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Possible effects of news technologies and operational concepts on airport runway separation parameters

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PRESENTATION OF THE TASK

Possible effects of new technologies and operational concepts on airport runway separation parameters

A whole series of new technologies and operational concepts is under development to increase airspace and airport capacity to meet the growing demand forecast of the next decades. Airport capacity is directly linked to the spacing between arrivals and departures on the runway system. The two major ATM improvement programs SESAR and NextGen nominate several significant chances of possible improvements to increase and maximize runway throughput.

Depending on the kind of operation, runway spacing requirements are given in longitudinal separations (e.g. 3 NM), conditional separations (e.g. preceding a/c has left the runway) or time separations (e.g. 60 sec). As runway throughput and capacity are measured in landings or takeoffs per hour longitudinal and conditional separations have to be translated in time separations in order to estimate their expected benefits.

The term “possible runway capacity enhancement” is covering a large scale of measures in various states of maturity ranging from a simple headline to an enhancement already in operation at another airport. As a result the scope of the available parameters for the assessment of a proposal is very broad and heterogeneous.

Therefore, in order to prepare the assessment of runway capacity enhancements using analytical models and fast-time simulations the tasks of this thesis are

- to outline the current situation in runway time separations (e.g. influencing parameters and rules, mean values and statistical distributions, relation to conditional and longitudinal separation rules),
- to identify possible candidates for future improvements,
- to develop a framework for assessing these candidates prior to a detailed capacity study with analytical models or simulations. Topics to consider in developing a framework are
    - the area of application (e.g. arrival/arrival, same runway vs. different runways)
    - potential for reduction of runway time separations (mean and variance),
    - maturity
    - applicability (e.g. percent of time, special weather conditions etc.)
    - introduction date
    - cost (e.g. additional on-board or ground equipment)
- Apply the framework on selected candidates/proposals.

The results of the work will be used as input for runway capacity studies and the associated analytical and fast-time simulation modelling tasks.

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PREFACE

"Every movement matters, every second counts" [1]

As the European air traffic increases constantly, forecasts anticipate that aircraft in the sky may double or triple in the next decades. In order to prepare the air traffic system to this projected augmentation, a capacity revolution must take place to prevent unnecessary limitations for the air traffic in the European sky.

Modern air traffic control has contributed to making air travel far safer than highway travel, and on a passenger-mile basis even safer than rail travel. This advantage must be maintained without restraining air traffic innovation.

This document was written for all those having a major interest in airport management. DLR Institute of Flight Guidance has much experience in this field of research. The studies of the Air Transportation department are mainly focused on modelling and analysing the air transportation at airports. In this report, the Terminal Maneuvring Area commonly known TMA lays down the geographical limits of the study in order to concentrate on optimisation of the airport structures and effectiveness of the take-off and landing phases.

Trade or manufacturers names appear herein solely because they are considered essential to the objectives of the work.
The theme of safety is not included within the scope of this report. This thesis assumes that the capacity enhancements maintain or increase the actual level of safety.

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ZUSAMMENFASSUNG

Die weltweite Nutzung des Flugzeuges als Transportmittel nimmt trotz Schwankungen in der Nachfrage deutlich zu, sodass die Ansprüche an die Flugverkehrskontrolle größer werden. Bei Betrachtung europäischer Großflughäfen zeigt sich, dass in kurz- bis mittelfristig Kapazitätsprobleme im Flughafennahbereich auftreten. Da kapazitätserhöhende Maßnahmen an Flughäfen, wie z.B. der Neubau von Start- und Landebahnen, langfristigen Planungen unterliegen, können damit die operativen Problemstellungen von Fluggesellschaften nicht kurzfristig behoben werden.. Daher arbeiten die Flughafenbetreiber an zeitnahen Lösungen für dieses Kapazitätsproblem (Zeithorizont 20 Jahre).
Erste Forschungen im Rahmen der SESAR- und NextGen-Programme zeigen, dass mit einem Maßnahmenkatalog für den Luftverkehr die Kapazitäten im Flughafennahbereich erhöht werden können. Dabei sind Sicherheitskriterien sowie der Abstand zwischen Flugzeugen bei Start und Landung besonders zu berücksichtigen.

In dieser Arbeit werden die bisherigen Forschungsergebnisse zur Verbesserung der Kapazitäten im Luftraum aus Sicht von Flughafenbetreibern hinsichtlich ihrer Wirksamkeit untersucht und bewertet. Als erstes wird die aktuelle Bahnkapazität des Systems mit ihren kapazitätsbeeinflussenden Parametern beschrieben. Der Hauptteil dieser Arbeit beschäftigt sich mit der Erstellung einer Methode, die es den Flughafenbetreibern gestattet, Lösungsvorschläge für ihr Kapazitätsproblem zu finden. In der vorliegenden Arbeit wird die Funktionalität der Methode am Beispiel des Flughafen Hamburg getestet.

