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Single European Sky Implementation support through Validation

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EXECUTIVE SUMMARY

This Exercise contributes to reducing capacity and throughput constraints at airport runway level.

The objective of the Exercise was to test a number of Operational Improvements which may lead to increased runway capacity, achieving maximum runway throughput in all weather conditions. This Fast Time Simulation evaluated potential gains in terms of;

- reduced runway occupancy time
- recovery of lost landing slots in headwind conditions
- increased runway throughput due to reduced wake turbulence separations
- maintaining throughput in low visibility conditions as close as possible to the throughput achieved in visual conditions

The methodology employed has been to simulate reference scenarios and then to simulate those scenarios with variations applied, allowing comparison between the reference and modified scenarios. Results are expressed in terms of;

- runway occupancy times of individual aircraft
- total runway occupancy times for a specific time period
- number of aircraft departing from a runway during a specific time period
- number of aircraft landing on a runway during a specific time period

The report describes the conditions under which the Operational Improvement steps tested in this Exercise may bring improvements to runway throughput and capacity.

Exercise results have been presented to the Episode 3 WP5.3.2 Airport Expert Group.

The Exercise results may be summarised as follows:

- The application of Brake To Vacate technology reduced runway occupancy time for individual equipped aircraft and as a factor of total runway occupancy time.
- Time-based Spacing allowed recovery of lost landing slots due to headwind conditions. The application of TBS in headwind conditions has the effect of reducing longitudinal distance between aircraft.
- Reduced wake turbulence separations dependent on crosswind conditions or on aircraft weight category increased runway throughput in segregated arrival or departure runway mode.
- Reduced ILS Critical and Sensitive Areas increased runway throughput under CATII/III conditions to a level close to throughput under CATI or better conditions.

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1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This document provides the Validation Exercise Report for Episode 3 WP5.3.3 Fast-Time Simulation on Runway Capacity.

1.2 INTENDED AUDIENCE

The document is intended for the following audience:

- Episode 3 WP5 participants
- Episode 3 partners
- SJU Project Leaders.

1.3 SCOPE AND STRUCTURE OF DOCUMENT

This document describes the objectives, preparation, execution and results of the Exercise.

Section 2 describes the Exercise objectives, hypotheses, choice of metrics, the simulation methodology used, and the environment and traffic simulated. Section 3 summarises the Exercise execution. Section 4 provides the detailed Exercise results while section 5 provides analysis of Exercise outcomes.

Section 6 contains conclusions and recommendations while Section 7 contains a list of applicable and reference documents.

1.4 EXPERIMENT BACKGROUND AND CONTEXT

The SESAR Definition Phase identified limits/blocking points for airport environment to achieve the required capacity targets. Accordingly the most relevant blocking points and possible solutions are:

- **Lack of relevant tools and procedures to manage bad weather conditions and imperfect meteorological forecasting,** which give substantial reduction of airport capacity (Taxiways and runways) in abnormal weather operations (CatII, CatIII, contaminated taxiways and runways). (PRR7) and leads to excessive maintenance of regulations. Under low visibility conditions the possibility of runway incursions rises dramatically. A degraded situational awareness of all partners involved (ground and cockpit) is the cause. The ROT (Runway Occupation Time) rises under these conditions with a consequent reduction in runway capacity.

- **Inadequate airport infrastructure.** Short-term improvements are possible (rapid exit taxiways, holding areas…), but have to be planned in the long-term cycle of the infrastructure building. It is also relevant to safety (prevention of runway incursions).

Episode 3 is charged with beginning the validation of the operational concept expressed by SESAR. The initial emphasis is on concept clarification relating to the timeframe 2020, ATM Capability Level 2/3 and the Operational Improvement Step IP2. This activity is complimented by initial performance studies focused on local implementations and initial development of a Performance Framework for the integration of these results. This experiment addresses IP1 Operational Steps of which the supporting operations or procedures are not transient and will continue to exist in the 2020 time horizon.

The validation process as applied in Episode 3 is based on the E-OCVM. In line with E-OCVM this document reports on the validation exercise – Episode 3 WP5.3.3 Runway Operations Fast-time

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Simulation, which is done within Episode 3 WP5.3 Airport and TMA, which is in the context of removing selected blocking points for increasing airport capacity.

1.5 CONCEPT OVERVIEW

This validation exercise addresses specifically the following elements of the SESAR ConOps (SESAR D3 [4]).

- Reducing applicable wake turbulence separation: The existing minimum wake turbulence separation is based on a very broad set of aircraft weight categories and provides the opportunity for a complete re-classification of aircraft into a wider range of weight categories more accurately based on the true wake turbulence related to the aircraft weight, speed, wingspan loading etc., and its transport and decay depending on meteorological conditions,
- Minimising Runway Occupancy Times (ROT): Runway occupancy is one of the constraining factors to runway throughput. It determines the minimum time interval between consecutive movements in situations where wake turbulence separation is not an issue,
- Final Approach Spacing: The application of time based spacing instead of distance spacing between consecutive aircraft on final approach mitigates the negative effect of strong headwind on the runway throughput rate,
- Reduced Departure Spacing: It should be feasible to reduce the time interval between two successive take-off movements where wake turbulence is an issue. Wake turbulence detection technology will make it possible to reduce the intervals without increasing the risk of wake turbulence encounters,
- Reduced Arrival Spacing: It should be feasible to reduce the distance interval between two successive arriving aircrafts where wake turbulence is an issue. Wake turbulence detection technology will make it possible to reduce the intervals without increasing the risk of wake turbulence encounters. Changes to the Wake Turbulence weight categories of aircraft will make it possible to reduce the intervals without increasing the risk of wake turbulence encounters.
- Increase runway utilisation during Low Visibility Conditions (LVC): The runway capacity of an airport reduces significantly with low visibility conditions. Not only is increased separation on final approach needed due to the requirement for an undisturbed ILS signal, ground movement traffic is limited due to the reduced ability of the ground controller to manage surface traffic by visual means, and due to reduced ability of pilots and vehicle drivers to ‘see and avoid’ surrounding traffic or obstacles. The introduction of Advanced Surface Movement Guidance and Control System (A-SMGCS) greatly enhances the possibility to improve the control of surface traffic in reduced visibility conditions.

More specifically the table below shows the list of selected OI steps from SESAR ATM Master Plan [5] that will be addressed by the Exercise using Fast Time Simulation Techniques:

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OI Id OI Title	OI Step Id OI Step Title	OI Step Description	OI Step Rationale	IP IOC/FOC	How addressed?
L10-04 Using Runways Configuration to Full Potential	AUO-0702 Brake to Vacate (BTV) Procedure	Brake to vacate at a pre-selected runway exit coordinated with ground ATC by voice.	Landing aircraft can make optimal use of existing exits (RETS or other) by adapting their braking techniques. During blue sky situations the pilot can adapt its braking as he can see the exit from quite a distance. During low visibility conditions this will become more difficult and longer ROTs will occur. Assisting the pilot in optimal braking techniques will result in lower ROTs and thus increasing capacity.	IP1 2008/2015	The application of BTV technology will be simulated in order to measure the runway occupancy time (ROT) of equipped aircraft. These values will be expressed as (a) ROT of individual aircraft, and (b) global ROT for the simulated period. For each simulated exercise, results will be expressed in terms of differences in ROT of equipped and non-equipped aircraft.
L10-05 Maximising Runway Throughput	AO-0301 Crosswind Reduced Separations for Departures and Arrivals	Under certain crosswind conditions it may not be necessary to apply wake turbulence minima.	The objective is to reduce dependency on wake vortex operations which under suitable weather conditions, will lead to reduced arrival / departure intervals, with a positive effect on delays and runway throughput.	IP1 2009/2013	This OI step will be tested in FTS in order to determine the impact on the runway throughput of implementing a set of reduced separations in crosswind conditions. It will be done through a comparison between a nominal situation, the baseline, against a scenario where it is assumed that the wind conditions are the proper ones to apply the reduced separations where there is dissipation of Wake turbulence due to crosswind conditions. The FTS will assume that these procedures are in place and it will not cover important key aspects related to the feasibility or safety of the procedures.

