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PJ37-W3-ITARO

INTEGRATED TMA, AIRPORT AND RUNWAY OPERATIONSINTEGRATED TMA, AIRPORT AND RUNWAY OPERATIONS

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Abstract

This document is the Environmental Impact Assessment report for the ITARO Departures Solution track PJ.37-W3-01B. It provides a synthesis of essential information (qualitative and quantitative) related to the assessment of the impact on the environment that ITARO Departures Solution track PJ.37-W3-01B could have when implemented. This information comes mainly from the Demonstration Plan (DEMOP-Part I) [5] that overviews and details all the exercises and SESAR Solutions involved in PJ.37 ITARO including the Real-Time Simulations (RTS) departure demonstration exercise related to this environmental analysis.

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1 Executive Summary

This document is the Environment Assessment Report for the **ITARO Departures Solution track PJ.37-W3-01B** and analyses the potential impacts on the environment that the Solution could have when implemented. The results are based on a Real-Time Simulation (RTS) in a Heathrow environment which assessed extended Optimised Separation Delivery (extended OSD) tool support for applying refined and reduced, more granular route spacings on departure. The RTS also assessed the integration of an emulated TMA data-feed into the extended OSD tool to dynamically adjust the departure flow rate into the TMA to ensure that the optimised route spacings did not put excessive demand onto TMA sectors.

The analysis assumes that more efficient departure spacings created by the ITARO Departures Solution track PJ.37-W3-01B could be directly translated into a reduced ground holding time, therefore decreasing the amount of fuel consumed whilst the engines of aircraft are idle and pilots waiting to be issued with take-off clearance. The results indicate that the ITARO Departures Solution track PJ.37-W3-01B will have a limited environmental benefits per departing flight at Heathrow during peak hours depending on the extended OSD tool deployed.

The analysis indicated that extended OSD with a TMA data-feed will increase departure efficiency and therefore reduce ground holding durations. The average departure separation time was reduced by 2 seconds between departing flights and average taxi time durations were reduced by 36 seconds compared to OSD. The results indicated potential reductions in fuel burn by 18 kg and CO₂ emissions of 57 kg per flight on average.

On the other hand, extended OSD without a TMA data-feed indicated smaller potential decreases in fuel burn by 7 kg and CO₂ emissions by 23 kg per flight on average. This was due to a reduced average departure separation time of 3 seconds between departing flights and a reduction of 49 seconds in average taxi time durations compared to OSD. Although the departures were more efficient, the small traffic sample and more aircraft types with high taxi fuel burn rates holding for longer durations contributed to the smaller environmental savings in this scenario. However, not using a TMA data-feed with the extended OSD tool risks causing excessive demand onto the TMA sectors by not dynamically adjusting the departure flow rate into the TMA. The participating ATCOs in the RTS expected to see more benefits for the solution **with** the TMA data-feed as it helps them to apply flow restrictions more accurately as well as allowing more granular flow restrictions to be applied (i.e., non-integer minutes such as 3m 30s instead of 4m).

At ECAC level, the ITARO Departures Solution track PJ.37-W3-01B will only apply to 19.35% of the ECAC traffic in 2035. The analysis indicates that using extended OSD with a TMA data-feed is expected to result in a fuel reduction of 0.07% or 3.7 kg per ECAC flight on average. This corresponds to reduced CO₂ emissions of 0.07% or 11.7 kg per ECAC flight on average. On the other hand, using extended OSD without a TMA data-feed is expected to decrease both fuel and CO₂ emissions by a smaller magnitude of 0.03%, or 1.6 kg of fuel and 5.0 kg of CO₂ emissions per ECAC flight on average.

Based on the results of the environmental assessment, it is recommended to use extended OSD with a TMA data-feed as it potentially can reduce fuel burn and CO₂ emissions during peak hours. Furthermore, integrating a TMA data-feed into the extended OSD tool to dynamically adjust the departure flow rate into the TMA will ensure that the optimised route spacings do not put excessive demand onto TMA sectors. However, these results are based on a very small RTS sample and are highly

dependent on the traffic samples and the ATCOs involved in the RTS based on a Heathrow environment.

2 Introduction

2.1 Purpose of the document

This document describes the results of the activities carried out, normally in accordance with the SESAR Environment Assessment Process [3], in order to assess the environmental impact that the ITARO Departures Solution track PJ.37-W3-01B could have when implemented. This information mainly comes from the Demonstration Plan (DEMOP-Part I) [4] and the results of the RTS exercises activities detailed within the DEMOP-Part I. Although, in this report, it is synthesised and is the most relevant for understanding the environmental impact of this solution¹.

2.2 Intended readership

The intended readership of this document are the PJ.37 team members working on the demonstration exercises, PJ.37 management, and the SESAR3 Joint Undertaking.

2.3 Scope of the document

This document provides an overview of the environmental performance of the ITARO Departures Solution track PJ.37-W3-01B at the local level but also, when possible, extrapolated to the ECAC region. It covers the following environmental aspects:

- Fuel used and CO₂ generated (at local and ECAC level).

2.4 Environment work schedule within the Solution

The assessment of environmental impact of the ITARO Departures Solution track PJ.37-W3-01B has been carried out following the guidance provided in the SESAR Environment Reference Material [3].

2.5 Structure of the document

This Environment Assessment report has the following structure:

Chapter 1 (Executive summary): contains a brief description of the document.