KAPAZITÄTSBEEINFLUSSENDE PARAMETER

Zunächst werden die kapazitätsbeeinflussenden Faktoren identifiziert. Wie oft eine Piste von einem Flugzeug benutzt werden kann, hängt u.a. von Geschwindigkeit und Masse des Flugzeuges sowie dem Betriebsverfahren (single oder mixed mode) ab. Dazu werden sechs Parameter ausgewählt, wobei je nach Flughafen die Parameter unterschiedlich starke Einflüsse ausüben können.

Zum einen stellen Wirbelschleppen eine starke Störung dar, die Flugzeuge dazu zwingen einen definierten Sicherheitsabstand einzuhalten. Die vorgeschriebenen Mindestabstände können nach Gesetzgebung der Länder und örtlichen Bestimmungen an Flughäfen variieren.

Zum anderen zeigen sich Probleme in der Radartechnologie. In Abhängigkeit von Auflösung und Update-Rate des verwendeten Radargerätes, sind in der Abbildung der Flugzeuge Abweichungen zur realen Position festzustellen. Dadurch muss ebenfalls ein Mindestabstand eingehalten werden.

Des Weiteren ist bei der Pistenbenutzung zu beachten, dass sich nur ein Flugzeug auf der Start- und Landebahn befinden darf.

Zusätzlich spielen meteorologische Faktoren eine starke Rolle, da Wettereinflüsse (wie reduzierte Sicht) zu Störungen führen können. In diesem Fall muss ein Sicherheitsabstand zum vorausfliegenden Flugzeug kontrolliert werden, während bei guter Sicht die Verantwortung für die Herstellung eines Abstandes auf den Piloten übertragen werden kann.

Die Anzahl und Lage der Pisten besitzen ebenfalls einen Einfluss auf die Kapazität eines Flughafens. Die Anzahl kann dabei variieren und sie können einzeln, parallel, gekreuzt oder v-förmig vorliegen und als Start-, Landebahn oder für beides genutzt werden. Dabei existieren unterschiedliche Abhängigkeiten zwischen den Operationen, die unterschieden werden können nach Start-Start, Start-Anflug, Anflug-Start, Anflug-Anflug.

ENTWICKLUNG DER METHODE

In einem ersten Entwicklungsschritt wird der Engpass des Systems identifiziert. Danach werden verschiedene Verbesserungsmaßnahmen diskutiert und anschließend hinsichtlich ihrer Kapazitätswirksamkeit genauer untersucht. In dieser Arbeit wird eine Methode vorgestellt, mit der Vorschläge zur Verbesserung der Kapazität eines Flughafens klassifiziert aufbereitet werden können.

In einem ersten Schritt werden mittels Fragebogen Bedürfnisse der Flughäfen erfasst. In einer Datenbank werden Kandidaten (hier Systeme oder Prozeduren) aus Forschung oder Praxis hinterlegt. Anhand der erfassten Bedürfnisse werden mit einer Matrix solche Kandidaten ausgewählt, von denen eine Kapazitätswirksamkeit zu erwarten ist. Dabei kann auch eine Gewichtung vorgenommen werden.

Zum Beispiel kann ein Bedürfnis sein, eine höhere Kapazität trotz schlechter Sichtbedingungen zu erreichen. In diesem Fall ist das Kriterium die „Sicht“.

Die Datenbank besteht im Wesentlichen aus Kandidaten, welche die unter Kapitel 1.1. genannten Parameter beeinflussen, wie auch aus Spezifikationen, welche die Kandidaten charakterisieren. Diese Kandidaten werden ebenfalls durch die gleichen, Bedürfnisse beschreibenden, Kriterien dargestellt. Durch das Kriterium Sicht wäre beispielsweise beschrieben, unter welchen Sichtbedingungen (z.B. IMC) der ausgewählte Kandidat kapazitätswirksam ist.

Die gefundenen Kriterien können in einer Matrix subjektiv gewichtet werden, je nachdem, ob ein Kriterium dem Flughafenbetreiber besonders wichtig erscheint. Danach können sie durch eine der vier möglichen Antwortmöglichkeiten „Ja“ (Yes), „Nein“ (No), „nicht gefragt im Fragebogen“ (NI) und „nicht angegeben in der Kandidaten-Datenbank“ (NC) bewertet werden. Falls ein Kandidat nicht den Kriterien des Bedürfnisses entspricht, wird er automatisch eliminiert und nicht weiter berücksichtigt.

