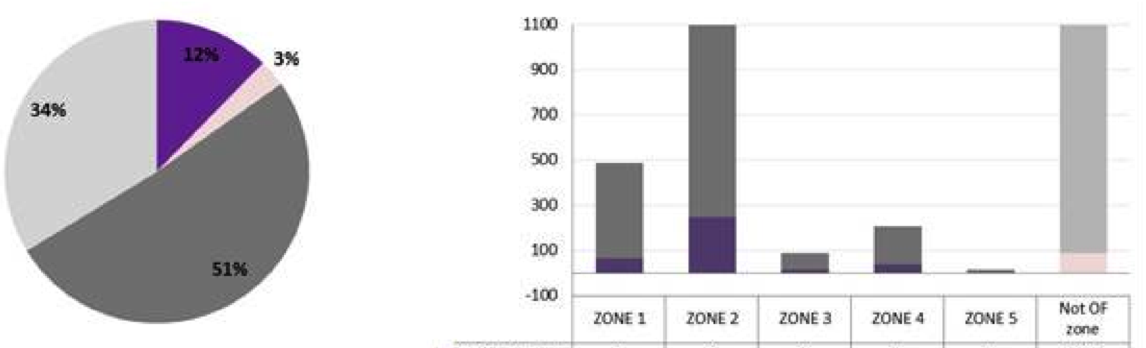


Figure 69: General complaints by zone

Not all of the general complaints made reference to the Operational Freedoms trial but they may still have been affected by an operational freedom flight. In the same way, others may have mentioned the trial and were not in a location that would be affected by Operational Freedoms flights.

Figure 70 below provides a breakdown of general complaints from locations both inside and outside the zones and by whether they made reference to the trial in some way:

- 12% of general complaints made reference to the trial in some way and were within the zones
- around 51% of the complaints did not make reference but were within a zone
- approximately 3% of general complaints referred to the trial and were outside of the zones.



	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	Not OF zone
NOF not in zone	0	0	0	0	0	1009
NOF in zone	423	852	72	168	15	0
OF not in zone	0	0	0	0	0	86
OF in zone	66	246	15	39	2	0

Figure 70: Breakdown of general complaints, zones affected and reference to trial

6.4.2.3 Specific complaints

For the period July 2012 to February 2013, approximately 85% of the complaints (17,505) referenced a specific time. 7,939 contacts were received from from 1,953 callers. 77% of the complaints were from locations within the zones identified as being potentially affected by flights operating as part of the Operational Freedoms trial. All of these zones are areas that may normally be overflown by aircraft regardless of the Operational Freedoms trial.

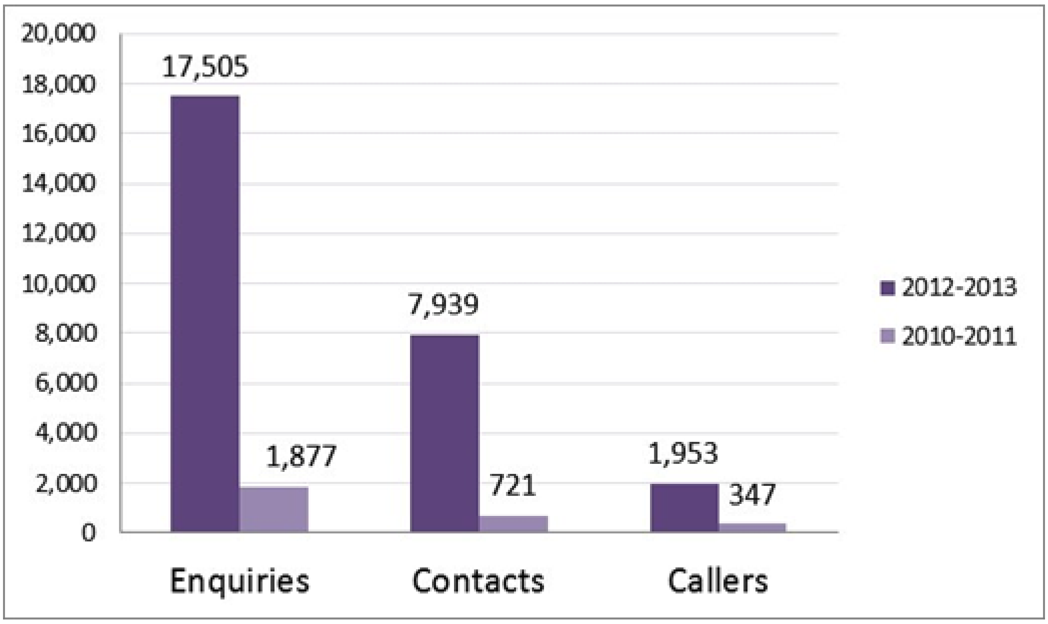


Figure 71: Specific complaints

Most callers are located in zone 2 which represent 44% of people contacting the airport. Since complaints about specific events dominate the overall, the trends associated with the overall numbers of complaints are reflected within the specific results.