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OI Id OI Title	OI Step Id OI Step Title	OI Step Description	OI Step Rationale	IP IOC/FOC	How addressed?
L10-05 Maximising Runway Throughput	AO-0302 Time Based Separation for Arrivals	Constant time separations independent of crosswind conditions and wake turbulence existence are introduced. Time based separation is an option to replace the distance criteria currently used to separate trailing aircraft on the approach beyond the wake turbulence of the leading aircraft.	The intent is to mitigate the effect of wind on final approach sequencing so as to achieve accurate and more consistent final approach spacing, and recover most of the capacity lost under strong headwind.	IP1 2012/2015	The use of Time-based spacing on final approach will be simulated in order to indicate the numbers of landing slots which could be recovered during periods of strong headwind; when aircraft groundspeeds are reduced, and fewer aircraft land in a given period using the standard radar separation.
L10-05 Maximising Runway Throughput	AO-0303 Fixed Reduced Separations based on Wake Turbulence Prediction	In the applicable situations, the controller uses reduced aircraft separations derived from forecasted wake turbulence behaviour.	Separation standards are too conservative for a variety of meteorological situations. Use of a statistical model giving wake-vortex behaviour with fixed aircraft separations - e.g. from collection of all relevant combinations of wake vortex behaviours in meteorological situations - could be an intermediate step towards individual wake-vortex forecasting.	IP1 2012/2015	Tested in FTS. The FTS assumes that the system to predict the wake turbulence behaviour is already implemented at the airport, and it will be focused on providing evidence about the expected increment on the runway throughput. Therefore, the FTS will not address issues like the operational feasibility of the related procedures, safety aspects, etc.

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OI Id OI Title	OI Step Id OI Step Title	OI Step Description	OI Step Rationale	IP IOC/FOC	How addressed?
L10-06 Improving Operations under Adverse Conditions incl. Low Visibility	AO-0503 Reduced ILS Sensitive and Critical Areas	Smaller ILS sensitive and critical areas in CAT II/III are created through changes in the ILS antenna and ILS interception procedures due to smaller angle of localizer beam.	ILS tuning will increase runway capacity during already limiting visibility conditions as landing aircraft will free the runway earlier. This seems even more important with the introduction of New Large Aircraft (NLA) and their effect on the ILS when taxing near/parallel to the landing runway.	IP1 2008/2015	Through FTS Techniques, the Exercise will assess the impact on the Runway Throughput of reducing the ILS Sensitive Areas. This OI step will be therefore analysed both in nominal and in Low Visibility conditions since the main objective of this OI step is maintaining the capacity provision of the runway regardless the weather conditions at the airport. The FTS will assume that these procedures are in place and it will not cover important key aspects related to the feasibility or safety of the procedures.

Table 1-1 Operational improvements

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SESAR has defined a set of 11 Key Performance Areas (KPAs), and within each area a set of Focus Areas (FA) focussing on well defined understandable subjects. This Exercise will be focused on the KPA Capacity, and more specifically on the Focus Area “Airport Capacity”.

The table below summarises the KPAs, Focus Areas and main KPIs covered by the Exercise. As it will be described later on, this Exercise will consider as an assumption that the runway is the most constraining factor for the airport capacity. This means that the KPAs and KPIs described in the table will be only partially covered; and here airport capacity is understood as runway capacity. The Exercise will not take into account any limitation related to the taxiway or apron system or the impact of the turn-around process.

The KPI refers to a 15-hour day between 07:00 and 22:00 local time. This corresponds to an airport’s ‘core’ business period. During this 15-hour period, there will be fluctuations in the traffic demand on the airport, hence variations in the numbers of aircraft requiring the runway(s) for landing and taking off. There will be some hourly periods when the runway throughput will fall below the declared runway capacity. The traffic samples used in this Exercise are (i) a 3-hour sample from Roissy Charles de Gaulle airport Paris, and (ii) a 24-hour sample from Malaga airport. The results for each Operational Scenario tested, and expressed in numbers of flight movements per hour, are representative of maximum achievable throughput according to the model parameters and environment data.

SESAR KPA	Description	Focus Area	Description	KPI
KPA - CAPACITY	This KPA addresses the ability of the ATM system to cope with air traffic demand in number and distribution through time and space. The global ATM system should exploit the inherent capacity to meet airspace user demand at peak times and locations while minimizing restrictions on traffic flow. To respond to future growth, capacity must increase, along with corresponding increases in efficiency, flexibility, and predictability while ensuring that there are no adverse impacts to safety giving due consideration to the environment. The ATM system must be resilient to service disruption, and the resulting temporary loss of capacity.	FA-2 Airport Capacity	Focus is on the throughput of individual airports in terms of aircraft movements, taking into account the composite effect of air- and landside constraints. So this Focus Area covers much more than just runway capacity. Focus is also on the throughput of individual congested airports both in VMC and in low visibility (IMC) conditions.	Hourly number of IFR movements including departures and arrivals, as possible during low visibility (IMC) conditions. Daily number of IFR movements including departures and arrivals, as possible during a 15-hour day (between 0700 and 2200 hrs local time) during low visibility (IMC) conditions. Hourly number of IFR movements including departures and arrivals, as possible during (VMC) conditions. Daily number of IFR movements including departures and arrivals, as possible during a 15-hour day (between 0700 and 2200 hrs local time) during (VMC) conditions.

Table 1-2 KPAs / KPIs

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1.6 GLOSSARY OF TERMS

Term	Definition
AENA	Aeropuertos Españoles y Navegación Aérea
AirTOp	Fast-time simulator of the Airtopsoft company
ANSP	Air Navigation Services Provider
A-SMGCS	Advanced Surface Guidance and Control System
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
BTV	Brake-To-Vacate
Cat	Category (of Instrument Landing System)
ConOps	Concept of operations
CSA	Critical and Sensitive Area
E-OCVM	European Operational Concept Validation Methodology
EP3	Episode 3
ERC	EUROCONTROL
FA	Focus area
FOC	Full Operating Capability
FTS	Fast-time Simulation
HMI	Human Machine Interface
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IOC	Initial Operating Capability
IP	Implementation Package
KPA	Key Performance Area
KPI	Key Performance Indicator
LVC	Low Visibility Conditions
OI	Operational Improvement
OS	Operational Scenario
PRR7	Performance Review Report 7
QoS	Quality of Service
ReCat	Revising wake turbulence categories to gain capacity
ROT	Runway Occupancy Time

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Term	Definition
RWY	Runway
SESAR	Single European Sky ATM Research Programme
TAAM	Total Airport and Airspace Model
TBS	Time-based Spacing
TMA	Terminal Control Area
TWR	Control Tower
TWR GND	Tower Ground Controller
VMC	Visual Meteorological Conditions
WT	Wake Turbulence
Xwind	Cross wind

Table 1-3 Glossary of terms

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2 SUMMARY OF EXPERIMENT AND STRATEGY PLANNING

2.1 EXPECTED EXPERIMENT OUTCOMES, OBJECTIVES AND HYPOTHESES

The table below shows the main stakeholders needs and expectations from an increment on the runway throughput and a reduction of the impact of bad weather conditions on airport capacity.