Aufgrund der Verschiedenartigkeit der Flughäfen kann die in dieser Arbeit entwickelte Methode unter anderem auch dazu verwendet werden, verschiedene Fragebögen auszufüllen, umso z.B. mehrere Start- und Landebahnkonfigurationen zu berücksichtigen.

Nach der Bewertung der Kriterien werden die verbliebenen Kandidaten in einer Liste als Vorschläge aufgeführt. Diese Vorschläge werden dann einer vertieften Analyse unterzogen und dabei auf ihre Realisierbarkeit geprüft.

BEISPIEL FLUGHAFEN HAMBURG FUHLSBÜTTEL

Das Vorgehen soll am Beispiel des Flughafens Hamburg Fuhlsbüttel genauer erläutert werden. Der Flughafen Hamburg Fuhlsbüttel investiert z.B bis zu Zehn Millionen Euro in die Verbesserung der Kapazität des Luftraumes um den Flughafen.
Der Flughafen Hamburg besteht aus zwei Bahnen, die jeweils in beide Richtungen als Start- und Landebahn verwendet werden können. Aus diesem Grund wurden vier Fragebögen mit den ermittelten Bedürfnissen erstellt. Des Weiteren wurden 12 Kandidaten identifiziert und in eine Datenbank eingefügt. Anschließend werden die Kriterien innerhalb der Matrix miteinander verglichen. In drei von vier Fragebögen erreicht das Brems- und Ausrollsystem „Brake to Vacate“ Platz 1 und stellt somit die beste Lösung dar, während „Ground Markers“ einmal als Kandidat mit dem größten Einfluss festgestellt wurde.

Die in dieser Arbeit beschriebene Methode gibt dem Anwender die Möglichkeit sein System hinsichtlich bestimmter „Bedürfnisse“ zu optimieren.

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Erklärung bezüglich selbstständiger Bearbeitung

Ich erkläre ich, dass ich die nachfolgende Arbeit selbständig und nur unter Zuhilfenahme der angegebenen Literatur angefertigt habe.

Braunschweig, den 30 September 2010

CONTENT

INTRODUCTION

Airport capacity is one of the major constraints to growth in air transportation, particularly at major European airports. With the continuing growth of air traffic, airport congestion is a serious issue to be dealt with. Major places in the world are reaching their capacity limits and are becoming a bottleneck in the air transportation system. Whilst there is much new investment for long term projects such as new runways and new airports, this will not resolve the short-term constraints.
Throughout the world, many efforts are being undertaken to achieve a better use of the airport and especially the throughput on the runway systems. An enhancement of the current throughput will help the airports to solve the short-term constraints and to be able to reach the long term projects.
Following the scheme centralized on the runway congestion, the runway use should be examined because the capacity of the runway limits the scope of the airport.

The variable throughput is often referred as the reference value for the airport capacity studies. Throughput is the measure of the number of landings or take-offs per hour on one runway.
Moreover the time separation between the landing and take-off operations plays an important role for the determination of the throughput and consequently the airport capacity. If it is possible to reduce the time separations between two consecutive movements, capacity and throughput can be considerably improved and solve for the meantime the capacity short term constraints of the airport.

In this enhancement perspective, research groups on both side of the Atlantic Ocean are developing the new capacity concepts to meet the short term objectives.
The United States of America work on the Next Generation Air Transportation System (NextGen) to enhance their air transportation system. On the old continent, European Commission and Eurocontrol develop the Single European Sky Air traffic management Research (SESAR) concepts to reach the projected traffic growth. These two research groups are proposing various solutions for the congestion problems at airports. The solutions range is particularly large and gets from the airborne systems to the airport structures improvements via the modification of procedures.

The aim of this report is to develop a method to determine an initial list of improvements which will probably enhance the capacity of a certain airport.
Prior to a detailed capacity study, the development of the method evaluating the contribution of the various solutions and answering to the particular needs of the airport should show efficiency for the airport operator and the researcher. This method should assist the user for taking the decision and the implementation of the solution should reduce the capacity problems. The process proposes a set of advantages, in particular to determine in early stages the capacity enhancement. It provides additionally a solution more independent than the subjective point of view of the experts.