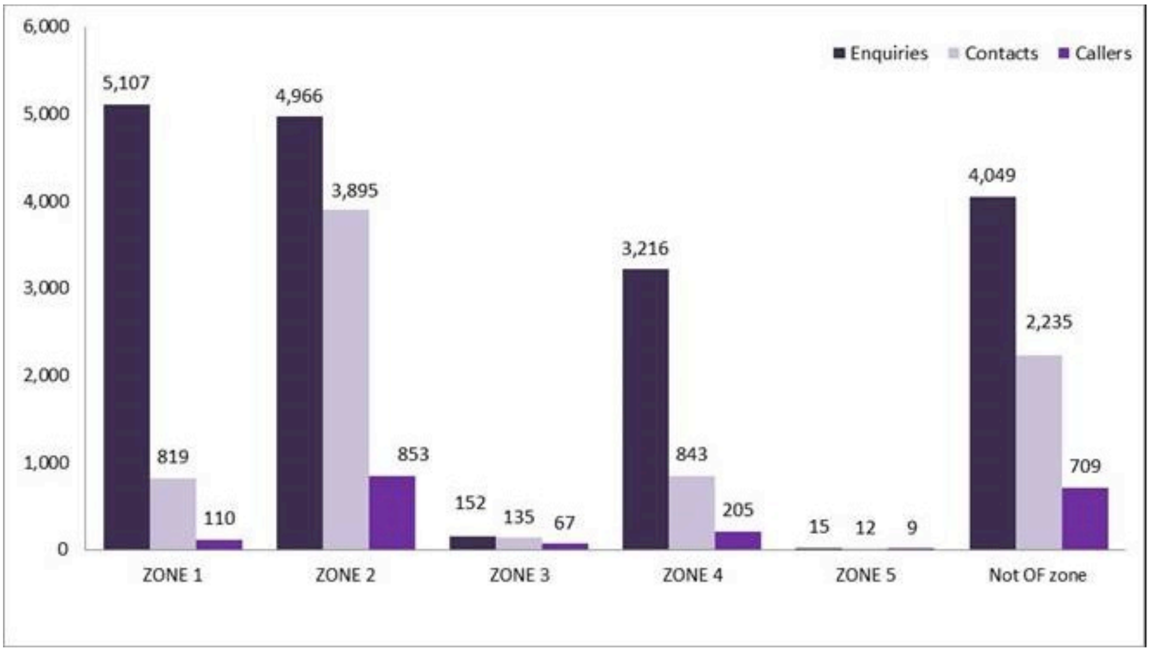


Figure 72: Specific complaints by zone

Of the specific event e complaints:

- approximately 29% were received from within Zone 1,
- 28% were received from within Zone 2

- 18% from within Zone 4
- approximately 1% from Zones 3 and 5 together
- and 23% from areas outside those most likely to be affected by Operational Freedoms.

Where a specific time has been mentioned it is possible to cross check this with NATS data to identify if the flight was operating as part of an operational freedom procedure. Figure 73 shows that 18% of complaints referred to times which could have been associated with an Operational Freedom flight. Some 3% of these also mentioned the trial. The remaining 82% were un-related to flights operated as part of the trial and 15% of these made reference to the trial.

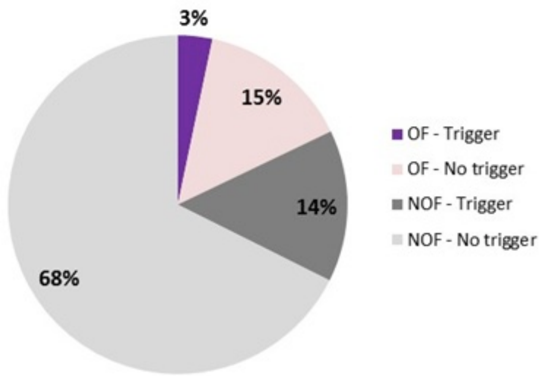
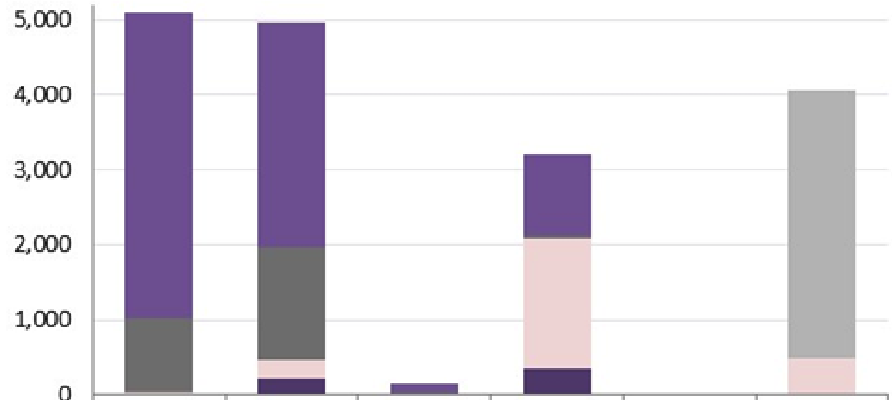


Figure 73: Specific complaints – affected zones and OF trigger events

Figure 74 below indicates how this breaks down by zone:

- In Zone 1, approximately 19% of specific complaints were at a time that could be attributed to a 27L/27R MID operational freedom. The remaining 81% were unlikely to have been specifically related to movements vectored under Operational Freedoms. Zone 1 results are also skewed by the significant number of complaints from within one postcode
- Approximately 35% of the specific complaints received from Zone 2 relate to a time when there were Operational Freedoms procedures being applied to westerly approaches
- 12% of complaints from Zone 4 related to times when Operational Freedoms early vectors were applied to easterly from runway Operational Freedoms were applied to easterly 09DVR departures.



	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	Not OF zone
NOF - No trigger	4,079	2,995	121	1,082	9	3,550
NOF - Trigger	986	1,496	7	48	2	
OF - No trigger	32	255	24	1,741	4	499
OF - Trigger	10	220		345		

Figure 74: Breakdown of specific complaints s by zone

6.4.3 Zone 2 – West London enquiries relating to westerly arrivals

Figure 75 shows the number of specific complaints by date together with the number of TEAM* operations. The correlation coefficient is <0.33.

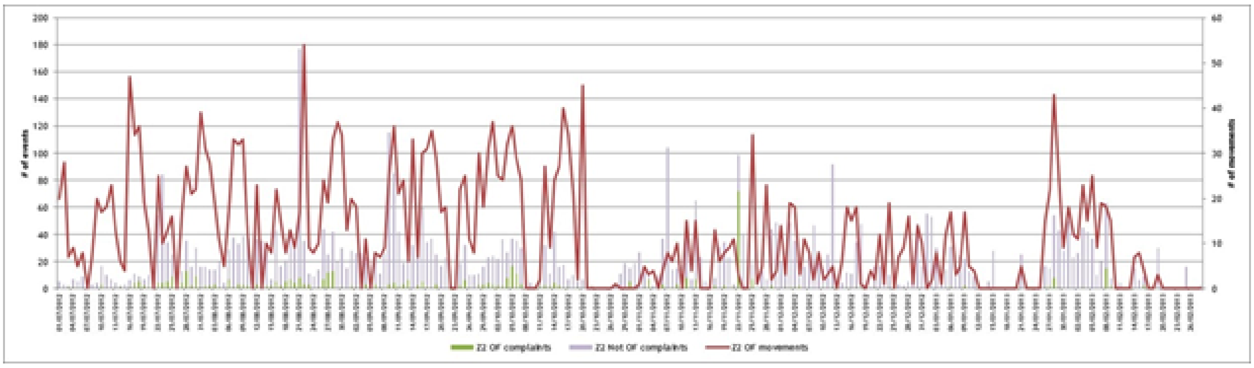


Figure 75: Correlation of specific complaints and TEAM* operations

The correlation coefficient increases to >0.44 when the specific complaints are matched with the total number of out of alternation arrivals which is illustrated in Figure 76.