Chapter 2 (Introduction): contains the purpose and scope of this document. Further significant information such as glossary of terms and list of abbreviations have been included at the end of the chapter.

¹ The opinions expressed herein reflect the author's view only. Under no circumstances shall the SESAR3 Joint Undertaking be responsible for any use that may be made of the information contained herein.

Chapter 3 (The environment Assessment Process: Objective and Approach): describes the detailed SESAR Environment Impact Assessment (EIA) Process implemented in the ITARO Departures Solution track PJ.37-W3-01B.

Chapter 4 (Environment Performance Assessment): includes the results of SESAR Environment Impact Assessment (EIA) application to ITARO Departures Solution track PJ.37-W3-01B.

Chapter 5 (References): the references, and applicable documents.

2.6 Terminology

Term	Description
Benefit and Impact Mechanism	A cause-effect description of the impacts of the solution proposed by a project. It describes the positive and the negative impacts that the project solution is expected to provide or demonstrate.
Benefit Diagram	A Benefit and Impact Mechanism is usually shown in a diagram giving an overview of the links between the (new) features that the project is bringing to the world of ATM and indicators (aspects which can be measured or calculated from other metrics), Positive or Negative Impacts for each performance area, and Key Performance Areas (KPA) or Key Performance Indicators (KPIs). This diagram is supplemented by textual descriptions of the feature, the numbered links and impacts.
Business Case	A Business Case is a tool for decision-makers; it aims to provide them with the information they need to make a fully informed decision on whether funding should be provided and/or whether an investment should proceed. A Business Case is much more than just a financial analysis as it also includes quantitative and qualitative arguments on performance and transversal activities that are key elements to determining the value of the project.
Deployment Scenario	Deployment Scenario consists of a set of SESAR Solutions selected to satisfy the specific performance needs of operating environments in the European ATM System and based upon the timescales in which their performance contribution is needed in the respective operating environments
Environment	Surroundings in which humans interact with the air, water, landscape, natural resources, flora and fauna. In terms of ATM, 'the environment' will be the surroundings in which Air Traffic Management activities are planned or conducted, including research through to development, deployment, and operations.
Environmental Impact	Any modification of the environment that has or could have an effect on the ecosystem. In this document the main environmental impacts of concern are: • Aircraft noise in the vicinity of an airport,

	• Airport Local Air Quality (mainly CO, NO_x and Particulate Matter), • Global emissions (mainly CO₂) Fuel burnt is also of concern for the environment because of the direct relationship between fuel burnt and CO₂.
Environmental Impact Assessment (EIA)	The process of identifying and evaluating the environmental impacts of projects as well as proposing mitigations to reduce these impacts on the environment. The assessment scope, as it relates to ATM, considers impacts on the environment that can be affected by aircraft operations or that can affect aircraft operations, e.g. through mitigation rules. The main impacts on the environment related to aircraft movements are caused by emissions resulting from fuel burn and noise produced by the engines and airframe.
EIA plan	The Environmental Impact Assessment plan describes the hypothesis to test, metrics to assess, the tools to use, the required input variables for the tools and methodology used for analysing the results.
EUROCONTROL	European Organisation for the Safety of Air Navigation
Pair Wise Separation (PWS-D)	Procedure designed for use between departures from the runway, based on an optimum adjusting of the needed separation between two aircraft taking into account their respective characteristics and giving Controllers more dynamic separation options.
RECAT-EU	European Wake Turbulence Categorisation and Separation Minima on Approach and Departure
S3JU Work Programme	The programme which addresses all activities of the SESAR3 Joint Undertaking Agency.
SESAR Programme	The programme that defines the Research and Development activities and Projects for the S3JU.

Table 1: Terminology

2.7 Acronyms

Term	Description
ATCO	Air Traffic Control Officer
BADA	Base of Aircraft Data
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
ECAC	European Civil Aviation Conference
extended OSD	Extended Optimised Separation Delivery
IMPACT	EUROCONTROL web portal for the analysis of aircraft noise and emissions
JU	Joint Undertaking
KPA	Key Performance Area
KPI	Key Performance Indicator
LAQ	Local Air Quality
NO _x	Oxides of Nitrogen, including nitrogen dioxide (NO ₂) and nitrogen oxide (NO).
OSD	Optimised Separation Delivery
PM	Particulate Matter
PWS-D	Pair Wise Separation for Departures
RECAT-EU	Re-categorisation EU
RTS	Real-Time Simulation
SEL	Sound Exposure Level
SID	Standard Instrument Departure
S3JU	SESAR3 Joint Undertaking (Agency of the European Commission)
SO _x	Oxides of Sulphur
SPR	Safety and Performance Requirements
TMA	Terminal Manoeuvring Area

VLD	Very Large Demonstration
VOC	Volatile organic compounds

Table 2: Acronyms

3 The Environment Assessment Process: Objective and Approach

The SESAR Environment Assessment Process [3] was derived from the ICAO Guidance document (Doc 10031) [4] “Guidance on Environmental Assessment of Proposed Air Traffic Management Operational Changes” and adapted to the SESAR validation framework.

As can be seen in on the Figure below, which shows the correspondence between the ICAO assessment process (right-hand side) and the one adopted for SESAR (left-hand side), the resulting process is quite generic and straightforward. Results from the environmental impact assessments can also be used to refine the ATM change, making the process cyclic and compatible with the classic Plan-Do-Check-Act approach to validation.