The report is structured into three main axes. The first section, dedicated to the state-of-the-art, introduces the current situation in runway separation and lists the different parameters influencing the runway throughput. After the definition of the capacity computation introducing the theme of the work, the study concentrates on the factors ruling the runway throughput. The wake turbulences rules, the radar requirements and the runway occupancy rule are taken into consideration in this chapter because they establish and justify the current spacing rules. Then, a listing of the parameters influencing the separation rules is presented in order to determine the implication of each of these parameters in the separation rule. The parameters can be sorted into two main categories: the first one contains the parameters imposed such as the meteorological conditions while the second category includes modifiable parameters such as geometric characteristics or runway scenarios. These parameters may be seen as the input parameters for the rules.
The parameters study is a strategic lever to establish the next stages of the work. The efficiency of the method for offering the suitable solution solving the airport capacity problems depends on the interaction between the solution and the parameters involved in the spacing rules.
The second section presents the development of a method creating a list of proposals which could help to solve the congestion problem of a particular airport. The chapter explains in detail the structure and composition of the method dedicated to the airport administrations, operators or consultants. Firstly, a questioning form has been developed to specify the needs of the airport. Secondly, a database of possible candidates has been created in order to answer to the particular needs of the airport. This database is composed of enhancements for the actual rules and of several systems which are fulfilling in the research program guidelines. Thirdly, a matrix is calculated to reach the needs of the airport described in the questioning form. This matrix aims to compare the questioning form and the database of the possible candidates. This indicator sorts the correct candidates into a list and the wrong ones are deleted from the process. A “list of proposals” is provided to the next stage of the airport capacity analysis, which is for instance a detailed capacity study.
To illustrate the applicability of this new process, the last section of the work presents the implementation of the method. In this case, a scenario of a runway bottleneck has been modelled and the different steps of the method developed are described to explain how a list of solutions will be selected belongs the candidates.

Figure 1: Simultaneous departure and arrival at London Gatwick [2]

1 CURRENT SITUATION

This section outlines the literature review of the current situation concerning the airport congestion. The actual frame of the air traffic rules and requirements is explained in detail as well as the parameters taken into consideration to establish the regulation. The influence of the parameters is a determining step for the development process which will be presented in the section two.

This section is divided into six chapters. The first chapter is devoted to a presentation of the capacity computation. This computation chapter reviews the definition of the airport capacity and stresses the calculations used to develop an analytical model.
The second chapter outlines the regulations, and for instance the current spacing requirements between two aircraft are explained. The separation rules are established accordingly to three factors: the wake turbulences, the radar requirements and the respect of the runway occupancy rule.
Moreover these three factors may be influenced by several parameters. A change of these parameters activates a modification of one of the factors and the regulation could consequently change in order to enhance the runway throughput. Thus the next chapters are devoted to the description of these parameters ranging from the weather conditions to the various runway scenarios. They are heterogeneous and at first sight not comparable because their scope is very broad. The connections of the parameters to the factors are emphasized in each chapter. Chapters three to six will define one parameter, each respectively indicating his relation to the different factors.
The description of the aeronautical meteorological conditions focuses the influence of weather in order to determine the optimal spacing between two aircraft. This parameter rules directly the separation and a bad weather impacts unfavourably the throughput.
The fourth chapter outlines the influence of the geometry of the airport with the capacity involvement. The different configurations of the runways induce some changes in the application of the three factors (e. g. possible reduction of the radar separation for parallel runways instead of the standard separation for a single runway) and hence may enhance the runway throughput.
Thanks to four runway scenarios, the fifth chapter deals with the use of the runway. In addition, this chapter describes the reference points of measure allowing the usual calculations of the time separation and the capacity of a runway. This explains the interactions between the runway scenarios and the factors, and highlights the possible candidates for future improvements in connection with each runway scenario.
For a comparison of the weather influence data (e. g. capacity variation between two seasons), calculations have been synthesized in the chapter six. Meteorological parameters are notably used to characterize aircraft time separation. Moreover, the parameters taking part into the determination of the aircraft airspeed are examined in order to change the longitudinal separation into time separation rules. The goal is clearly to reduce the time steps between two flying aircraft and thence to generate an enhancement of the runway throughput.

1.1 RUNWAY CAPACITY COMPUTATION

The chapter reviews the capacity of an airport in order to provide the variables essential to the comprehension of this work. It includes the calculation used to define the arrival capacity of a single runway. The capacity and throughput words are very often referenced as fundamental variables to this work. They are actually used to evaluate the efficiency of the airport runway.