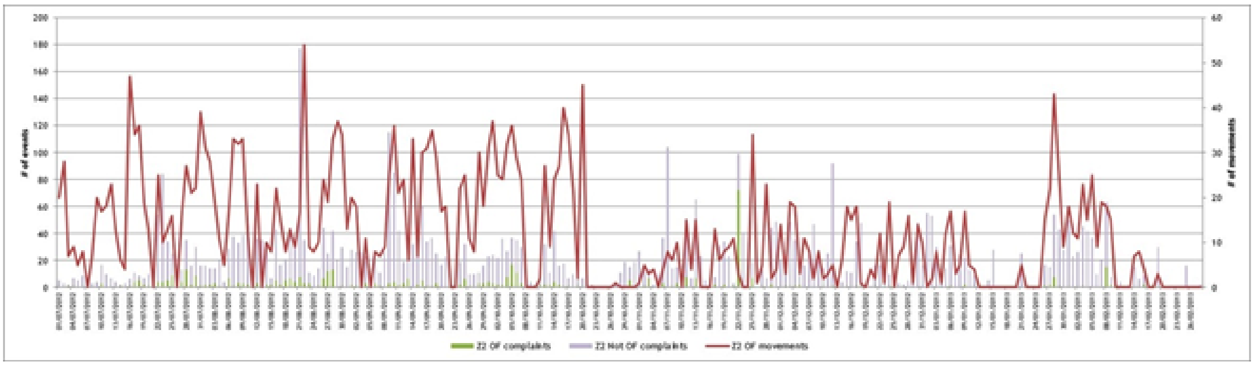


Figure 76: Correlation of specific complaints s and out-of-alternation arrivals

6.4.4 Zone 4 – West London vectored departures on 09RDVR

The relationship between complaints in zone 4 and the frequency of vectored departures on the Dover SID has a correlation coefficient of approximately 0.12 and is illustrated in Figure 77.

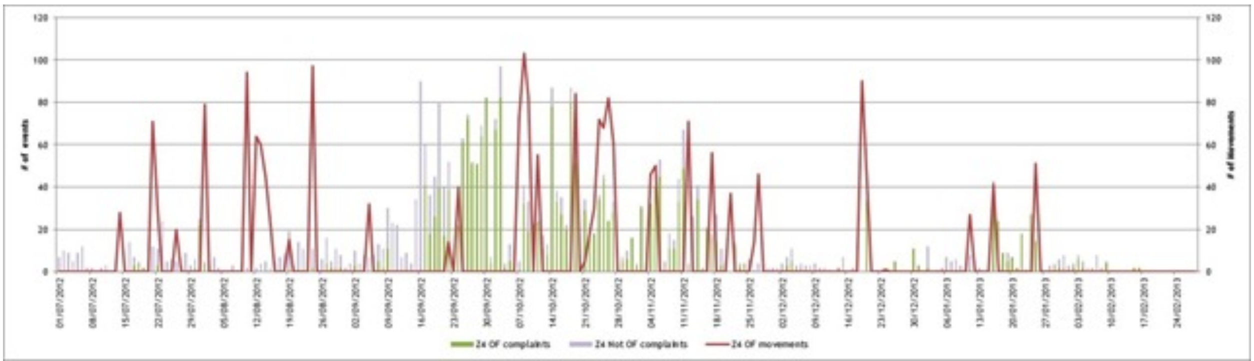


Figure 77: Correlation of zone 4 complaints and Dover OF vectors

6.4.5 Zone 1

Since 99% of the complaints from within Zone 1 are from 2 specific post codes the statistical significance of the relationship between number of 27L/27R MID vectors and the number of complaints is low. Therefore detailed analysis and correlation coefficients have not been calculated. However Figure 78 below presents the daily number of operational freedom vector movements and the number of complaints from Zone 1.

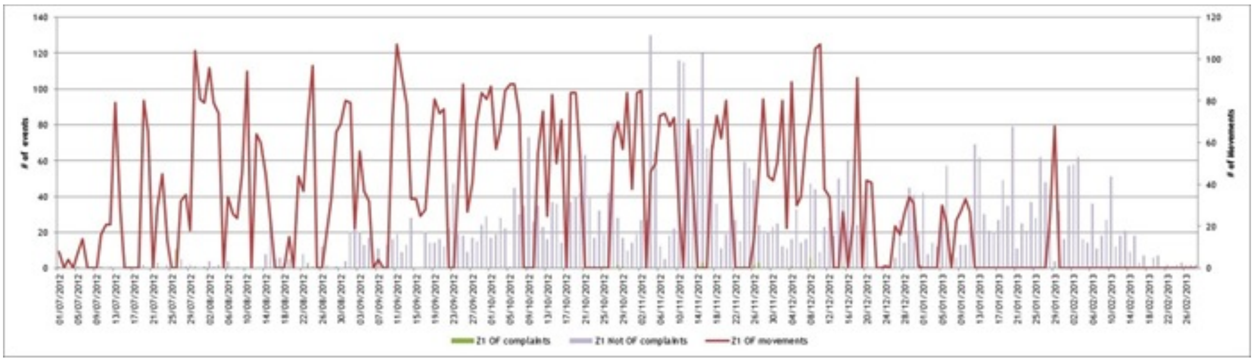


Figure 78: Complaints and movements for Zone 1

6.4.6 Caller Analysis

The overall rate of complaint is illusrated in Figure 79 below. This figure indicates that overall 80% of the complaints (whether general or specific or where they are from) are received from 9% of the total number of callers.

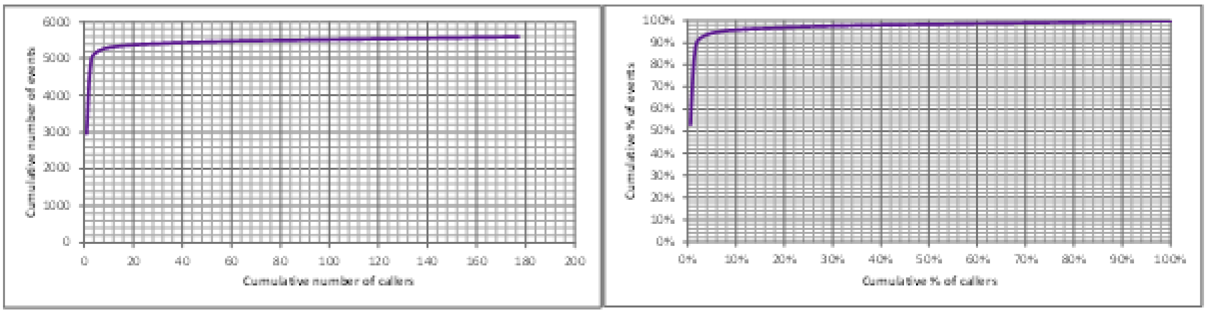


Figure 79: Overall rate of complaint by caller

Most complaints were received from Zones 1, 2 and 4. The cumulative rate at which these are received is discussed below.