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Stakeholder	Involvement	Why it matters to stakeholder	Performance expectations
Airport Operator	Airport Operators will participate in the Episode 3 WP5.3.2 Expert Group on Airport Issues that will provide inputs including hypothesis and Assumptions to this Exercise.	- Airport capacity is the key challenge in the SESAR timeframe. Runway throughput must be optimised at congested airports to levels that exceed current 'best-in-class' operations. This requires a spectrum of measures including long-term infrastructure development, realistic airport scheduling, real-time demand and capacity balancing, sequencing and metering, time-based spacing, wake vortex detection, runway occupancy improvements. - Maintaining the runway capacity levels during bad weather conditions e.g. low visibility conditions, while enhancing safety levels through tools to support runway incursion prevention is another key issue for the Airport Operator.	- Increased runway throughput. - Increased runway utilisation. - Reduction of the existing capacity gap between visual and instrumental conditions.
Airport ATC Including air traffic controllers in the airport such as TWR RWY, TWR GND and indirectly in the context of this experimental plan, APP controllers,	Airport ATC will participate in the Episode 3 WP5.3.2 Expert Group on Airport Issues that will provide inputs including hypothesis and assumptions to this Exercise.	- The Operational Improvements which are the focus of this Exercise will possibly lead to an increment on runway throughput. Therefore they will imply an increment on the number of aircraft simultaneously taxiing to/from the runway and also an associated increment on the workload. - At the same time, some OIs steps aim at reducing the separation between successive departures, arrivals due to wake turbulence issues and therefore will impact their daily work. - Other set of OIs steps will maintain the airport level of service during low visibility conditions	- Safe application of reduced Wake Vortex separation minima. - Develop controller working procedures and related support tools for low visibility conditions will help ATC to safely maintain the runway capacity levels.
Airlines	N/A	- An increment of runway throughput will be translated into a better accommodation of the airlines demand at airport level. It will increase the business possibilities at congested airports. - These OIs will increase the resilience of the airport capacity under low visibility conditions. Schedules will be more respected as planned in different weather conditions.	- Increased runway throughput. - Increased runway utilisation. - Reduction of the existing capacity gap between visual and instrumental conditions.

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Stakeholder	Involvement	Why it matters to stakeholder	Performance expectations
Pilots	N/A	- Validate the safe application of reduced wake vortex separation minima. - More generally: acceptance by the human actors (Pilots).	- Safe application of reduced Wake Vortex separation minima and brake to vacate procedures.
ANSPs	Represented by AENA	- Validate the safe application of reduced wake vortex separation minima. - More generally: acceptance by the human actors (ATCOs).	- Increased knowledge of the position and planned movements of aircraft. Enabling fine-tuning of the airport ATC and turn around processes e.g. early sequence renegotiation. - Knowledge of the areas where more investment is needed to increase airport capacity.
Research and development centres	Represented by EUROCONTROL as Exercise leader	- Deeper knowledge of techniques for reducing the impact of the wake turbulence and the brake to vacate concept	- Knowledge of the areas where more research is needed to increase airport capacity.

Table 2-1 Stakeholder expectations

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2.1.1 Description of Experiment Objectives

1. The Experiment addresses the following sections of the Episode 3 Runway Management – E1 DOD, [1]

- Section 2.1 SESAR concept for runway management, specifically sections 2.1.1 Increasing runway throughput and 2.1.2 Increasing runway utilisation
- Section 2.3 Related SESAR Operational Improvements (OIs)
- Section 4.2.5 Enablers

2. The first objective of this Exercise is to measure independently the impact of the Operational Improvement Steps described in the previous section and included within the SESAR Concept of Operations [4], on the Runway throughput:

- AUO-0702: Brake to Vacate (BTV) Procedure,
- AO-0301: Crosswind Reduced Separations for Departures and Arrivals,
- AO-0302: Time Based Separation for Arrivals,
- AO-0303: Fixed Reduced Separations based on Wake Turbulence Prediction,
- AO-0503: Reduced ILS Sensitive and Critical Areas.

When relevant, the impact of these OI steps will be assessed both in CAT I or better conditions and CAT II/III conditions.

3. The second objective is to demonstrate that the Operational Improvements addressed by the Exercise will effectively contribute to maintain the airport throughput in adverse weather conditions at levels close to nominal ones.

4. Finally, the Exercise addresses the combined effect on runway capacity of different sets of the previous list of Operational Improvements. The objective is to evaluate the possible crossing effects and overall contribution on runway throughput of the joint implementation of such techniques and procedures.

The following combinations of OIs are foreseen to be analysed:

Set 01: It will include AUO-0702 Brake to vacate and AO-0302 Time-based spacing.

Set 02: It will include AO-0303 Fixed Reduced Separations based on Wake Turbulence Prediction together with the AO-0503 reduced ILS Sensitive and Critical Areas.

Set 03: It will include AO-0301 Crosswind Reduced Separations for Departures and Arrivals together with the AO-0503 reduced ILS protection zone.

2.1.2 Description of Experiment Hypotheses

The list below contains the main hypothesis identified for this exercise:

H1 The implementation of Brake to Vacate procedures at the airport will reduce Runway Occupancy Time,

H2 The implementation of Time Based Spacing Techniques will prevent the loss of landing slots during periods of strong headwind,

H3 The implementation of Crosswind Reduced Separations for Departures and Arrivals will increase Runway Throughput when favourable wind conditions prevail,

H4 The implementation of Fixed Reduced Separations based on Wake Turbulence Prediction will increase Runway Throughput,

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H5 The reduction of ILS Sensitive and Critical Areas will result in a reduction in the loss of runway throughput due to Low visibility conditions,

H6 The implementation of OIs in combination, will result in an additional runway throughput improvement greater than the sum of their individually observed contributions.

2.1.3 Summary of Experiment Hypotheses and associated Metrics

HYPOTHESES	METRICS
HI - The implementation of Brake to vacate procedures at the airport will reduce Runway Occupancy Time	CAP.LOCAL.APT.PI 1 CAP.LOCAL.APT.PI 2
H2 - The implementation of Time Based Spacing Techniques will prevent the loss of landing slots during periods of strong headwind	CAP.LOCAL.APT.PI 1 CAP.LOCAL.APT.PI 2
H3 - The implementation of Crosswind Reduced Separations for Departures and Arrivals will increase Runway Throughput when favourable wind conditions prevail	CAP.LOCAL.APT.PI 1 CAP.LOCAL.APT.PI 2
H4 - The implementation of Fixed Reduced Separations based on Wake Turbulence Prediction will increase Runway Throughput	CAP.LOCAL.APT.PI 1 CAP.LOCAL.APT.PI 2
H5 - The reduction of ILS Sensitive and Critical Areas will result in a reduction in the loss of runway throughput due to Low visibility conditions	CAP.LOCAL.APT.PI 21
H6 - The implementation of OIs in combination, will result in an additional runway throughput improvement greater than the sum of their individually observed contributions	CAP.LOCAL.APT.PI 1 CAP.LOCAL.APT.PI 2 CAP.LOCAL.APT.PI 21

Table 2-2 Hypotheses and Metrics

CAP.LOCAL.APT.PI 1: Airport Capacity (VMC): Maximum achievable movements per hour.

CAP.LOCAL.APT.PI 2: Airport Capacity (IMC): Maximum achievable movements per hour.

CAP.LOCAL.APT.PI 21: Difference between Airport Capacity (VMC) and Airport Capacity (IMC): Difference between Airport Capacity in VMC and IMC conditions.