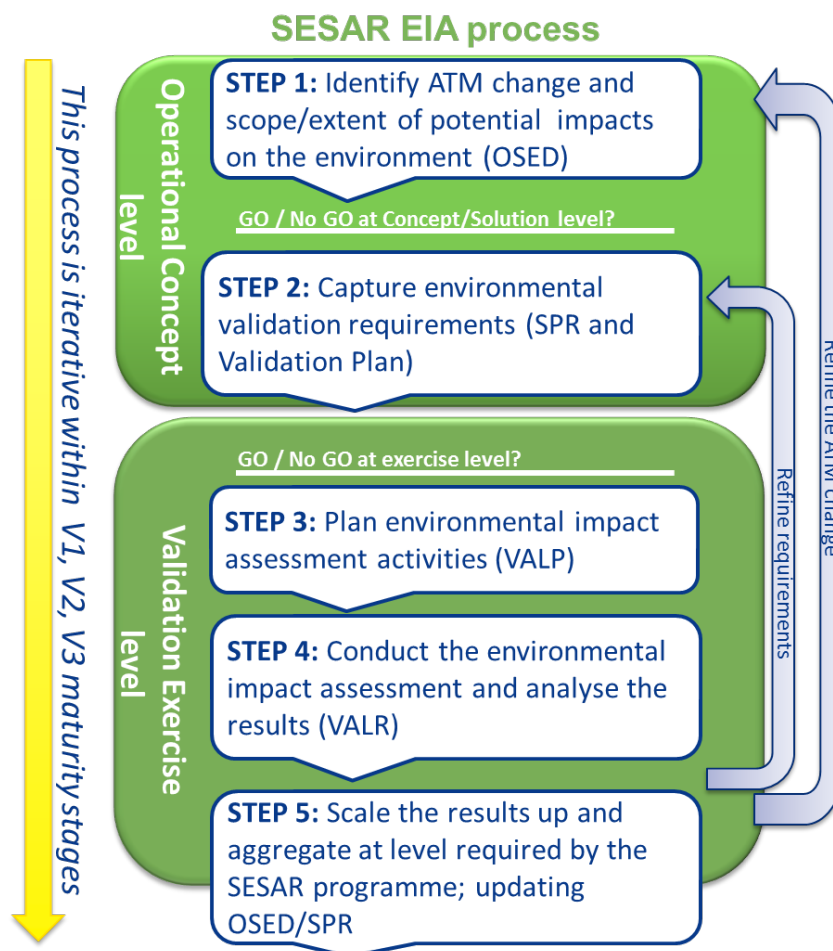


Figure 1: SESAR environmental impact assessment process

This process should enable environmental impact assessment activities to be easily carried out as part of the overall validation process where necessary.

The SESAR EIA process consists of 5 main steps:

- EIA Step 1: Identify ATM change and the scope of potential impacts on the environment.
- EIA Step 2: Define environmental validation requirements.
- EIA Step 3: Plan environmental impact assessment activities.
- EIA Step 4: Conduct the environmental impact assessment exercise.
- EIA Step 5: Scale the results up and aggregate.

The SESAR EIA process encompasses two "Go-No-Go" decisions about carrying out further environmental impact assessments. The first one occurs after EIA Step 1 in order to identify very early on in the process whether it is worth undertaking an environmental impact assessment or whether or not more assessments are required later on in the process. The second one occurs at the Exercise level and allows the decision on conducting a detailed environmental impact assessment to be taken before the writing of the validation plan for that exercise. This decision will be based on criteria determined by the validation exercise management. In any case, every "Go-No-Go" decision should be included in the validation plan.

Please refer to the SESAR Environment Assessment Process for full guidance [3].

4 Environment Performance Assessment

4.1 Assessment Sources and Summary of Validation Exercise Performance Results

No previous Validation Exercises are relevant for this assessment.

SESAR Validation Exercises of this ITARO Departures Solution track PJ.37-W3-01B (completed ones and planned ones) are listed below.

Exercise ID	Exercise Title	Release	Maturity	Status
EXE-PJ.37-W3-004	ITARO for departures in segregated runway operations	R12	TRL7-ongoing	Completed

Table 3: SESAR2020 Validation Exercises

The following table provides a summary of information collected from available performance outcomes.

Exercise	OI Step	Exercise scenario & scope	Performance Results	Notes
EXE-PJ.37-W3-004	AO-0329 (OSD) [5]	NATS real time simulation for the integrated departure management process solution	There is evidence to show there is a reduction in the average fuel burn per flight in the Solution Scenario versus the Reference Scenario.	The fuel burn analysis is carried out in this EIA report.

Table 4: Summary of Validation Results

4.2 Conditions / Assumptions for Applicability

The following assumptions apply:

- The fuel burn and CO₂ emissions analysis are based on the results of a Real-Time Simulation in a Heathrow environment.
- It is assumed that the airport operator will not utilise the departure separation improvements to introduce additional runway movements.
- For simplicity, a more efficient spacing on departure is associated directly with a corresponding reduction in average ground holding durations (i.e., taxi time).

- Average fuel burn rates per minute of taxi time is determined by the BADA 4.2 Taxi Fuel Allowances² for the Heathrow aircraft traffic mix.
- A direct link between fuel burnt and the amount of CO₂ produced of 3.15 times the mass of fuel burnt.
- Heathrow operates on a 30:70 Easterly/Westerly weighted ratio for runway use based on actual 2019 runway usage³.
- SJU common assumptions [7], are applicable. The document contains assumptions regarding, for example, flight movements per Sub Operational Environment and year.