In Zone 1, 99% of the complaints received were from two postcodes as described above – this is a very limited number of people and as a result statistical analysis has not been undertaken.

In Zone 2, 81% of the complaints are from 24% of callers; and in Zone 4 81% of the complaints are received from 6% of the callers. The distribution for Zones 2 and 4 is illustrated Figure 80 and Figure 81 below.

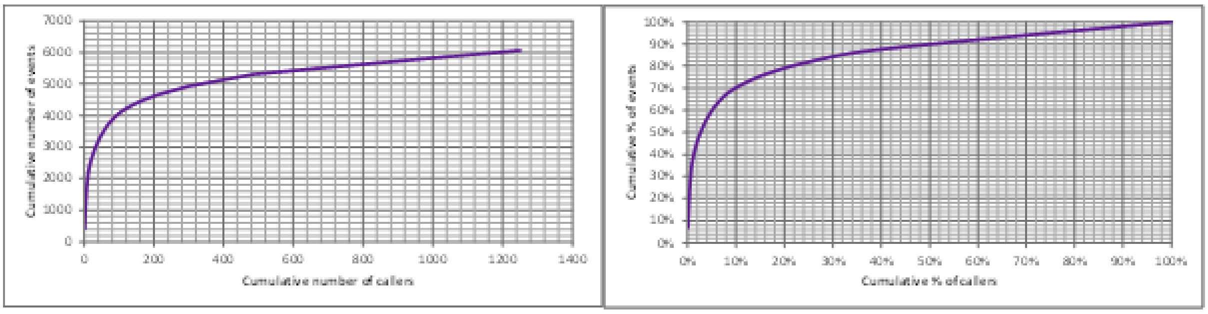


Figure 80: Distribution of complaints s across zone 2

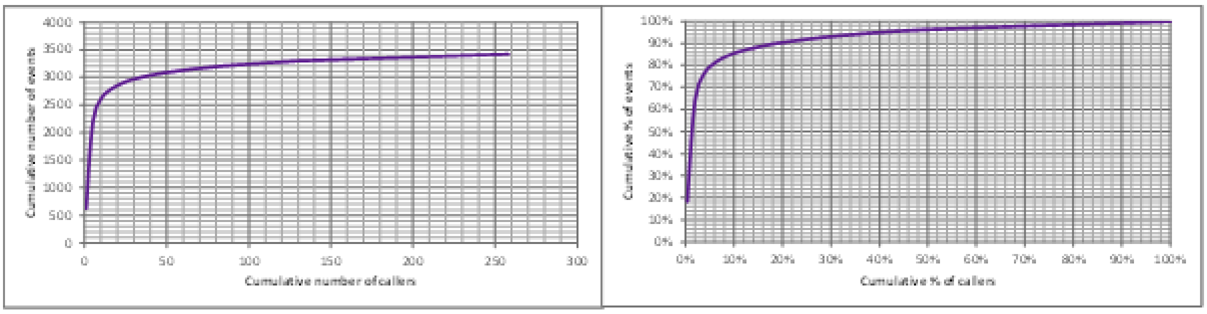


Figure 81: Distribution of complaints across zone 4

Figure 82 indicates the number of complaints reported by caller. It shows that across all complaints, approximately 1,800 (63%) Callers reported one enquiry event in this period and approximately 400 (15%) reported two complaints.

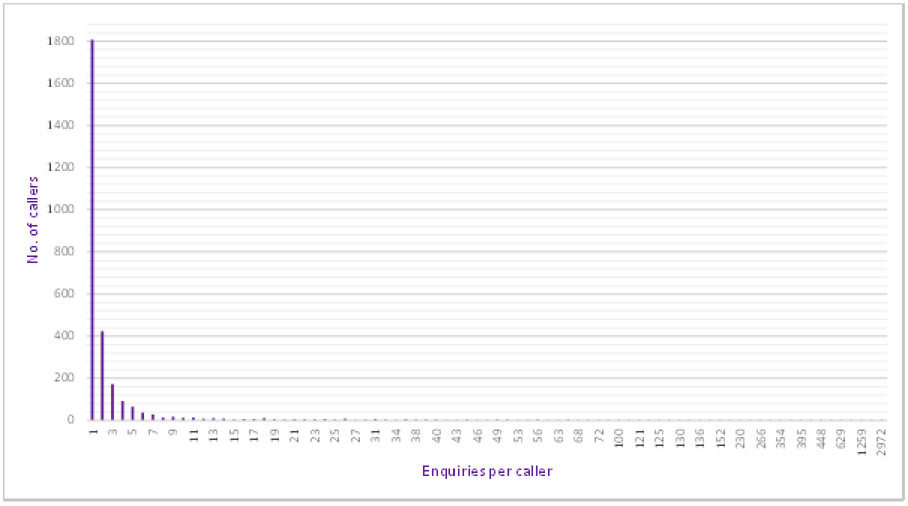


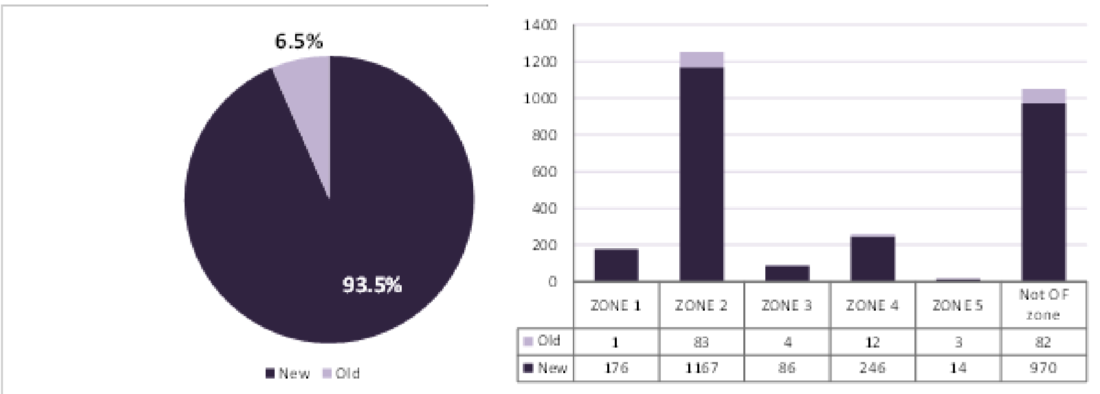
Figure 82: Distribution of complaints by caller

This figure also indicates that there a number of Callers who have each recorded more than 500 complaints.