1.1.1 DEFINITION

The definition of the capacity states:
The maximum throughput capacity indicates the average number of movements that can be performed on the runway system in one hour in the presence of continuous demand, while adhering to all the separation requirements imposed by the air traffic management system [3]

Furthermore, the capacity can be divided into three categories:

- Practical capacity, which characterizes the expected number of movements that can be performed in 1 h on a runway system with an average delay per movement of 4 min. [3]
- Declared capacity, which designates the number of aircraft movements per hour that an airport can accommodate at a reasonable level of service. [3]
- Sustained capacity, defined as the number of movements per hour that can be reasonably sustained over a period of several hours. [3]

The taxiway and the terminal have also their capacity measurements but they don't appear in this report.
To give an order of ideas of the typical capacity value, the capacity of an airport made with a single runway operation is approximately between twenty and fifty movements per hour. Some airports with six or seven active runways reach a capacity value of approximately 200 movements per hour. These capacity estimations depend of course on the activity, the mix of aircraft types, the sequencing of the runway movements and the weather conditions. Other elements such as the taxiway systems, separations on final approaches, ATC procedures influence also the capacity values. [4]

1.1.2 COMPUTATION

Analytical models have been developed to compute the capacity. Let's consider an example where two aircraft are expected to land. The lead aircraft *i* want to land and it is immediately followed by another aircraft of type *j*. The symbol T_i indicates the time that lead aircraft passes over runway threshold while the symbol T_j indicates the time that trail aircraft passes over runway threshold. The symbol p_{ij} indicates the probability that lead aircraft *i* will be followed by trail aircraft *j*.

The average runway separation time $E[T_{ij}]$ can be written as follow:

$$E[T_{ij}] = \sum_i \sum_j p_{ij} \cdot T_{ij} \qquad (1.1)\ [5]$$

The capacity C of the runway to process this mix of arrivals is then equal to:

$$C = \frac{1}{E[T_{ij}]} \qquad (1.2)\ [5]$$

For more complex runway scenarios, the analytical models are more difficult to create and hence simulation models are preferred to achieve this task. The simulation models of the capacity tend to be generalized because the airport operators need to determine with accuracy the limits of the airport capacity.
The throughput will be indeed a major problem for solving for the long term constraints because the available runway capacity does not meet the growing demand of air traffic.

1.2 REGULATION

The regulation chapter is divided into three subchapters in which each part is structured around a factor playing a role to maximise the runway throughput.
Wake turbulence separation comes as the first factor because it is particularly restrictive and many research programs are dedicated to enhance this separation. Wake turbulence is an aerodynamical perturbation which occurs after the passage of the aircraft. This phenomena can be extremely hazardous for the trailing aircraft and can come up to its lost of control.
Radar regulation stands as second factor ruling the throughput of a runway. It depends mainly on the radar technology. Radar system is governed by the air traffic controller who is in charge of the Terminal Control Area (TMA) or the Tower Area.
The third subchapter enunciates the runway occupancy restrictions. Runway occupancy mainly deals with the runway operation rules and is in the centre of a number of studies to solve the European congestions problems.

1.2.1 WAKE TURBULENCE SEPARATION

Wake vortices (WV) are an aerodynamical phenomenon resulting from the passage of an aircraft. For many airports, the capacity is limited by minimum separation distances especially for the approach because of the possible hazard generated by wake vortices. It is desirable to enhance separation rules without compromising safety.

1.2.1.1 AIRCRAFT WEIGHT CATEGORIES

For the purpose of assessing wake turbulence separation, aircraft are divided into four ICAO weight categories. These classes are related to the Maximum TakeOff Weight (MTOW) and the wake turbulence influences generated by the aircraft.
The report defines the weight categories related to the ICAO standards and other local administrations (See Table 1). There are various values due to divergence between international aerospace administration (ICAO) and national administrations (FAA, CAA, DGAC, for example). It should be noted that the subdivisions into aircraft classes influences the capacity: by increasing the number of aircraft classes, the distance steps can be reduced

and consequently the landing capacity is significantly improved. That point explains why some national aerospace administrations authorize the subdivision of the classes. A review of 2 European and US administrations are listed here along with the ICAO standards.

Table 1: Weight categories [Ref [3] Page 378; [6]; [7]; [8]]

Authority	aircraft wake turbulence class	Maximum certified take-off weight	For the landing case only
ICAO	Light L	7 000 kg or less	
	Medium M	7 000 kg < MTOW < 136 000 kg	
	Heavy H	136 000 kg or more	
DGAC	Cat 1	7 000 kg or less	
(France)	Cat 2	7 000 kg < MTOW < 40 000 kg	
	Cat 3	40 000 kg < MTOW < 136 000 kg	
	Cat 4	136 000 kg < MTOW	
FAA	small S	41 000 lb or less	
(USA)	large L	41 000 lb < MTOW < 255 000lb	
	heavy H	255 000 lb < MTOW	
	super	just for A380	
CAA	Light	MTOW =< 17 000 kg	MTOW =< 17 000 kg
(United	small S	17 000 kg < MTOW =< 40 000 kg	17 000 kg < MTOW =< 40 000 kg
Kingdom)	Medium M	40 000 kg < MTOW < 162 000 kg	N/A
	Upper Medium UM	N/A	104 000 kg < MTOW < 162 000 kg
	Lower Medium LM	N/A	40 000 kg < MTOW =< 104 000 kg
	Heavy H	162 000 kg =< MTOW	162 000 kg =< MTOW