2.2 CHOICE OF METRICS AND MEASUREMENTS

The Exercise provides an initial measurement of Airport Capacity focused in single runway airports. The indicators that will be selected aim to give measurements on **Capacity Provision** (provide airport capacity for accommodating demand with expected QoS) and **Reduction of Capacity Gap between VMC and IMC conditions**:

Explanatory note

The terms VMC and IMC are inherited from Episode 3 documentation. In the context of this exercise, these terms are not sufficient to describe the different meteorological conditions and associated ATM operations and levels of supporting instrument landing systems which are addressed by the exercise. In order to be more precise and at the same time to respect the intended meaning of the metrics, the terms VMC and IMC shall mean CAT I or better conditions, and CAT II/III conditions respectively. In text which has been inherited from other documentation VMC and IMC will prevail, while text written to describe the Exercise uses the alternative descriptions.

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Runway Capacity Impact through runway throughput improvement and maintained close to normal even in adverse weather conditions.

The following capacity metrics have been selected from the Episode 3 Performance Framework [2]:

Capacity Provision:

CAP.LOCAL.APT.PI 1: Airport Capacity (VMC): Maximum achievable movements per hour.

CAP.LOCAL.APT.PI 2: Airport Capacity (IMC): Maximum achievable movements per hour.

Capacity gap between VMC and IMC conditions:

CAP.LOCAL.APT.PI 21: Difference between Airport Capacity (VMC) and Airport Capacity (IMC): Difference between Airport Capacity in VMC and IMC conditions.

2.3 CHOICE OF METHODS AND TECHNIQUES

The Fast Time Simulation (FTS) exercises require a platform that is capable of accurately modelling aircraft performance, ATC constraints and airport runways and taxiways. The platform must also allow flexibility in modifying aircraft performance characteristics.

Given these criteria, **TAAM** Total Airspace and Airport Modeller, developed by Preston, has been selected for the Episode 3 WP5.3.3 Runway Operation FTS Exercises to be carried out by EUROCONTROL and AENA simulation experts. The Total Airspace and Airport Modeller (TAAM), is a comprehensive, interactive software tool for modelling air traffic, both en route and in the airport area, as well as on the ground. Its main objective is to be used to assist with the design of airspace, airport systems, and facilities and can benefit the operational planning activities of airlines.

TAAM is used to create a model of any airport or air traffic environment, together with any given set of circumstances affecting that environment. This model can then be used to simulate realistic air traffic control simulations.

TAAM will produce quantitative data on runway throughput through a series of runs for each validation scenario. They will be evaluated using standard statistical methods as described in detail in the experimental plan.

Data logging must be sufficient for the scope of the FTS validation exercises, in particular for reconstruction and analysis of the simulation results. The storage of the following output data will be required to measure the addressed metrics:

- Runway throughput

TAAM is a mature and widely used tool and as such, has proven to be very suitable for simulation of the operations tested in the exercise. Some development work was necessary however to adapt the model to accurately replicate the BTV aircraft performance characteristics.

The EUROCONTROL simulation team is also evaluating the AirTOp fast time simulator, and has accordingly run parallel Brake-to-Vacate exercises on the AirTOp model. Results from both models have been compared and indicate similar performances. AirTOp is a product of Airtopsoft SA.

2.4 SIMULATION METHODOLOGY

AENA

The effectiveness of a transportation system is commonly measured in terms of its ability to efficiently process the transported unit. Since the system performance is dependant upon the individual components of that system, it is usually necessary to evaluate these components to determine overall system capabilities. In cases where use of the system requires the

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sequential utilization of a group of processors, the overall efficiency of the system is usually limited by the characteristics of the least efficient component.

Considerable emphasis has been placed upon research to analyse the level and causes of capacity deficiencies. It is now possible to accurately determine the capability of airport and aviation system components to process demand and to pinpoint the causes of deficiencies in these systems. This knowledge allows the technicians to propose solutions to the problems identified.

The problem will then consist on providing sufficient capacity to accommodate fluctuating demand with an acceptable level or quality of service. In the context of this exercise:

- Capacity is understood as the maximum number of aircraft operations that an airfield can accommodate during a specified time when there is a continuous demand of service. This means that there are always aircraft ready to take off and land.

The methodology is therefore based on 24 hours of 2020 traffic estimation cloned so as to saturate the runway and make sure that it runs at full demand in order to obtain maximum throughput.

EUROCONTROL

The EUROCONTROL Experimental Centre simulation specialists have a wide experience of conducting operational fast-time simulation exercises. The preferred methodology is to use a three hour traffic sample. The aircraft and environment data are prepared and tested, and the performance of the model is analysed against expected operational characteristics. Simulation runs of the traffic are conducted and model parameters are adjusted until the experts are satisfied as to the correctness of the output data in terms of reflecting the realism of the operational environment. Exercise results are based on the refined traffic and environment scenario(s).

2.5 SCENARIO SPECIFICATIONS

Taking into account the objectives of this exercise, a series of validation scenarios will be carried out to test the effects of the operational improvements steps described in the previous section on the runway landing/taking off rates. Next table shows a summary of the validation scenarios that will be addressed by this exercise.

Operational Improvement Scenario	OI Step	OI Step Title
OI1	AUO-0702	Brake-to-Vacate (BTV) procedure
OI2	AO-0302	Time-based Spacing (TBS) for arrivals
OI3	AO-0301	Crosswind Reduced Separations for Departures and Arrivals
OI4	AO-0303	Fixed Reduced Separations based on Wake Turbulence Prediction
OI5	AO-0503	Reduced ILS Sensitive and critical areas
SET_1	AUO-0702 + AO-0302	
SET_2	AO-0303 + AO-0503	
SET_3	AO-0301+ AO-0503	

Table 2-3 Scenarios

Since the scope of the Exercise addresses among other things Operational Improvement Steps dealing with reducing the capacity gap between VMC and IMC conditions, scenarios

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OI3, OI4 and OI5 were modelled assuming CAT I conditions or better and CAT II/III conditions weather conditions.

2.6 EXPERIMENTAL VARIABLES AND DESIGN

Traffic Load:

The traffic loads for both runways simulated represented the maximum throughput level demand which could be expected to be accommodated.

Aircraft equipage:

The OI1 Brake-To-Vacate scenarios tested different levels of aircraft BTV equipage. The following table shows the rate of BTV equipage by scenario for the three hour traffic sample.

Scenario	Arrivals	BTV equipped aircraft	BTV equipped as % of total aircraft
SC A	121	0	0
SC B	121	37	31%
SC C	121	51	42%
SC D	121	59	49%

Table 2-4 Rate of BTV equipage by scenario

Aircraft weight category mixture:

The weight category classifications in these tables are as follows;

- ICAO classification L-Light, M-Medium, H-Heavy
- proposed weight categories SS-Small, LM-Lower Medium, MM-Medium, UM-Upper Medium, H-Heavy.

See also section 0.