6.4.7 New/previous callers

Analysis of the data was conducted to understand whether callers during the summer period were “new”. This analysis was based whether the caller had contacted Heathrow before 2012. Therefore a “new” caller is soemone who did not call Heathrow before 2012.

On this definition, over 94% of Callers during 1 July 2012 – 28 February 2013 were “new” (i.e. they have not contacted Heathrow before 2012 to register an complaint). Most of these people were from Zone 2. Almost all the callers from Zone 1 are new (99%) and approximately 95% of callers from Zone 4. Across all the Zones less than 10% of callers have complained prior to 1 July, except for Zone 5.



	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	Not OF zone
Old	1	83	4	12	3	82
New	176	1167	86	246	14	970

Figure 83: Ratios of new and existing callers

6.4.8 Households

If an assumption is made that one household is represented by one caller the analysis of the caller data for each zone indicates that approximately 4.2% of households in Zone 1 registered an complaint (this is likely to be skewed by an underestimate of the number of households within the zone), 0.6% in Zone 2, 0.1% in Zone 3, 0.7% in Zone 4 and 0.7% from Zone 5. Note this does not relate to the number of complaints, but the number of callers. This is illustrated in Figure 84 below.

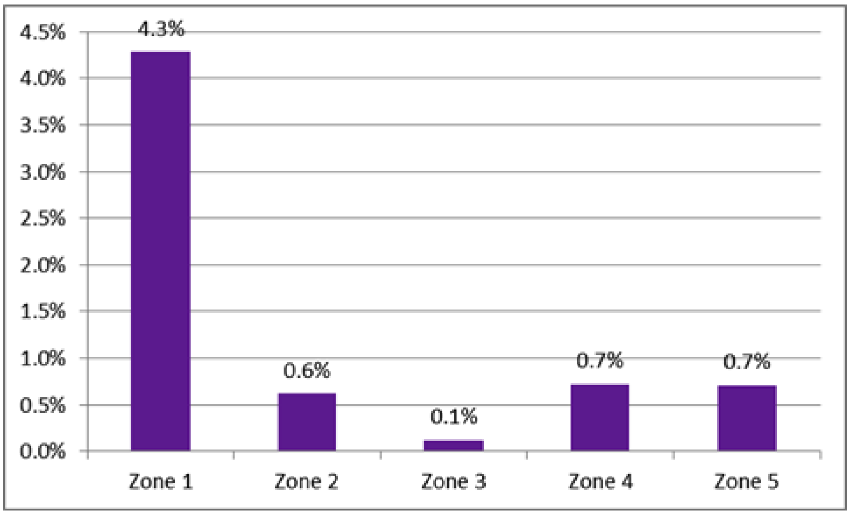


Figure 84: Callers as a proportion of households in the zone

6.4.9 Summary

In summary, analysis of the complaints indicates:

- In total, 20,498 complaints were received from 2,844 callers during Phase 2 of the trial in 10,818 contacts;
- 27% of the complaints were from Zone 1. Analysis of Zone 1 data specifically indicates 99% of the complaints came from 2 post codes. One representing Ham Island where 165 people reported 1,193 complaints; the other, an area near Windlesham where 4,391 events were registered from 3 callers. This area is affected by departures generally and specifically during the trial by vectored westerly departing aircraft using the Midhurst route.
- 30% of the complaints were from Zone 2 (from overall 44% of the callers). 87% of these complaints were received from 5 post code areas. This area is affected by aircraft approaching Heathrow from the East.
- 10% of complaints were from Zone 3;
- 17% of complaints were from Zone 4 which would be affected by departures vectored on the easterly Dover route;
- Less than 1% of complaints were from Zone 5;
- Approximately 25% of complaints were from outside areas that would be affected by the trial;
- 15% of the total complaints were registered as general complaints having reported no specific time, 85% of the complaints reported a specific time;
- Of the complaints reporting a specific time, overall 18% referred to times that could have been associated with an aircraft operating with an operational freedom. 19% of specific complaints reported in Zone 1 were at a time that could have been an Operational Freedoms departure; 35% in Zone 2 and 12% in Zone 4;

- In zone 2 there is a correlation of approximately 0.3 between the number of westerly arrivals operating under Operational Freedoms, and a correlation of more than 0.4 between the number of arrivals operating "out of alternation" generally and complaints;
- In zone 4 there is a correlation of approximately 0.1 between the number of vectored aircraft using the easterly Dover route and the number of complaints;
- There were insufficient callers from the other zones to draw meaningful correlations between movements and complaints;
- In Zone 2, approximately 80% of complaints were received from approximately 25% of the callers, in Zone 4 approximately 80% were reported by approximately 5% of the callers;
- Approximately 65% of the callers report only one complaint, 15% report two complaints;
- 94% of the callers had not previously contacted Heathrow (i.e. they were new);
- If one caller represents one household then complaints were received from 4.2% of the households in Zone 1 and less than 1% from each of Zones 2, 3, 4 and 5.

7 Conclusions

7.1 Overall operational impacts

Air traffic operations at Heathrow take place in a high density traffic environment which is complex and operating at 99% of capacity. There are strong interactions between all operational processes and actors to deliver punctual performance of flights arriving and departing the airport. The range of actors includes the airport operator, airlines, ground handlers and air traffic control. There are also many external factors, not least the weather, that have a significant impact on performance and introduce a degree of unpredictability into the system.

Performance is influenced both by performance upstream, for example arrival punctuality affects departure punctuality, and downstream factors, for example delays occur at Heathrow due to constraints at destination airports and in en route airspace. The impact of disruption ripples through the system and persists for significant periods of time after the cause of the disruption. Because the system is highly interconnected, applying a lever to improve performance at one point in space or time often has consequences at other places or times; akin to a balloon bulging on one side when it is pressed on the other.