The following Table 5 summarises the applicable operating environment.

OE	Applicable sub-OE	Special characteristics
Airport	Very Large Airport	Capacity constrained airports during peak periods
Airport	Large Airport	Segregated mode on independent runways only

Table 5: Applicable Operating Environments

4.3 Environment: Fuel Efficiency / CO₂ emissions

Does the Solution impact this KPA? Yes

To reduce the CO₂ emissions from flights, it is necessary to reduce their fuel consumption as every tonne of fuel burned generates 3.15 tonnes of CO₂ emissions.

The ITARO Departures Solution track PJ.37-W3-01B enables reduced and more granular route spacing times so departure pairs will be spaced closer together. This allows the average ground holding (i.e., taxi time) duration per flight to be reduced during peak periods. Reducing ground holding therefore decreases the amount of fuel burnt and CO₂ emitted whilst the engines of aircraft are idle and pilots waiting to be issued with take-off clearance.

4.3.1 Performance Mechanism

Is there a Benefit Mechanism available? No as this solution is VLD-Like.

The lower the average ground holding duration per flight, the less fuel is burnt on the ground (e.g., in case of taxi time holding), leading to a positive impact on Fuel Efficiency in terms of the airline's fuel costs.

² Taxi Fuel Allowances (TFAs) taken from BADA 4.2 UMv1.3 XML files.

³ Actual Electronic Flight Progress System (EFPS) data showed a 27%:73% runway usage on Heathrow's Easterly and Westerly runway directions in 2019.

4.3.2 Assessment Data (Exercises and Expectations)

The environmental assessment is based on the data from RTS⁴ conducted on segregated runway operations in the Heathrow environment, which is classified as a Very Large Airport according to the Airports' classification scheme in SESAR 2020 [8]. The RTS exercises were based on Heathrow runway operations between the peak periods of 09:00 to 10:00 and 11:00 to 12:00.

The RTS investigated the application of reduced, more granular non-wake SID separations on departure with an extended OSD tool. The RTS also assessed the integration of an emulated TMA data-feed into the extended OSD tool to dynamically adjust the departure flow rate into the TMA to ensure that the optimised SID separations do not put excessive demand onto TMA sectors.

To assess the environmental benefits of the ITARO Departures Solution track PJ.37-W3-01B with and without the TMA data feed (Solution Scenarios), a comparative assessment is conducted against a Reference Scenario:

1. RECAT-EU 6-CAT or PWS-D wake time separations with OSD tool.

There are two Solution Scenarios:

1. Time-Based PWS-D or PWS-D with extended OSD tool support without a TMA data-feed.
2. Time-Based RECAT-EU or PWS-D with extended OSD tool support with an emulated TMA data-feed.

Only flights that were airborne in one of the Solution Scenarios and the corresponding Reference Scenario were included in the environmental analysis. As a result, the total sample size was reduced by 60% from 2,694 flights down to 1,071 flights for comparison.

Table 6 shows that the generally the extended OSD tool with or without the TMA data-feed would decrease the average departure separation times compared to the Reference OSD tool⁵, therefore reducing ground holding (i.e., taxi time) durations and potentially decrease the amount of fuel burnt and CO₂ emitted. Scenario 1 presented the most efficient departure separation times resulting in lower average taxi time durations compared to Scenario 2; however, there is a risk of overloading the TMA sectors by not using a TMA data-feed.

⁴ Details are contained in the DEMOP-Part I [5].

⁵ Not all aircraft were airborne in the RTS; those that were airborne are classified as flights in this report.

Scenario	Average Departure Separation Time	Average Taxi Time Duration
Reference Scenario: OSD	1m 7s	11m 18s ⁶
Scenario 1: extended OSD without TMA data-feed	1m 4s	10m 29s
Scenario 2: extended OSD with emulated TMA data-feed	1m 5s	10m 42s

Table 6: Average departure separation time and taxi time durations per airborne flight in the Scenarios

To perform the fuel burn analysis the taxi time durations⁷ were calculated in each scenario. For each aircraft type, the BADA 4.2 taxi fuel burn rate was applied to the taxi time durations. The resulting taxi time fuel burns were then compared against its ground holding fuel burn in the corresponding Reference Scenario to calculate the fuel burn and CO₂ emissions differences⁸ for each flight. The average fuel burn and CO₂ emissions differences per flight from the Reference Scenarios are shown in Table 7.

Solution Scenario	Average Difference Per Flight from Reference Scenario	
	Fuel Burn Difference	CO ₂ Emissions Difference
Scenario 1: extended OSD without TMA data-feed	-7 kg	-23 kg
Scenario 2: extended OSD with emulated TMA data-feed	-18 kg	-57 kg

Table 7: Average fuel burn and CO₂ emissions difference per flight compared to the Reference Scenario

Scenario 2 resulted in the highest average environmental savings of 18 kg fuel burn reduction and 57 kg reduced CO₂ emissions per flight compared to the Reference Scenario. Although Scenario 1 had more efficient departures and lower taxi time durations, it had smaller average environmental savings with reduced fuel burn of 7 kg and CO₂ emissions of 23 kg per flight compared to the Reference Scenario. This was due to more aircraft types with high taxi fuel burn rates holding for longer durations in Scenario 1 compared to Scenario 2 and also the small sample sizes likely to have an effect on the results.