	L	M	H
Arrivals	10	325	10
Departures	10	325	10
Mixed mode	10	320	10

Table 2-5 Malaga 24 hour traffic sample, Operational Improvement Scenarios OI3 and OI5

	SS	LM	MM	UM	HH
Arrivals	10	60	235	30	10
Departures	10	60	265	0	10
Mixed mode	10	60	245	15	10

Table 2-6 Malaga 24 hour traffic sample, Operational Improvement Scenario OI4

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	L	M	H
Arrivals	0	96	26
Departures	0	35	5

Table 2-7 Paris Charles de Gaulle 3 hour traffic sample, Operational Improvement Scenario OI1

	L	M	H
Arrivals	0	104	17

Table 2-8 Paris Charles de Gaulle 3 hour traffic sample, Operational Improvement Scenario OI2

Wind conditions:

Operational Improvement Scenario OI2 – Time Based Spacing for arrivals, assumed a headwind component of 20knots

Operational Improvement Scenario OI3 - Crosswind Reduced Separations for Departures and Arrivals, assumed a crosswind component of 10knots

The remaining scenarios made no assumptions regarding wind conditions

Weather conditions:

Weather conditions were assumed as corresponding to CATI or better meteorological conditions, or corresponding to CATII/III supported operations according to the requirements of the scenario

Separation standards:

Standard radar separation of 3NM was applied between arriving flights. ICAO Wake Turbulence separation was applied between WT affected arriving or departing aircraft pairs

Runway configuration:

The simulated runways were configured as follows:

OI1 Brake to vacate – mixed mode

OI2 Time-based Spacing – segregated arrival

OI3 Crosswind reduced Separations for departures and arrivals – segregated arrival, segregated departure and mixed mode

OI4 Fixed reduced separations based on wake turbulence prediction - segregated arrival, segregated departure and mixed mode

OI5 Reduced ILS critical and sensitive areas - segregated arrival, segregated departure and mixed mode

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3 CONDUCT OF VALIDATION EXERCISE RUNS

3.1 EXPERIMENT PREPARATION

In the first instance, the EUROCONTROL and AENA Exercise participants agreed the division of the work in January 2008.

The traffic samples and airport environments for Roissy Charles de Gaulle and Malaga airports were subsequently prepared by EUROCONTROL and AENA simulation experts for simulation in the TAAM model.

3.2 EXECUTED EXPERIMENT SCHEDULE

Preparation of the data and execution of the simulated scenarios, including verification of the model's performance took place between January 2008 and October 2008.

3.3 DEVIATIONS FROM THE PLANNING

The final report deliverable has not met the original target. This is due in the first instance to an over-ambitious time-scale, and to subsequent delays in template delivery.

It was stated in the Experimental Plan that a comparison exercise would be carried out between TAAM and the AirTOp model. While some progress was made, further work needs to be done in this regard. It can be stated however, that trends between both models indicate good consistency in treatment of data used in this exercise.

4 EXPERIMENT RESULTS

Generally, this topic is described in step 4 of the E-OCVM. However, the E-OCVM puts more emphasis on the analysis of the results.

4.1 MEASURED EXPERIMENT RESULTS

4.1.1 Brake to Vacate Exercises - Scenario OI1

Scenario hypothesis (HI) - The implementation of Brake to vacate procedures at the airport will reduce Runway Occupancy Time.

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Table 4-1 shows the organisation of exercises related to OI1 as described in the Experimental plan [7]. The Scenarios tested and reported in this document are designated in the table in brackets.

Exercise	Segregated Arrival	Mixed mode	No BTV	BTV	BTV equipped aircraft
OI1 BTV Ref A*	X		X		
OI1 BTV A*	X			X	Airbus A320
OI1 BTV Ref B [Scenario A]		X	X		
OI1 BTV B1 [Scenario B]		X		X	A318/319/320/321 of 2 major carriers
OI1 BTV B2 [Scenario C]		X		X	All A318/319/32/321
OI1 BTV C [Scenario D]		X		X	All Airbus aircraft

Table 4-1 Brake to vacate exercises

* The segregated arrival modules were abandoned as they brought no added value to the scenario objectives. Results in terms of Runway Occupancy Times are the same whether in mixed mode or segregated arrival. A potential advantage of simulating mixed mode was to assess if BTV would allow an increase in departure movements.

The Paris Charles de Gaulle traffic sample was modified to reflect a fully loaded arrival sequence with departures for runway 26L operating in mixed mode configuration. The traffic covered a three hour period. The Brake To Vacate performance characteristics were modelled in TAAM according to data supplied to the EUROCONTROL simulation experts by Airbus.

The traffic sample was simulated throughout four different scenarios, the scenarios differentiated by aircraft model to reflect various levels of BTV equipped aircraft. The traffic sample was constructed to incorporate utilisation of the runway exits in a manner as observed directly at Paris Charles de Gaulle. Standard ICAO wake turbulence separation was applied. The number of landed and departed aircraft during each hour was recorded together with Runway Occupancy Time (ROT) for arrivals and departures. It is the ROT of arrivals which are the focus of the results of the exercise.

The results are organised as follows:

- aircraft arrival movements for each of the three hours simulated and the corresponding ROT together with the surplus in ROT gained with each scenario.

06H00 – 07H00 42 Arrivals	Number of BTV equipped aircraft	ROT	Gained free runway time compared to SC A
SC A	0	00:26:37	-
SC B	16	00:25:09	00:01:28
SC C	21	00:24:40	00:01:57
SC D	25	00:23:21	00:03:16

Table 4-2 Results : ROT of arrivals 06H00 - 07H00

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07H00 – 08H00 43 Arrivals	Number of BTV equipped aircraft	ROT	Gained free runway time compared to SC A
SC A	0	00:26:23	-
SC B	12	00:25:14	00:01:09
SC C	13	00:25:09	00:01:14
SC D	17	00:23:42	00:02:21

Table 4-3 Results : ROT of arrivals 07H00 - 08H00

08H00 – 09H00 36 Arrivals	Number of BTV equipped aircraft	ROT	Gained free runway time compared to SC A
SC A	0	00:22:50	-
SC B	9	00:22:03	00:00:47
SC C	17	00:21:05	00:01:47
SC D	17	00:21:05	00:01:47

Table 4-4 Results : ROT of arrivals 08H00 - 09H00

This study indicated a reduction in ROT for individual equipped aircraft with a consequent global reduction in ROT. There was no increase in the number of aircraft landing during the simulated period as the constraining factor is the minimum radar or wake turbulence separation applied on final approach. However, the reduced ROT allowed the model to process two extra departures in Scenario D during the 08H00-09H00 period.

It should be noted that a greater reduction of ROT was achieved by “Heavy” category A330 and A340 aircraft, and as such, the totality of ROT reductions increases at a greater rate with a greater amount of “Heavy” BTV equipped aircraft as compared to traffic flows incorporating only A320 BTV equipped aircraft. Typical reduced ROT values ranged from two seconds to twenty seconds for individual aircraft.

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4.1.2 Time-based Spacing (TBS) for arrivals Exercises – Scenario OI2

Scenario hypothesis (H2) - The implementation of Time Based Spacing Techniques will prevent the loss of landing slots during periods of strong headwind

Table 4-5 shows the organisation of exercises related to OI2. Exercise Ref B was used to validate the performance of the TAAM time separation algorithms and the results are not re-produced here.

Exercise	Minimum radar and wake turbulence separation	TBS	No Wind	Head Wind
OI2 TBS Ref A	X		X	
OI2 TBS Ref B*		X	X	
OI2 TBS A	X			X
OI2 TBS B		X		X

Table 4-5 Time based spacing exercises

The Paris Charles de Gaulle traffic sample was modified to include only an arrival sequence. The traffic covered a three hour period.

The reference scenario simulated the arrival flow in still wind conditions. Minimum radar and wake turbulence separation was specified. The number of landed aircraft during each hour of the three hour period was recorded. The same traffic was simulated using the TAAM wind module to reflect a headwind component of 20kts. Minimum radar and wake turbulence separation was again specified, and the total number of aircraft landed during each hour of the three hour period was recorded.

Then, in the TBS exercise, instead of specifying minimum radar and wake turbulence separation, TAAM was programmed to apply a time difference between each aircraft over the runway threshold, equal to the time difference between aircraft when flying at standard approach speeds in still wind conditions. The total number of aircraft landed during each hour of the three hour period was again recorded. The longitudinal distances between aircraft were also recorded.