The FAA list differs from the ICAO references for all the classes. The gap between Small and Large aircraft is greater than the ICAO recommendations but on the contrary the FAA weight difference is smaller than the ICAO one.
The 255 000lb value is the particular MTOW for a Boeing B757-200ER. In this scheme, B757 are excluded of the Large group and put into the heavy aircraft class. This particularity finds an explanation in the wake turbulence study. It should be noted that UK differentiates the aircraft according to the flight phase: the category highly depends on the departure or arrival sequence. For example, the UK equivalent of the ICAO Large category is divided into two categories called “Upper Medium” (UM) and “Lower Medium” (LM) in the landing case. As explain behind, this is a solution to improve the landing capacity, in particular for the congestion problems at London Heathrow airport.
Finally the boundary between the French Cat 1 / Cat 2 has a value which is greater than the equivalent ICAO Small / Large boundary. The other French boundaries are similar to the ICAO requirements: they are just expressed in the metric unit (kg) instead of the imperial unit (lb).

1.2.1.2 WAKE TURBULENCE PHENOMENA

An aircraft produces wake turbulence as it passes through the air. Depending on the type of aircraft and weather, wake vortices can remain for three minutes or longer.

The effects of wake turbulence on an aircraft are induced roll and yaw and can be highly dangerous during take-off and landing phases. The initial intensity of the aircraft wake vortices is determined by the weight, speed, configuration, wingspans and angle of attack.

The most dangerous situation is encountered when a small aircraft flies directly into the wake of a larger aircraft. This case usually happens during Instrument Landing System (ILS) approaches. These straight approaches are in the centre of discussions of the enhancement because they restrain directly the approach capacity. Pilots and Air Traffic Controller are responsible for maintaining a sufficient wake turbulence separation, and the transfer of responsibility depends on the active flight rules (See chapter 1.3).

Figure 2: Wake turbulence [2]

1.2.1.3 POSSIBLE ENHANCEMENTS OF THE FACTOR

Wake turbulence is strongly influenced by atmospheric conditions. The severity of a wake turbulence encounter significantly depends on the wind and turbulences.
A 3-to-5-knots crosswind will tend to keep the upwind turbulences in the runway area and may cause the downwind turbulences to drift towards another runway. Atmospheric turbulences generally cause them to break up more rapidly. The International Civil Aviation Organization (ICAO) is undertaking an overall review of wake turbulence provision, including its current wake turbulence categorisation scheme. [9]

However, an aircraft with smaller wingspans generates more intense wake vortices than an aircraft with equivalent weight and longer wingspans. It is also most affected by wake turbulence. As introduced in the weight chapter, the B757 is in some legislation recorded as a Heavy aircraft in the leading sequence and as a medium when it follows another aircraft. B757 have small wings for their sizes: they need to fly faster than anybody else to compensate this “lack of lift” and generate bigger than normal wake vortices. ATC need to give to the B757 extra spacing to avoid any unrecommended trailing aircraft movements.

1.2.2 RADAR SEPARATION

The radar separation is the second factor used to establish the separation rules.
Radar implications on the arrival sequence and the time separation depending on the radar are discussed in this chapter. Radar provides the aircraft positions and the distance separation between two aircraft is conducted with the ATC radars.

1.2.2.1 GENERAL CASE

The requirement concerning the minimum radar separation between two aircraft has a value defined of 3 NM.
Currently, the minimum radar separation can be reduced to 2.5 NM under some circumstances. Three requirements are necessary to allow the reduction of the minima:

- The trailing aircraft is within 20 NM of the threshold,
- Appropriate vortex spacing is not required between the 2 pairs,
- Speed control is used to avoid separation eroding below 2.5 NM. [9]

1.2.2.2 POSSIBLE ENHANCEMENTS OF THE FACTOR

As the study concentrates only on the major airports, runway systems in these airports could be constituted with parallel runways and staggered threshold. In this case, aircraft established on adjacent parallel runways can be separated by 2.0 NM diagonally only if both runways have each an ILS LLZ (See Figure 3). [3]