⁶ Average across all airborne flights in the Reference Scenario for info. This value is different when only flights airborne in both the Reference and the corresponding Solution Scenario are compared – see detailed results contained in Appendix A.

⁷ The ground holding duration is calculated as the time from the aircraft starting up its engine (which is consistent across all scenarios) to its airborne time in each of the scenarios.

⁸ Using the direct link between fuel burn and the amount of CO₂ produced (3.15 times the mass of fuel burnt).

The analysis indicates that extended OSD with a TMA data-feed would be more beneficial in environmental savings than extended OSD without a TMA data-feed. Furthermore, using a TMA data-feed may prevent excessive demand on the TMA sectors by dynamically adjusting the departure flow rate into the TMA. The participating ATCOs in the RTS expected to see more benefits for the solution **with** the TMA data-feed as it helps them to apply flow restrictions more accurately as well as allowing more granular flow restrictions to be applied (e.g., 3m 30s instead of 4m).

Exercise ID or Expert judgement	Benefits contribution to FEEF1	Benefits contribution to ENV1
EXE-PJ.37-W3-004	Scenario 1 (extended OSD Tool without TMA Data Feed): reduction in fuel burn of 7 kg per flight compared to the Reference Scenario. Scenario 2 (extended OSD Tool with an emulated TMA data feed): reduction in fuel burn of 18 kg per flight compared to the Reference Scenario.	Scenario 1 (extended OSD Tool without TMA Data Feed): reduction in fuel burn of 23 kg per flight compared to the Reference Scenario. Scenario 2 (extended OSD Tool with an emulated TMA data feed): reduction in CO₂ emissions of 57 kg per flight compared to the Reference Scenario.

Table 8: Fuel burn and CO₂ emissions saving per exercise

OI step	Relative benefits contribution to FEEF1	Relative benefits contribution to ENV1
AO-0329	100%	100%
TOTAL	100%	100%

Table 9: Fuel burn and CO₂ emissions saving relative benefit per OI step

4.3.3 Extrapolation to ECAC wide

An average of 18kg of fuel could be saved per flight departing from Heathrow at peak times with extended OSD with a TMA data-feed (Scenario 2). As the common assumption [7] for average fuel burn per flight is 5280kg, a saving of 18kg represents 0.34%⁹ of fuel consumption reduction per flight.

However, as only flights departing from Very Large airports and Large Airports at peak times will reap the benefits of this operational improvement, the benefit of the improvement at ECAC / Network level will concern only 19.35%¹⁰ of the ECAC traffic in 2035. This results in 0.07%¹¹ of fuel reduction or

⁹ Calculated by 18 kg / 5280kg = 0.34%.

¹⁰ Assumption of Peak Traffic at Very Large (30.37%) and Large (8.33%) airports [9], from which only 50% (departing traffic) is affected; (30.37% * 50%) + (8.33% * 50%) = 19.35%

¹¹ Calculated by 0.34% * 19.35% = 0.07%.

3.7kg¹² of fuel per ECAC flight on average. This equates to an average CO₂ reduction of 0.07% or 11.7kg¹³ of CO₂ per ECAC flight on average.

The same method of extrapolation to ECAC is applied to the average fuel burn and CO₂ emissions differences in Table 7 for Scenario 1 to obtain the expected performance benefits in Table 10.

KPIs / Pls	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
FEFF1 Actual Average fuel burn per flight	Kg fuel per movement	Total amount of actual fuel burn divided by the number of movements	YES	Sc1 Extended OSD without a TMA data-feed: -1.6 kg Sc2 Extended OSD with an emulated TMA data-feed: -3.7 kg	Sc1 Extended OSD without a TMA data-feed: -0.03 % Sc2 Extended OSD with an emulated TMA data-feed: -0.07 %
ENV1 Actual Average CO ₂ Emission per flight	Kg CO ₂ per flight	Amount of fuel burnt x 3.15 (CO ₂ emission index) divided by the number of flights	YES	Sc1 Extended OSD without a TMA data-feed: -5.0 kg Sc2 Extended OSD with an emulated TMA data-feed: -11.7 kg	Sc1 Extended OSD without a TMA data-feed: -0.03 % Sc2 Extended OSD with an emulated TMA data-feed: -0.07 %

Table 10: Fuel burn and CO₂ emissions saving for Mandatory KPIs / Pls

Table 11 shows the average fuel burn and CO₂ emissions per phase of flight (where applicable).

Solution Scenario	Taxi out	TMA departure	En-route	TMA arrival	Taxi in
FEFF1 Actual Average fuel burn per flight	Sc1 Extended OSD without a TMA data-feed Sc2 Extended OSD with an emulated TMA data-feed	7 kg per flight saving 18 kg per flight saving	N/A	N/A	N/A
ENV1 Actual Average CO ₂ Emission per flight (Kg)	Sc1 Extended OSD without a TMA data-feed Sc2 Extended OSD with an emulated TMA data-feed	23 kg per flight saving 57 kg per flight saving	NA	N/A	N/A

Table 11: Average fuel burn and CO₂ emissions per phase of flight.

Were there any benefits obtained in SESAR2020 Wave 1 for this Solution? Yes.

¹² Calculated by 0.07% * 5280 kg = 3.7 kg.

¹³ CO₂ is 3.15 times fuel burnt; 3.7 kg * 3.15 = 11.7 kg.