To take into account the highly interconnected system and multiple strong drivers of performance, a sophisticated statistical analysis technique, based on multivariate regression analysis has been applied to isolate the effects of the Operational Freedoms. As with all statistical techniques, there are uncertainties inherent in the results of analysis. In addition, using this technique alone, it is sometimes not straightforward to draw conclusions on cause and effect as the results only shows an association between variables, not that a change in one causes a change in another.

The results of the analysis confirm the complexity of Heathrow's operations and also indicate that Operational Freedoms, as executed during the trial, often only have a small impact and can be swamped by other factors. The general conclusion is that Operational Freedoms deliver some useful operational performance improvements in some limited areas, and as a result they should be retained for use at Heathrow. However, it is also concluded that they do not provide wholesale significant benefits that would facilitate recovery from major disruption if they were to be implemented in isolation and without further enhancement.

7.2 Impacts of TEAM*

From the air traffic controller's perspective, TEAM* increased flexibility compared to pre-existing TEAM availability. However, the impact on departures needed careful management when using TEAM* as increasing numbers of aircraft arriving on the designated departure runway effectively meant that increasing numbers of departure movements on that runway were lost, as confirmed by the statistical analysis, summarised below.

As expected, the freedom to use the designated departure runway for arrivals has the effect of **increasing the arrival rate** above what is achieved on a single runway by up to approximately two arrivals per hour when TEAM* is applied. This has the opposite impact of **decreasing the departure rate** by approximately three departures per hour when TEAM* is applied. The queue for the departure runway is also increased when TEAM* is applied. This negative impact can be managed by the judicious application of TEAM* taking departure demand into account.

The other impact of the application of TEAM* is generally to increase **the level of de-alternation** although the change of procedures for triggering TEAM*, linking it more strongly to departures delays, applied in winter 2012-13 resulted in a lower application of TEAM* and a reduction in the level of de-alternation compared not only to other periods in the trial but also to previous years. TEAM* did not have any measurable impact on other environmental or noise related operational procedures, specifically the rate of compliance with continuous descent approach (CDA) requirements.

Evidence could not be found for any significant and immediate reduction in **stack-holding** caused by the application of TEAM*; however it should be noted that the operational capability to anticipate delay and the subsequent identification of a valid trigger condition existing may have had an impact. Indeed the application of TEAM* is associated with high levels of stack-holding as would be expected because the freedom is not applied until a trigger threshold is exceeded. However, the application of TEAM* appears to have positive effects:

- it is associated with a negative rate of change of stack-holding, i.e. TEAM* appears to apply the brakes to any potential subsequent increases
- leading on from this, it is associated with reduced stack-holding in subsequent time periods.
- qualitative comparison with previous years of stack-holding levels when dual arrivals are in operation shows lower levels of stack-holding with the 10 minute trigger condition than with the previous 20 minute trigger condition suggesting positive effects of the revised TEAM* trigger condition.

The results do indicate that the application of TEAM* has a **positive effect on air traffic flow management** (ATFM) delays due to Heathrow, at least in the summer season. This is likely because the availability of TEAM* delays or avoids the need to apply ATFM regulations or enables them to be applied at a higher flow rate. Results for the winter season do not show any significant association between TEAM* and ATFM. A potential explanation of this is perhaps because the disruptions that cause ATFM delays in winter are larger than those in summer and beyond the capability of TEAM* to address. The statistics do, however, indicate that there are many other unknown factors in play influencing ATFM and that these influences may be much stronger that TEAM*.

The uncertainties associated with the results for the impact of TEAM* on taxi-in times are large, again suggesting that there are many other factors that influence performance in addition to TEAM*. Uncertainties notwithstanding, the results suggest that application of TEAM* is associated with a **small reduction in taxi-in time** from landing to the aircraft reaching its stand. Unsurprisingly this reduction is most pronounced for Terminal 4 (T4) arrivals where TEAM* provides the opportunity to land T4 arrivals on the southern runway, avoiding a long taxi as well as a runway crossing. In connection with this, the results of the analysis also suggest a **reduction in the number of runway crossings** for arrivals associated with TEAM* although again there are again large uncertainties associated with this inference.

Finally, there appears to be a **small improvement in arrival punctuality** associated with the application of TEAM* in summer. The results are inconclusive for the winter part of the trial when TEAM* where the link between TEAM* and arrivals punctuality is not significant. As with ATFM, a possible interpretation of this is that the drivers of poor punctuality are much stronger in winter than summer and beyond the capability for TEAM* to provide a counterbalance.

7.2.1 TEAM* Enhancements

As detailed above, the use of TEAM* during the Operational Freedoms Trial did provide a number of operational benefits. Both the trial data and feedback from the Air Traffic Control Officers (ATCOs) at Heathrow showed that the provision of TEAM*, as a more flexible method for increasing runway efficiency during times of increased operational demand, was beneficial. However, although more flexibility was provided than with pre-existing TEAM constraints, restrictions that were still placed on the use of TEAM* during the trial (e.g. the 10 minute arrival delay trigger) meant that ATCOs were unable to utilise TEAM* at other times when, if it's use had been allowed, they may have had the capability to further improve operational efficiency and hence airport resilience.

It can also be concluded, based upon observations during the trial, that any increased use of TEAM* associated with reduced triggers would effectively be self-regulating. This is due to the resultant operational impacts that would be observed in the departure rate if TEAM* were to be used indiscriminately. The application of TEAM* must be dynamically managed by ATC at all times to ensure a balanced mix of arrivals and departures can be maintained.

Possible enhancements to the TEAM* model deployed during the trial; to extend the availability of using the designated departures runway for arriving traffic, without delay trigger or weather based restrictions, should therefore be considered. Resultant benefits, already demonstrated to some degree within the trial could reasonably be expected to be; increased arrival rates, reduced taxi time, reduced runway crossings and overall efficiency improvements in the arrivals sequence, all allowing improved operational performance and resilience during periods of disruption.

7.3 Impacts of early vectoring

Early vectoring under Operational Freedoms allowed air traffic controllers to amend the outbound routing of aircraft to deviate from their planned departure route earlier thus allowing reduced time based separation between aircraft. From the air traffic controller's perspective, there were operational benefits because early vectoring provided mitigation against delays caused by a sub-optimal mix of aircraft types in the departure queue. However, the method of vectoring employed during the trial required that the air traffic controller delivered an amended clearance and routing to the aircraft; for example when the aircraft was on the runway it was instructed to fly a different route. This adds considerable workload to an already heavily loaded controller and would not be a long-term solution. An alternative method of issuing such amended clearances would need to be found to ensure that this freedom could be safely managed routinely in the future.