Result:

Arrivals	Minimum radar and wake turbulence separation no headwind	Minimum radar and wake turbulence separation 20 Knot headwind	Time-Based Spacing 20 Knot headwind
0600-0700	42	30	42
0700-0800	43	30	43
0800-0900	40	32	43

Table 4-6 Results Time-based spacing

When a headwind component was applied to the reference scenario and with the same separations, there was an expected reduction in the number of landing aircraft during each hour due to wind induced slower ground speeds of aircraft.

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With the introduction of time-based spacing rather than distance based radar and wake turbulence separation, the lost landing slots in each hour were recovered, bringing the landing rate back to reference scenario levels.

However a consequence of using time-based spacing in other than still wind conditions leads to a reduction in the longitudinal separation between aircraft to below the minimum radar and wake turbulence separation. The greater the headwind component, the greater the reduction in longitudinal separation.

4.1.3 Crosswind Reduced Separations for Departures and Arrivals - Scenario OI3

Scenario hypothesis (H3) - The implementation of Crosswind Reduced Separations for Departures and Arrivals will increase Runway Throughput when favourable wind conditions prevail

The Malaga traffic sample was simulated in segregated arrival, departure and mixed mode configurations, assuming CATI conditions and applying wake turbulence separations as required between aircraft pairs. The number of landed and departed aircraft was recorded for the period.

The sample was then simulated with no wake turbulence separations, on the assumption that a crosswind took the vortices away from the path of succeeding aircraft. The number of landed and departed aircraft was again recorded for the period.

The scenarios were then simulated again with no wake turbulence separations but assuming CATII/III conditions, applying the more stringent separations required.

Results:

CATI

In arrival or departure configuration, removing wake turbulence separations showed significant increases in runway throughput.

In mixed mode configuration however, there was no overall increase in throughput, as the requirement to integrate arriving and departing flights, generally negates the need to apply wake turbulence separations.

CATII/III

In arrival configuration, removal of the requirement to apply wake turbulence separations does not increase throughput, as the constraining factor is the required increased longitudinal separation between landing aircraft under CATII/III conditions.

In departure configuration, a small increase was noted.

In mixed mode configuration, a small increase in throughput was noted due to the small increase in the number of departures.

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		Reference VMC-CATI	Crosswind VMC-CATI	Reference CATII/III	Crosswind CATII/III
Arrival		43	49	22	22
Departure		42	48	29	31
Mixed	Arrival	24	24	14	15
	Departure	24	24	14	15
	Global	48	48	28	30

Table 4-7 Results : Nb of Runway throughputs and Crosswind Reduced Separations

4.1.4 Fixed Reduced Separations based on Wake Turbulence Prediction - Scenario OI4

Scenario hypothesis (H4) - The implementation of Fixed Reduced Separations based on Wake Turbulence Prediction will increase Runway Throughput

The revised aircraft weight categories and corresponding wake turbulence separation standards for arriving aircraft obtained from the preliminary results of ReCat, a collaboration between the Federal Aviation Administration of the United States and EUROCONTROL, and Reset, a European Commission 6th framework project, were applied to the traffic sample.

Table 4-8 below describes the five aircraft weight categories, while Table 4-9 describes the corresponding wake turbulence separations to be applied.

Category	W: Aircraft weight in tons
SS	7 >W
LM	40 > W > 7
MM	116 > W > 40
UM	136 > W > 116
HH	W > 136

Table 4-8 Aircraft Categories by weight

	Follower					
Leader		HH	UM	MM	LM	SS
	HH	2	2	3	4	5
	UM	2	2	3	4	4

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	Follower					
	MM	2	2	2	3	4
	LM	2	2	2	2	3
	SS	2	2	2	2	2

Table 4-9 Wake Turbulence Separations

The traffic sample was simulated in segregated arrival, departure and mixed mode configurations, assuming CATI conditions and applying current wake turbulence separations as required between aircraft pairs.

The traffic was then simulated with current wake turbulence separations applied to departing aircraft while the revised wake turbulence separations were applied between arriving aircraft. The number of landed and departed aircraft was recorded for the period.

The scenarios were then simulated again assuming CATII/III conditions, applying the more stringent separations required.

Results:

CATI

The modified weight categories and separations brought increased throughput for the segregated arrival configuration. The improvement indicated a throughput level between the reference scenario figures, where standard wake turbulence separations are applied, and the crosswind reduced scenario figures, where wake turbulence separations are abandoned.

In mixed mode configuration however, there was no overall increase in throughput, as the requirement to integrate arriving and departing flights, generally negates the need to apply wake turbulence separations as in Scenario OI3 above.

CATII/III

In arrival configuration, modification of wake turbulence separations does not increase throughput, as the constraining factor is the required increased longitudinal separation between landing aircraft, as in Scenario OI3 above.

In mixed mode configuration, a small increase in throughput was noted due to the small increase in the number of arrivals.

		Reference VMC-CATI	Fixed reduced VMC-CATI	Reference CATII/III	Fixed reduced CATII/III
Arrival		43	48	22	22
Departure		42	41	29	29
Mixed	Arrival	24	24	14	15
	Departure	24	24	14	14
	Global	48	48	28	29

Table 4-10 Nb of Runway throughputs and Fixed Reduced Separations

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4.1.5 ILS Protection Zone exercises - Scenario OI5

Scenario hypothesis (H5) - The reduction of ILS Sensitive and Critical Areas will result in a reduction in the loss of runway throughput due to Low visibility conditions

Table 4-11 shows the organisation of exercises related to OI5.

Exercise	VMC - CATI	CATII/III
Reference	X	X
OI5 ILS zone A	X	
OI5 ILS zone B		X

Table 4-11 ILS protection zone exercises

The separations required under CATII/III conditions were revised to be less stringent, but still greater than those applied in CATI conditions. Wake turbulence separations remained unchanged from current ICAO requirements and were applied between relevant aircraft pairs. Scenarios assuming CATI, CATII/III and CATII/III with reduced ILS CSA were simulated in arrival, departure and mixed mode operations. The tables below describe the separations applied under arrival, departure and mixed mode configurations, for CATII/III and CATII/III with a reduced ILS CSA:

	DEP-DEP		ARR-DEP-ARR		ARR-ARR	
	Reference ILS CSA	Reduced ILS CSA	Reference ILS CSA	Reduced ILS CSA	Reference ILS CSA	Reduced ILS CSA
Light* ILS	-	-	6 NM	6 NM	3 NM	3 NM
Medium* ILS	2 min	-	12 NM	6 NM	8 NM	3 NM
Heavy* ILS	6 min	2 min	22 NM	12 NM	9 MN	8 NM

Table 4-12 Separations applied under arrival, departure and mixed mode configurations, for CATII/III and CATII/III with a reduced ILS CSA

* The definitions of Light ILS, Medium ILS and Heavy ILS are extrapolated from ICAO ANNEX 10 - Aeronautical Telecommunications - .and are based on the size – height of the tail, width of the wings etc., and not on the weight of the aircraft. The definitions are used to classify aircraft groups according to their propensity to interfere with ILS signals. The classification is as follows:

- Heavy: aircraft larger than B757
- Medium: aircraft smaller than B757
- Light: aircraft similar or smaller than MD80

The results indicated a throughput rate of the same order as that achieved under CATI conditions, for all scenarios tested.

These results, as for all scenarios in the Exercise are influenced by the traffic mix i.e. the proportion of L, M and H category aircraft in the traffic sample.

The benefits of the reduced ILS CSA as simulated here, would be greater given a traffic mix with more M category aircraft than H category aircraft. In fact, if a runway had no H aircraft, the throughput in CATII/III conditions with reduced ILS CSA separations as applied in this exercise, could be expected to be of the same order as for CATI conditions.