The ITARO Departures Solution track PJ.37-W3-01B will extend the OSD tool developed in SESAR 2020 Wave 1 to provide support for reduced and more granular route spacings on departure.

4.3.4 Discussion of Assessment Result

The ITARO Departures Solution track PJ.37-W3-01B aims at assessing the impact of reduced route spacings supported by the extended OSD tool with and without a TMA data-feed as a comparative assessment against the deployed route separations currently employed at Heathrow without extended OSD tool support.

Analysis on the RTS data has indicated that the extended OSD tool with a TMA data-feed would give fuel burn savings of 18 kg and CO₂ emission savings of 57 kg per flight on average compared to the OSD tool. These savings are due to more efficient departure separation times between aircraft, therefore reducing ground holding (i.e., taxi time) durations and the amount of fuel burnt and CO₂ emitted compared to OSD.

However, the extended OSD tool without a TMA data-feed presented the most efficient departure separation times and lowest ground holding durations but resulted in smaller average environmental savings of 7kg fuel burn and 23 kg CO₂ emissions per flight respectively compared to the OSD tool. This was due to more aircraft types with higher taxi fuel burn rates holding for longer durations and also likely the small sample sizes likely to have an effect on the results.

As expected, the participating ATCOs in the RTS expected to see more benefits for the solution with the TMA data-feed as it helps them to apply flow restrictions more accurately as well as allowing more granular flow restrictions to be applied (e.g., 3m 30s instead of 4m). However, as these results are based on a very small RTS sample, they are highly dependent on the traffic samples and the ATCOs involved in the RTS. Furthermore, the RTS are focused on the London Heathrow operation only and considerations should be made on departure sequencing behaviours that are not necessarily universal at other airports. Other limitations include the simplified RTS environment (such as no other airport traffic simulated) and aircraft fleet mix which was used to determine these environmental benefits. The results should therefore be considered as indicative and further investigations could be carried out using more sophisticated methods such as Fast-Time Simulations with larger traffic samples.

4.4 Environment: Noise, Local Air Quality, and non-CO₂ Emissions

Does the Solution impact this KPA? No

While ITARO Departures Solution track PJ.37-W3-01B is aimed at improving departure spacing, the impact is expected to be primarily on ground holding delay incurred by aircraft during the taxi phase, particularly if it is assumed that airport operators will not utilise the more efficient departures to introduce additional runway movements.

Under this assumption, the impact on noise can be considered to be negligible, as the reduction in noise is then related to reduction of APU use and time of engine at taxi power, which is of second order compared to full thrust noise emissions prevalent during take-off.

Similarly, the impact on local air quality and non-CO₂ emissions through the reduction of aircraft ground delay can be considered negligible in comparison to other emission sources.

4.5 Overall conclusion on the environmental impact of the Solution

The environmental analysis assumes that the more efficient departure spacings created by the ITARO Departures Solution track PJ.37-W3-01B could be directly translated into reduced ground holding durations, therefore decreasing the amount of fuel consumed whilst the engines of aircraft are idle and pilots waiting to be issued with take-off clearance.

In conclusion, the impact of the ITARO Departures Solution track PJ.37-W3-01B would vary depending on the extended OSD tool deployed. The analysis has indicated that extended OSD with or without a TMA data-feed could potentially give environmental savings by increasing departure efficiency and reduce ground holding durations and therefore the amount of fuel burn and CO₂ emitted. The TMA data-feed helps ATCOs to apply flow restrictions more accurately as well as allowing more granular flow restrictions to be applied (e.g., 3m 30s instead of 4m). On the other hand, not using a TMA data-feed risks causing excessive demand onto the TMA sectors by not dynamically adjusting the departure flow rate into the TMA.

Due to the impact of the Solution Scenarios primarily being changes in ground holding delay durations, and the assumption that capacity gains are not realised in additional movements, an assessment of noise and local air quality impact was not conducted due to the estimated minimal size of the impact relative to other pollution sources.

5 References

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Appendix A Detailed Analysis Results per Scenario

Only flights that were airborne in one of the Solution Scenarios and the corresponding Reference Scenario were included in the environmental analysis. This meant that the average taxi time durations for the Reference Scenarios used for comparison were different for the two Solution Scenarios as shown in Tables Table 13. The average taxi fuel burn and CO₂ emissions per flight for each Solution Scenario shown here are reported in the results. Table 12 Table 13: Average taxi time duration, fuel burn and CO₂ emissions difference between flights airborne in both the Reference Scenario and Scenario

A.1 Scenario 1 extended OSD without a TMA data-feed

	Number of Airborne Flights Compared	Average Taxi Time Duration Per Flight	Average Taxi Fuel Burn Per Flight	Average Taxi CO ₂ Emissions Per Flight
Reference Scenario	598	10m 51s	196 kg	617 kg
Scenario 1	598	10m 29s	189 kg	595 kg
Difference	-	22s	7 kg	22 kg

Table 12: Average taxi time duration, fuel burn and CO₂ emissions difference between flights airborne in both the Reference Scenario and Scenario 1

A.2 Scenario 2 extended OSD with a TMA data-feed

	Number of Airborne Flights Compared	Average Taxi Time Duration Per Flight	Average Taxi Fuel Burn Per Flight	Average Taxi CO ₂ Emissions Per Flight
Reference Scenario	473	11m 35s	211 kg	665 kg
Scenario 2	473	10m 42s	193 kg	608 kg
Difference	-	53s	18 kg	57 kg