The operational analysis shows that application of early vectors **increases the departure rate** by approximately 0.3 departures per early vector applied. This has to be interpreted in the context that it was only possible to apply early vectors to the approximately 20% of departing traffic using the standard instrument departure routes (SIDs) designated for the trial. The departure rate would likely increase further if it were possible to apply early vectoring on additional SIDs. In contrast to TEAM*, early vectoring has no negative impact on arrivals. However, early vectoring often takes aircraft to the edge of the noise preferential route and results in a **reduction in track-keeping compliance** on the routes where it is applied. This reduction in compliance was clearly an expected outcome of vectoring aircraft away from the noise preferential routes (NPRs) during the trial.

It should be noted that the operational freedom of conducting early vectoring is only required as a result of the dated and therefore sub-optimal (based on modern airframe and engine capabilities) airspace design surrounding Heathrow Airport. Using any such freedom will therefore, by definition, result in aircraft following a flight path which will bring them close to and often outside the boundary of these dated and sub-optimal noise preferential routes. Section 7.3.1 provides the associated view of the airport community with regards to new airspace design which could include revised departure procedures and associated NPRs, thus removing the need for the model of early vectors as used during the Operational Freedoms Trial.

The analysis could find no statistically significant association with any other of the departure key performance indicators.

7.3.1 Early Vectoring Enhancements

As detailed above, the use of early vectoring during the Operational Freedoms Trial did provide some degree of operational benefit. Both the trial data and feedback from the Air Traffic Control Officers (ATCO) at Heathrow showed that the provision of early vectoring, as a more flexible method for increasing runway efficiency during times of increased operational demand, was beneficial.

However, it is reasonable to postulate that the limited availability of early vectors (during the trial only westerly Midhurst and easterly Dover departure routes had associated early vector procedures available for use) did not allow the large operational benefits that would potentially result if ATCOs had options to employ early vectors on more departure routes in both directions.

The provision of early vectors similar to the Midhurst vector used during the trial, for all departure routes would facilitate maximum departure capability during periods of departure disruption. Such additional vectors would form a key input to the design of any new Standard Instrument Departures (SID), which may in turn support the considerations and recommendations resulting from the London Airspace Management Programme (LAMP).

Operational Freedoms experience has also highlighted that other changes to departure procedures may be beneficial in providing operational resilience during periods of disruptions:

- Additional parallel SID procedures on Compton routings to reduce delays on this high demand westbound route;
- Combination of easterly Southampton and Midhurst routings to reduce southbound departure separations and complexity

7.4 Impacts of proactive tests

It was not possible during the analysis to disentangle the separate impacts of the three types of proactive tests applied during the trial. However, the analysis does allow the impact of the proactive tests to be estimated on each of the key performance indicators separately.

As with TEAM*, application of proactive tests is associated with an **increase in arrival rate** above what is achieved on a single runway by up to approximately two arrivals per hour but also having the opposite effect of decreasing the departure rate by approximately three departures per hour.

The proactive tests are also associated with **a decrease in taxi-in time** especially for T4 arrivals, although the results of the analysis have a high level of uncertainty and indicate that there are additional, unknown factors that might have a strong influence on taxi-in time. Again as with TEAM*, there is an association of the application of the proactive tests with a reduction in the runway crossing rate for arrivals, albeit with large associated uncertainties.

The analysis could find no statistically significant association of the proactive tests with any other of the key performance indicators.

7.5 TEDs

Tactically enhanced departures (TEDs) were only enacted on eight individual days and to 38 departures out of a total of approximately 55860 westerly departures (approximately 0.07%) during Phase 1 of the trial. This limited application of TEDs during the Phase 1 of the trial was caused by the restrictive structure of Heathrow's established departure routes, designed for use at an aerodrome with "dependent" runways, with all their attendant vortex separation, speed table and geographical direction requirements, which consequently do not readily support simultaneous departures from both runways. As such, within the current departure route structure, the application of TEDs often resulted in detrimental impacts onto the arrival flow of aircraft and was perceived to hinder, rather than support, the overall operation. The small proportion of TEDs enacted did have not any measurable impact on departure performance. For these reasons, TEDs were not pursued in the second Phase of the trial.

7.6 Landing inbound aircraft without holding between 05:30 and 06:00 hours

The planned freedom, to land inbound aircraft without holding between 05:30 - 06:00 hours in return for a reduction in the number of flights between 04:30-05:00 hours, was not enacted as a result of findings from detailed work and discussions with the industry that concluded it was not possible to implement this measure during the trial due to operational factors.

7.7 Community impacts

A comprehensive community engagement programme was undertaken as part of the Operational Freedom trial. Research involving in-depth interviews with residents living around Heathrow Airport, although not necessarily fully representative of the population around the Airport suggests that:

- the trial was generally seen as a positive by residents and a constructive and imaginative move by Heathrow.
- all residents were supportive of reducing the number of early morning flights and late night departures.
- some residents felt Heathrow could have done more to communicate about the trial.
- the provision of more information during these interviews led to residents forming a more positive view of Heathrow.
- the majority of residents were unaware of defined periods of respite. Many felt that this was because they had either not been told about it or did not notice the 'quiet' periods when aircraft weren't flying overhead.

The research on respite demonstrated that the great majority of participants are able to trade-off between alternative hypothetical noise management options, some of which can include hypothetical financial compensation. This trade-off required that participants were given sufficient information to ensure that any views expressed were fully informed by factual details. It was not possible in this qualitative research to obtain statistically definitive (albeit small or even negligible) monetary values for marginal loss of respite, but the research demonstrated that by using the techniques developed for this research, it would be possible to obtain statistically definitive monetary values if repeated on a much larger and more quantitative scale.

There are some interesting observations that can be made regarding the **complaint analysis**:

- in terms of the **volume of complaints**, in total during Phase 2 of the trial 20,498 complaints were received from 2,844 callers in 10,818 contacts. This is a significant increase over the previous, pre-trial like-for-like period when 3,184 complaints were received from 725 callers in 1,882 contacts.

- in terms of the **callers** themselves:

  - 94% of the total had not previously contacted Heathrow

  - 65% of the total registered a single complaint

  - 15% of the total registered two complaints

  - the remaining 20% registered multiple complaints.