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IMPORTANT NOTE: At present, ICAO is proposing an increase to the ILS Critical and Sensitive areas' dimensions and consultation is taking place with Member States.

		Reference VMC-CATI	Reference CATII/III	Reduced ILS CSA
Arrival		43	22	43
Departure		42	29	41
Mixed	Arrival	24	14	24
	Departure	24	14	22
	Global	48	28	46

Table 4-13 Nb of Runway throughputs and reduction of ILS Sensitive and Critical Areas

4.1.6 Combined Brake to Vacate (OI1) and Time Based Spacing (OI2) – Scenario SET1

Scenario hypothesis (H6) - The implementation of OIs in combination, will result in an additional runway throughput improvement greater than the sum of their individually observed contributions

Table 4-14 shows the Exercise related to scenario Set_1, a combination of OI1 and OI2.

Exercise	BTV	TBS	Headwind
Set_1	X	X	X

Table 4-14 Combined BTV and TBS exercise

The traffic sample tested under Operational Improvement Scenario OI2 (see 4.1.2 above) was modified to include all Airbus aircraft as Brake-to-vacate equipped (see 4.1.1 above). The modified sample was simulated with no wind component applied and the number of landed aircraft in each hour was recorded. A headwind component of 20KTS was then applied using the TAAM wind module. The sample was once more simulated and the number of landed aircraft in each hour was recorded.

Results:

The combined use of Brake-to-vacate and Time-based Spacing does not bring any added benefits, other than the specific benefits both BTV and TBS bring in isolation. While BTV as modelled in this Exercise reduces the ROT, it does not increase the number of aircraft landing in a given period as explained in section 4.1.1. When TBS is applied with the effect of headwind, the throughput is increased, while the benefit from BTV is reduced ROT for that number of aircraft.

The benefits are not greater than the sum of OI1 and OI2 benefits.

The table below shows the number of flights for each of the simulated hours together with the corresponding Runway Occupancy Time.

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Time	No BTV	BTV	TBS no BTV	SET 1
06H00-07H00	39	39	43	43
07H00-08H00	38	38	45	45
08H00-09H00	44	44	33*	33*
ROT	01:15:34	01:08:44	01:15:44	01:08:44
Total Aircraft	121	121	121	121

Table 4-15 Nb of Runway throughputs and combined BTV and TBS

* The reduced number of aircraft is due to the increase in number of aircraft processed under 'TBS no BTV' and 'SET 1' conditions in the previous two hours. The traffic sample contained 121 flights, but had it been extended into another hour, supplementary flights from the next hour would have been brought forward to the 08H00-09H00 period.

4.1.7 Combined Fixed Reduced Separations for Arrivals (OI4) and Reduced ILS Protection Zone (OI5) – Scenario Set 2

Scenario hypothesis (H6) - The implementation of OIs in combination, will result in an additional runway throughput improvement greater than the sum of their individually observed contributions

The modified weight categories and separations tested in Operational Improvement Scenario OI4 were applied together with the CATII/III reduced ILS CSA separation standards as in Operational Improvement Scenario OI5.

As OI4 has no impact on departures there was no change for departure configuration.

In arrival configuration, the throughput is of the same order as when the fixed reduced separations are applied to the traffic sample in isolation. This throughput is also greater than that brought by the application of reduced ILS CSA in isolation. However, the reduced ILS CSA separations, even though reduced from the standard CATII/III separations, remain more restrictive than the WT reduced separations, and are therefore the retraining factor to further gains in throughput.

The benefits are not greater than the sum of OI4 and OI5 benefits.

		OI4 VMC-CAT I	OI4 CAT II/III	OI5	SET 2
Arrival		48	22	43	47
Departure		41	29	41	41
Mixed	Arrival	24	15	24	24
	Departure	24	14	22	23
	Global	48	29	46	47

Table 4-16 Nb of Runway throughputs and combined fixed reduced separations for arrivals and reduced ILS protection zone

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4.1.8 Combined Crosswind Reduced Separations for Departures and Arrivals (OI3) and Reduced ILS Protection Zone (OI5) – Scenario Set 3

Scenario hypothesis (H6) - The implementation of OIs in combination, will result in an additional runway throughput improvement greater than the sum of their individually observed contributions

The traffic was simulated with no wake turbulence separations between arriving aircraft and between departing aircraft as in Operational Improvement Scenario OI3, together with the CATII/III reduced ILS CSA separation standards as in Operational Improvement Scenario OI5.

In arrival configuration, the throughput is slightly reduced but is of the same order as when the crosswind reduced separations are applied to the traffic sample in isolation. This throughput is also greater than that brought by the application of reduced ILS CSA in isolation. However, the reduced ILS CSA separations, even though reduced from the standard CATII/III separations, remain more restrictive than the WT reduced separations, , and are therefore the retraining factor to further gains in throughput.

There was an increase of one departure in mixed mode configuration above the throughput with OI5 alone. This increase is not significant, and the constraining factor remains the required increased longitudinal separation between landing aircraft under CAT II/III conditions, whether reduced ILS CSA or not.

The benefits are not greater than the sum of OI3 and OI5 benefits.

		OI3 VMC-CAT I	**OI3 CAT II/III**	**OI5**	**SET 3**
Arrival		49	22	43	47
Departure		48	31	41	47
Mixed	Arrival	24	15	24	24
	Departure	24	15	22	23
	Global	48	30	46	47

Table 4-17 Nb of Runway throughputs and combined crosswind separations for departure and arrivals and reduced ILS Protection zone

4.2 CONFIDENCE IN EXPERIMENT RESULTS

4.2.1 Quality of Results of Experiment

The TAAM model provides a high level of accuracy in terms of aircraft performance and the modelling of Air Traffic Control rules. The results of the type described in this report can be accepted with confidence as accurately representing aircraft performance characteristics together with the precision of the operations tested.

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4.2.2 Significance of Results of Experiment

The results of this experiment demonstrate the gains in runway throughput, together with prevention of loss of throughput under certain conditions, which could be expected from the Operational Improvement Step elements tested.

The results can serve as guidance for future experimentation, not only in terms of runway management, but also as input to future TMA development.

4.3 Unexpected Experiment Results

There were no unexpected results in the context of E-OCVM step 3.2.

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5 ANALYSIS OF EXPERIMENT OUTCOMES

5.1 ANALYSIS OF OUTCOMES ON THE BASIS OF DETERMINED HYPOTHESES

H1 The implementation of Brake to vacate procedures at the airport will reduce Runway Occupancy Time,

> The hypothesis is proven. Reduced runway occupancy times in the order of two minutes in a 60 minute period have been recorded by the model.

H2 The implementation of Time Based Spacing Techniques will prevent the loss of landing slots during periods of strong headwind,

> The hypothesis is proven. The application of TBS negates the effect of headwind reducing the ground speed of aircraft,

H3 The implementation of Crosswind Reduced Separations for Departures and Arrivals will increase Runway Throughput when favourable wind conditions prevail,

> The hypothesis is proven for an arrival or departure runway configuration in CAT I or better conditions. In mixed mode runway configuration under CAT I or better conditions, there is no benefit unless the traffic sequence is managed in such a way that pairs of arriving or departing aircraft are integrated into the traffic sequence. Under CAT III/III conditions, the requirement to provide increased separation between aircraft is the constraining factor,

H4 The implementation of Fixed Reduced Separations based on Wake Turbulence Prediction will increase Runway Throughput,

> The hypothesis is proven for an arrival runway configuration under CAT I or better conditions. Under CAT III/III conditions, the requirement to provide increased separation between aircraft is the constraining factor,

H5 The reduction of ILS Sensitive and Critical Areas will result in a reduction in the loss of runway throughput due to Low visibility conditions,

> The hypothesis is proven.