Table 13: Average taxi time duration, fuel burn and CO₂ emissions difference between flights airborne in both the Reference Scenario and Scenario 2

Appendix B Environmental Benefits by Wake Scheme

B.1 Assessment Data (Exercises and Expectations)

It is interesting to see the environmental benefits of the ITARO Departures Solution track PJ.37-W3-01B based on the wake schemes (i.e. RECAT-EU or PWS-D) and with or without the TMA data feed (Solution Scenarios). So a comparative assessment is conducted against two Reference Scenarios and presented in this Appendix. There are two Reference Scenarios:

1. RECAT-EU 6-CAT wake time separations with OSD tool organisation (no non-wake SID separation tool support).
2. PWS-D solution organisation based on 103x103 PWS and 20-CAT PWS wake time separations with OSD tool support (no non-wake SID separation tool support).

There are four Solution Scenarios:

1. Time-Based RECAT-EU with extended OSD (extended OSD) tool support without a TMA data-feed.
2. Time-Based RECAT-EU with extended OSD (extended OSD) tool support with an emulated TMA data-feed.
3. Time-Based PWS-D with extended OSD tool support without a TMA data-feed.
4. Time-Based PWS-D with extended OSD tool support with an emulated TMA data-feed.

Only flights that were airborne in one of the Solution Scenarios and also the corresponding Reference Scenario were included in the environmental analysis. As a result, the sample size was reduced by 60% from 2,694 flights down to 1,071 flights for comparison. Table 14 below shows that the generally the extended OSD tool with or without the TMA data-feed would decrease the average departure separation times compared to the RECAT-EU or PWS-D OSD tool¹⁴. Average taxi time durations for Scenarios 1 and 2 decreased compared to its Reference Scenario 1. However, for Scenarios 3 and 4 the taxi time durations increased even though the average departure separation times fell by 1 second compared to its Reference Scenario 2.

¹⁴ Not all aircraft were airborne in the RTS; those that were airborne are classified as flights in this report.

Scenario	Average Departure Separation Time	Average Taxi Time Duration
Ref 1: RECAT-EU OSD	1m 9s	11m 50s
Sc1: RECAT-EU extended OSD without TMA data-feed	1m 5s	9m 30s
Sc2: RECAT-EU extended OSD with emulated TMA data-feed	1m 6s	10m 5s
Ref 2: PWS-D OSD	1m 5s	10m 46s
Sc3: PWS-D extended OSD without TMA data-feed	1m 4s	11m 17s
Sc4: PWS-D extended OSD with emulated TMA data-feed	1m 4s	11m 25s

Table 14: Average departure separation time and taxi time durations per flight in the Scenarios by Wake Scheme

To perform the fuel burn analysis the ground holding durations¹⁵ were calculated in each scenario. For each aircraft type, the BADA 4.2 taxi fuel burn rate was applied to the ground holding durations. The resulting ground holding (or taxi) fuel burns were then compared against its ground holding fuel burn in the corresponding Reference Scenario to calculate the fuel burn and CO₂ emissions differences¹⁶ for each flight. The average fuel burn and CO₂ emissions differences from the Reference Scenarios are shown in Table 15.

Solution Scenario	Average Difference Per Flight from Reference Scenario	
	Fuel Burn Difference	CO ₂ Emissions Difference
Sc1: RECAT-EU extended OSD without a TMA data-feed	-27 kg	-86 kg
Sc2: RECAT-EU extended OSD with an emulated TMA data-feed	-33 kg	-104 kg
Sc3: PWS-D extended OSD without a TMA data-feed	+9 kg	+29 kg
Sc4: PWS-D extended OSD with an emulated TMA data-feed	-1 kg	-4 kg

¹⁵ The ground holding duration is calculated as the time from the aircraft starting up its engine (which is consistent across all scenarios) to its airborne time in each of the scenarios.

¹⁶ Using the direct link between fuel burn and the amount of CO₂ produced (3.15 times the mass of fuel burnt).

Table 15: Average Ground Holding Fuel Burn and CO₂ Emissions Difference per Flight Compared to the Reference Scenario by Wake Scheme

Solution Scenario 2 resulted in a reduced average departure separation time of 1m 6s between flights and average fuel burn savings of 33 kg and 104 kg of reduced CO₂ emissions per flight compared to the Reference Scenario 1. Scenario 1 had, on average, a lower departure separation time of 1m 5s compared to the Reference Scenario 1 at 1m 9s, and on average reduced fuel burn of 27 kg and CO₂ emissions of 86 kg per flight. Both Scenarios 1 and 2 indicated more efficient departures with lower taxi time durations compared to the Reference Scenario 1.

The analysis indicates that RECAT-EU extended OSD with a TMA data-feed would be more beneficial in environmental savings than RECAT-EU extended OSD with a TMA data-feed. The TMA data-feed will also prevent excessive demand on the TMA sectors by dynamically adjusting the departure flow rate into the TMA, allowing for more granular flow restrictions, e.g., 3m 30s instead of 4m.

Table 14 shows that Solution Scenario 4, on average, a lower departure separation times of 1m 4s compared to the Reference Scenario 2 at 1m 4s, and on average reduced fuel burn of 1 kg and CO₂ emissions of 4 kg per flight. However, Scenario 3 increased the average fuel burn by 9 kg per flight and CO₂ emissions by 29 kg per flight compared to Reference Scenario 2 even though the average departures separation time was lower by 1s. This was due to more aircraft types with higher taxi fuel burn rates holding for longer durations compared to Reference Scenario 2 in the RTS and the small sample size likely to have an effect on the results. Furthermore, both Scenarios 3 and 4 both indicated less efficient departures overall compared to the Reference Scenario 2 with higher taxi time durations offsetting the reduced departure separation times.