- in terms of **location of complaints**:

  - approximately 27% of complaints were from Zone 1, the areas affected by vectoring on westerly departures. 99% of these complaints came from 2 post codes: representing Ham Island where 165 people reported 1,193 complaints; the other, an area near Windlesham where 4,391 events were registered from 3 callers

  - approximately 30% of complaints were from Zone 2, the area is affected by aircraft approaching Heathrow from the east (i.e. westerly arrivals) where 87% of these complaints were received from 5 post code areas. 80% of Zone 2 complaints were received from 25% of the callers

  - approximately 17% of complaints were from Zone 4 which would be affected by departures vectored on the easterly Dover route. 80% of Zone 4 complaints were received from 5% of callers

  - approximately 10% of complaints were from Zone 3; which like Zone 2 is affected by aircraft approaching Heathrow from the East but is further from the Airport

  - approximately 25% of complaints were from outside areas that would reasonably be expected to be affected by the trial.

- in terms if **households**, if it is assumed that one caller represents one household then complaints were received from 4.2% of the households in Zone 1 and less than 1% from each of Zones 2, 3, 4 and 5.

- in terms of **correlating complaints with Operational Freedoms**, overall the observed correlations are low for those 85% of total complaints that registered a specific time and location. Only 19% of the total number of specific complaints corresponded to times and locations where Operational Freedoms were in operation. Geographically, this was broken down as follows:

  - for Zone 1 complaints, 19% of specific complaints occurred when Operational Freedoms were in operation. There was an insufficient volume of data to draw a quantitative correlation between the number of complaints and the number of Operational Freedoms flights affecting this Zone

  - for Zone 2 complaints, there was a correlation coefficient of approximately 0.3 between the number of complaints and the number of Operational Freedoms arrivals;

this correlation coefficient increased to 0.4 if all out-of-alternation westerly arrivals were considered. 35% of Zone 2 complaints referred to a time when Operational Freedoms was in operation

- for Zone 4 complaints, there was a low correlation coefficient of 0.1 between the number of complaints and the number of aircraft vectored on the easterly Dover route. 12% of Zone 4 complaints referred to a time when Operational Freedoms vectoring was in operation.

7.8 Overall conclusions and recommendation

Since the Department for Transport granted permission for the temporary, limited and controlled use of Operational Freedoms in 2011, Heathrow Airport, NATS and other parties involved in this process have been clear that, due to the artificial nature of a trial, it would be difficult to draw definitive conclusions. Unfortunately this has proved to be the case. Despite the best endeavours of all parties, within such a complex operational environment as Heathrow Airport, it is very difficult to quantify benefits in any simple and meaningful way. As a result, there is considerable uncertainty associated with the results and it is accepted that these will be open to different interpretations. Quite rightly, it will be for all interested parties to present their views and opinions to the Department for Transport and the Civil Aviation Authority.

It is the view of the airport community that the evidence in this report indicates that the application of Operational Freedoms delivered perceptible operational improvements during the trial. The evidence also shows that not all were at the level or significance that was originally envisaged. Consequently, it is important that when drawing overall conclusions and giving recommendations, the operational complexity is taken into account and not lost via a process of over-simplification.

The trial demonstrated that the application of some of the Operational Freedoms that were trialled, specifically relating to departures, was constrained by the structure of Heathrow's airspace and the wider London Terminal Manoeuvring Area (TMA) – and it is the view of the airport community that consideration of the enhancements described in section 7.3.1 of this document would increase the benefits gained.

The evidence from the trial shows that the application of all the Operational Freedoms had perceived negative impacts on the local communities. These impacts varied according to the specific freedom used and the area affected, but it is clear that the use of procedures specifically associated with respite arising from alternation for arrivals and degraded track-keeping for departures caused most concern.

As stated above, reaching clear conclusions from the evidence produced is not easy but it is the view of the airport community that, on balance, Operational Freedoms, as trialed, delivered useful operational performance improvements in limited areas. While their use did not provide the wholesale significant benefits that could be required to facilitate recovery from major disruption if they were to be implemented in isolation and without further enhancement, it is recommended that the following Operational Freedoms should be retained for permanent use at Heathrow:

7.8.1 TEAM*

Currently during westerly operations, TEAM (Tactically Enhanced Arrivals Measures) is available for use after 07:00 and is triggered by actual or anticipated delays of 20 minutes or more. The number of TEAM landings that can be operated outside the 06:00 – 07:00 hour is limited to 6 per hour.

The TEAM* Operational Freedom, as trialled, modified this procedure such that all existing exceptions including arrivals between 06:00 and 07:00 hours were still applicable on westerly operations but the limit for the number of de-alternated landings that could be operated outside this time increased from 6 to 12 per hour.

Heathrow Airport is minded going forward to replicate the runway use and reporting methodologies currently employed for westerly runway operations for those conducted in the easterly direction.

Application of the procedure should be subject to the following triggers:

- Actual or anticipated arrival or departure delays that are likely to impact operations
- The headwind component on approach to Heathrow is forecast to be greater than 20 knots at 3000ft.
- Aircraft are arriving on their stand more than 30 minutes later than their scheduled time or if 30% of all aircraft (arrivals and departures) operating from Heathrow are running 15 minutes late.
- There is disruption to the operation, for example from snow.

7.8.2 Early Vectors

Currently, all aircraft departing from Heathrow are required to follow set departure routes or Noise Preferential Routes (NPRs) until they reach an altitude of 4,000ft. Such aircraft can be ‘early vectored’ when there is weather disruption such as a thunderstorm in close proximity to the airfield or, for example, to avoid police helicopter activity in the area. In addition to these exceptions, the early vectoring Operational Freedom should allow departing aircraft flying the Midhurst and Dover departure routes to be radar vectored away from the relevant NPR, early (i.e. when below 4,000ft altitude) subject to the following triggers:

- Actual or anticipated departure or arrival delays that are likely to impact operations
- The headwind component on approach to Heathrow is forecast to be greater than 20 knots at 3000ft.
- Aircraft are departing from their stand more than 30 minutes later than their scheduled time or if 30% of all aircraft (arrivals and departures) operating from Heathrow are running 15 minutes late.
- There is disruption to the operation, for example from snow.

7.8.3 Proactive Freedoms

It is recommended that the three sets of proactive freedoms, as trialled, should be available at all times:

- The option to move A380 landing aircraft out of the arrival stream to land on the currently active departures runway and/or the option to move the aircraft in front of or behind the A380 out of the arrival stream to land on the currently active departures runway.
- The option to move Light/Small wake vortex category aircraft out of the arrival stream and land them on the currently active departure runway.

- The option to land T4 traffic on the Southern Runway when the landing runway is 09L/27R (Northern Runway).

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