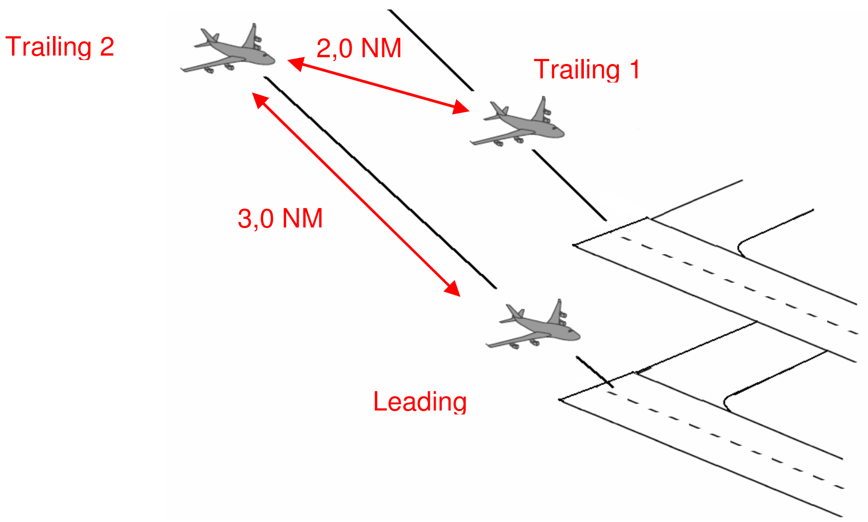

Figure 3: Radar separation reduction for parallel runways with staggered threshold

Three points allow the reduction the radar spacing to 2.0 NM on parallel runways with staggered threshold:

- Both aircraft are established on the ILS LLZ for different runways (various runways show the influence of the geometric parameter of the airport to reduce the radar spacing),
- Visual separation is confirmed and can be maintained by the pilot of the succeeding aircraft (visibility shows the influence of the meteorological parameter),
- AIR is informed (procedure parameter),

With this radar separation reduction, the radar spacing is currently improved to ensure the enhancement of the capacity. The authorities have demonstrated that this modification can be implemented without further difficulties.

1.2.3 RUNWAY OCCUPANCY

Runway occupancy subchapter states the rule concerning the use of the runway and this is the last lever presented in the report having a role in the capacity measurement. The runway occupancy rule could be sometimes considered as extremely restrictive in the civil aviation due to security justifications.

1.2.3.1 DEFINITION

The ICAO requirements note that the runway is considered occupied when an aircraft is located on the runway. For that reason other aircraft are not allowed to proceed on the runway. That means that the trailing approaching aircraft has to execute a go-around or the trailing departing aircraft must hold before proceed on the runway. [9]

The following figure introduces this disposition. An aircraft is actually on the runway and the other aircraft has to wait until the vacation of the runway or have to execute a go around if the rule is not respected.

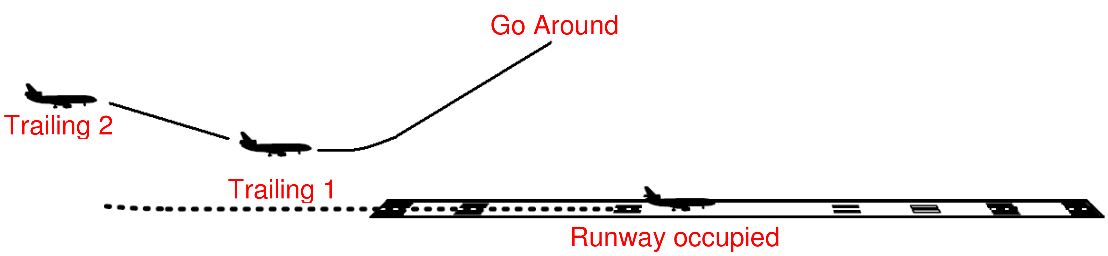

Figure 4: Runway occupancy rules

1.2.3.2 RUNWAY OCCUPANCY TIMES

To calculate the time when the aircraft remains on the runway, an indicator known as the Runway Occupancy Time (ROT) has been created.

The ROT of an arriving aircraft is defined as the time between the instant the aircraft touches down on the runway and the instant it is on a runway exit, with all parts of the aircraft out of the runway. [3]

1.2.3.3 POSSIBLE ENHANCEMENTS OF THE FACTOR

Some situations allow optimising the runway occupancy, in particular when a departing or landing aircraft rolls respectively on the runway. In this case, procedures to optimise the Runway Occupancy Time (ROT) can authorize another aircraft to line up behind the first aircraft but have to wait for the runway to be clear.

1.3 WEATHER CONDITIONS

The airport operator does not choose the weather, he only has the possibility to deal with it. This sentence shows how the weather parameter limits the capacity of an airport. The weather in aeronautics is ruled by three categories which are defined in the beginning of this chapter. Then the lever role to determine the capacity is emphasized and the way to adapt the capacity with this "external" parameter is highlighted.