H6 The implementation of OIs in combination, will result in an additional runway throughput improvement greater than the sum of their individually observed contributions.

> The hypothesis is not proven for any of the combinations tested.

5.2 ANALYSIS OF CONSEQUENCES OF OUTCOMES FOR EXPERIMENT OBJECTIVES

Capacity Provision:

CAP.LOCAL.APT.PI 1: Airport Capacity (VMC): Maximum achievable movements per hour.

CAP.LOCAL.APT.PI 2: Airport Capacity (IMC): Maximum achievable movements per hour.

Capacity gap between VMC and IMC conditions:

CAP.LOCAL.APT.PI 21: Difference between Airport Capacity (VMC) and Airport Capacity (IMC): Difference between Airport Capacity in VMC and IMC conditions.

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Operational Improvement step	Hypotheses	Hypotheses status	Associated metrics	Applicability of hypotheses to specific metric	Improvement brought by OI step
AUO-0702 Brake To vacate	HI	Proven	CAP.LOCAL.APT.PI 1	Valid	The reduction in ROT is significant as a factor of total ROT
			CAP.LOCAL.APT.PI 2	Valid	
AO-0302 Time Based Spacing	H2	Proven	CAP.LOCAL.APT.PI 1	Valid	The recovery of lost landing slots using TBS is significant as a factor of the number of lost slots
			CAP.LOCAL.APT.PI 2	Valid	
AO-0301 Crosswind reduced WT separations	H3	Proven in part	CAP.LOCAL.APT.PI 1	Valid	Reduced WT separations provide a significant increase in throughput in segregated ARR or DEP runway configuration. Reduced WT separations do not facilitate increased throughput in mixed mode runway configuration
			CAP.LOCAL.APT.PI 2	Benefits constrained by the more stringent separation requirements	Reduced WT separations do not facilitate increased throughput under CATII/III conditions
AO-0303 Fixed reduced WT separations	H4	Proven in part	CAP.LOCAL.APT.PI 1	Valid	Fixed reduced WT separations provide a significant increase in throughput in segregated runway configuration
			CAP.LOCAL.APT.PI 2	Benefits constrained by the more stringent separation requirements	Fixed reduced WT separations do not facilitate increased throughput under CATII/III conditions
AO-0503 Reduced ILS sensitive and critical area	H5	Proven	CAP.LOCAL.APT.PI 21	Valid	Reduced CATII/III ILS sensitive and critical area significantly increases throughput as a factor of CATI or better conditions' throughput
	H6	Not proven	CAP.LOCAL.APT.PI 1	The combination of	None

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Operational Improvement step	Hypotheses	Hypotheses status	Associated metrics	Applicability of hypotheses to specific metric	Improvement brought by OI step
AO-0303/AO-0503 AO-0301/AO-0503			CAP.LOCAL.APT.PI 2	OI steps does not bring benefits greater than the sum of the individual OI steps under any of the specific metrics	None
			CAP.LOCAL.APT.PI 21		None

Table 5-1 Hypotheses and metrics

5.3 Implementation issues – TBS (OI2) and Reduced Crosswind Separations for Arrivals and Departures (OI3)

While this Exercise does not address implementation of the Operational Improvement steps tested, the following implementation considerations should be noted:

TBS

- a HMI interface providing a representation of the longitudinal distance to be applied to aircraft, which is derived from the time spacing computed as a factor of the relative ground speeds of aircraft. This is necessary as radar controllers work with distance rather than time
- controller training in the use of the HMI
- a safety assessment of collision and wake turbulence encounter risk as a result of the reduced longitudinal separation between aircraft
- regulatory approval for the application of a procedure which may reduce distance separation below the current minimum radar and WT separations.

Crosswind Reduced Separations for Departures and Arrivals

- a HMI providing a go/no go display to controllers for the application of WT reduced separations between aircraft pairs
- controller training in the use of the HMI
- a safety assessment of wake turbulence encounter risk as a result of the reduced WT separation between aircraft
- regulatory approval for the application of a procedure which may reduce distance separation below the current minimum WT separations

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6 CONCLUSIONS AND RECOMMENDATIONS FOR PROJECT LEVEL

6.1 CONCLUSIONS

ID	Description of Conclusions
OI1	Brake-to-vacate technology can reduce Runway Occupancy Time. Further research is required to explore how reductions in ROT may be transformed into increased runway throughput. That research would be a continuation of this work, and would use the expertise and understanding of BTV gained thus far.
OI2	Time-based spacing can prevent loss of landing slots when the ground speed of aircraft is reduced by headwind, and standard distance separation is applied. TBS has the effect of reducing the distance between aircraft on final approach to below the minimum radar separation. Appropriate supporting tools, controller training, safety assessment, and regulatory approval would be required prior to application of the procedure.
OI3 **OI4**	Reducing or abandoning wake turbulence separations can increase runway throughput. Appropriate support systems, safety assessment, and regulatory approval would be required prior to application of the procedure. The constraining factor to fully benefiting from reduced WT separations in all weather conditions is the increased separations required during CAT II/III conditions (see OI5 below).
OI5	Reduced ILS CSA dimensions and associated separation requirements in the air and on the ground would allow a runway throughput greater than that achieved under CAT II/III conditions. While the throughput achieved in CAT I or better conditions may not be achieved, a significant improvement could be expected. CAT II/III ILS CSA requirements also have a negating effect on Operational Improvements OI3 and OI4.
SETs 1, 2, 3	The combination of OI steps did not bring any benefit greater the sum of each OI step in each SET simulated.

Table 6-1 Conclusions and OI steps

6.2 IMPACT ON EPISODE 3

The Operational Improvement Steps tested in the Exercise have been validated against the chosen hypotheses and Performance Framework metrics. The results of the Exercise do not indicate a requirement to reconsider the validity of those OI steps as enablers to increased runway throughput, as described in **Episode 3** Runway Management – E1 DOD [1].

The Exercise did not address SESAR Operational Scenarios directly, although the Exercise results may influence discussion of OSs by the Episode 3 WP5.3.2 Airport Expert Group.

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6.3 RECOMMENDATIONS

ID	Description of Recommendations:
OI1	Disseminate results to Episode 3 Airport Expert Group and to SESAR JU WP6.8
OI2	Disseminate results to Episode 3 Airport Expert Group and to SESAR JU WP6.8
OI3	Disseminate results to Episode 3 Airport Expert Group and to SESAR JU WP6.8
OI4	Disseminate results to Episode 3 Airport Expert Group and to SESAR JU WP6.8
OI5	Disseminate results to Episode 3 Airport Expert Group and to SESAR JU WP6.8

Table 6-2 Recommendations and OI steps

7 REFERENCES AND APPLICABLE DOCUMENTS

7.1 REFERENCE DOCUMENTS

[1] Episode 3 Runway Management – E1 DOD - D2.2-03

[2] Episode 3 Performance Framework - D2.4.1-04

[3] EUROCONTROL Performance Review Report PRR7 - April 2004

[4] SESAR D3 The ATM Target Concept - DLM-0612-001-02-00a

[5] SESAR ATM Master Plan **-** DLM-0710-001-02-00

7.2 APPLICABLE DOCUMENTS

[6] SESAR Concept of Operations, DLT-0612-222-01-00, 17-07-2007

[7] Episode 3 Runway Operations Fast Time Simulation Plan D5.3.3-01

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END OF DOCUMENT

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