For PWS-D, the analysis indicates that using extended OSD and a TMA data-feed is likely to provide environment savings as well as preventing excessive demand onto the TMA sectors. However, not using a TMA data-feed risks causing excessive demand onto the TMA sectors by not dynamically adjusting the departure flow rate into the TMA and therefore can increase average fuel burn and CO₂ emissions per flight.

B.2 Extrapolation to ECAC wide

An average of 33 kg of fuel could be saved per flight departing from Heathrow at peak times with RECAT-EU extended OSD with a TMA data-feed. As the common assumption [7] for average fuel burn per flight is 5280 kg, a saving of 33 kg represents 0.63%¹⁷ of fuel consumption reduction per flight.

However, as only flights departing from Very Large airports and Large Airports at peak times will reap the benefits of this operational improvement, the benefit of the improvement at ECAC / Network level

¹⁷ Calculated by 33 kg / 5280kg = 0.63%.

will concern only 19.35%¹⁸ of the ECAC traffic in 2035. This results in 0.12%¹⁹ of fuel reduction or 6.3 kg²⁰ of fuel per ECAC flight on average. This equates to an average CO₂ reduction of 0.12% or 19.8kg²¹ of CO₂ per ECAC flight on average.

The same method of extrapolation is applied to the average fuel burn and CO₂ emissions differences in Table 15 for each Solution Scenario and runway to obtain the expected performance benefits in Table 16 below.

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
FEFF1 Actual Average fuel burn per flight	Kg fuel per movement	Total amount of actual fuel burn divided by the number of movements	YES	Sc1: RECAT-EU extended OSD without a TMA data-feed: -5.3 kg Sc2: RECAT-EU extended OSD with an emulated TMA data-feed: -6.3 kg Sc3: PWS-D extended OSD without a TMA data-feed: +1.6 kg Sc4: PWS-D extended OSD with an emulated TMA data-feed: 0kg	Sc1: RECAT-EU extended OSD without a TMA data-feed: -0.10 % Sc2: RECAT-EU extended OSD with an emulated TMA data-feed: -0.12 % Sc3: PWS-D extended OSD without a TMA data-feed: +0.03% Sc4: PWS-D extended OSD with an emulated TMA data-feed: 0%
ENV1 Actual Average CO ₂ Emission per flight	Kg CO ₂ per flight	Amount of fuel burnt x 3.15 (CO ₂ emission index) divided by the number of flights	YES	Sc1: RECAT-EU extended OSD without a TMA data-feed: -16.7 kg Sc2: RECAT-EU extended OSD with an emulated TMA data-feed: -19.8 kg Sc3: PWS-D extended OSD without a TMA data-feed: +5.0 kg Sc4: PWS-D extended OSD with an emulated TMA data-feed: 0 kg	Sc1: RECAT-EU extended OSD without a TMA data-feed: -0.10% Sc2: RECAT-EU extended OSD with an emulated TMA data-feed: -0.12 % Sc3: PWS-D extended OSD without a TMA data-feed: +0.03% Sc4: PWS-D extended OSD with an emulated TMA data-feed: 0%

Table 16: Fuel burn and CO₂ emissions saving for Mandatory KPIs /PIs by Wake Scheme

¹⁸ Assumption of Peak Traffic at Very Large (30.37%) and Large (8.33%) airports [9], from which only 50% (departing traffic) is affected; $(30.37\% * 50\%) + (8.33\% * 50\%) = 19.35\%$

¹⁹ Calculated by $0.63\% * 19.35\% = 0.12\%$.

²⁰ Calculated by $0.12\% * 5280 \text{ kg} = 6.3 \text{ kg}$.

²¹ CO₂ is 3.15 times fuel burnt; $6.3 \text{ kg} * 3.15 = 19.8 \text{ kg}$.

Table 17 shows the average fuel burn and CO₂ emissions per phase of flight (where applicable).

	Solution Scenario	Taxi out	TMA departure	En-route	TMA arrival	Taxi in
FEFF1 Actual Average fuel burn per flight	Sc1: RECAT-EU extended OSD without a TMA data-feed	27 kg per flight saving	N/A	N/A	N/A	N/A
	Sc2: RECAT-EU extended OSD with an emulated TMA data-feed	33 kg per flight saving 9 kg per flight disbenefit				
	Sc3: PWS-D extended OSD without a TMA data-feed	1 kg per flight saving				
	Sc4: PWS-D extended OSD with an emulated TMA data-feed					
ENV1 Actual Average CO2 Emission per flight (Kg)	Sc1: RECAT-EU extended OSD without a TMA data-feed	86 kg per flight saving	N/A	N/A	N/A	N/A
	Sc2: RECAT-EU extended OSD with an emulated TMA data-feed	104 kg per flight saving 29 kg per flight disbenefit				
	Sc3: PWS-D extended OSD without a TMA data-feed	4 kg per flight saving				
	Sc4: PWS-D extended OSD with an emulated TMA data-feed					

Table 17: Average fuel burn and fuel burn savings per phase of flight by Wake Scheme

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