1.3.1 DEFINITION

The subchapter makes a review of the weather conditions rules. Three categories rule the air traffic:

- Visual Meteorological Conditions (VMC) – weather allows vectoring for visual approaches.
- Marginal VMC – weather does not allow vectoring for visual approaches, but visual approaches on final are possible.
- Instrument Meteorological Conditions (IMC) – neither visual approaches nor visual separation on final are possible.

As for the aircraft weight categories, the division of the meteorological conditions in several categories gives the ability to adjust the capacity of the airport to the weather. [10]

1.3.2 VMC

Any time a flight is operating in VMC, the crew is responsible for seeing and avoiding other traffic. ICAO requirements about VMC are described in the ICAO doc 4444 and in the Annex 2 - Chapter 4 [10] for the minima.
VMC are characterized by a sufficient visibility and cloud ceilings minimums to fly the aircraft maintaining visual separation from terrain and other aircraft. The boundary is defined with the local VMC minima, but these minima rarely vary significantly from the ICAO requirements.
The set of regulations Visual flight rules (VFR) allows a pilot to operate an aircraft in weather conditions generally clear enough (VMC). The pilot has to see where the aircraft is going. Specifically, the weather must be at least better than basic VFR weather minimums, as specified in the rules of the relevant aviation authority.
This category has the highest rate for the capacity and especially when the responsibility of the separation between the aircraft in approach is delegated to pilots (VFR).

1.3.3 MMC

The Instrument Meteorological Conditions are defined as less than the minima specified for Visual Meteorological Conditions. That opens a space for a category inserted between VMC and IMC and known as the "Marginal VMC".
Since the basic traffic avoidance principle of flying under VFR is "see and avoid", this rule also applies to clouds, which is an important factor in the VMC minima: as aircraft in cloud cannot be seen, a buffer area around clouds is required.
The aim of the category is to propose an alternative to the IMC category, which is particularly restrictive for the capacity rates of the airport. Adding a new category placed between the IMC and VMC helps to adapt the limits of the rules to the variation of the weather.
The reason which contributes to develop the MMC category is that the visibility minimums of the VMC are different from values limiting the IMC category.

1.3.4 IMC

When ceiling and visibility are reduced such that aircrew cannot visually navigate, reliably see and avoid other traffic, then the weather conditions require shifting into Instrument Meteorological Conditions (IMC). Flight rules must be shifted in Instrument Flight Rules (IFR) and ATC provides separation services.
IMC are also characterized in the ICAO doc 4444. This flight category describes the way to fly primarily by reference to instruments and under Instrument Flight Rules (IFR). In fact low visibility may increase the possibility of flight crew becoming disorientated and unsure of their position. That is why the exclusive use of instruments is important under IMC.

IFR rules include the use of the ground based instrument approach Instrument Landing system ILS for the approaches. This approach system provides accurate guidance of an aircraft approaching and landing on a runway.
During an arrival configuration under IMC, aircraft are heading to the same landing track and the crew does not see and avoid other traffic: they are “blind”. After landing, the taxiing and vacating of the runway is difficult for the “blind” crew. The ROT is consequently increased because of the difficulty to taxi after landing and the increased separations between the aircrafts. During the taxing sequence, pilots are less assisted with the systems, need more time to see the exits and take carefully their decisions, being sure that the position and activity of other aircraft are known.
The several ILS landing categories are listed with their parameters in the following table:

Table 2: RVR Minima and decision heights [5]

	criterion					
	Decision Height		Visibility		Runway Visual Range	
category	meters	feet	meters	feet	meters	feet
CAT I	DH >= 60	DH >= 200	VIS >= 800	VIS >= 2800	RVR >= 550	RVR >= 1800
CAT II	30 >= DH > 60	100 >= DH > 200			RVR >= 350	RVR >= 1200
CAT III - A	0 >= DH > 30	0 >= DH > 100			RVR >= 200	RVR >= 700
CAT III - B	DH < 15	DH < 50			50 =< RVR < 200	150 =< RVR < 700
CAT III - C	no DH	no DH			No RVR	No RVR

1.3.5 CONCLUSION

It should be noted that IFR separations at major commercial airports are maintained almost every time as a rule, regardless of prevailing weather conditions. It is important not to confuse IFR with IMC. A significant amount of IFR flights is conducted in Visual Meteorological Conditions (VMC).
In the case of bad weather, airports acceptance rate is degraded because weather forces exclusive instrument flight conditions and the separations provided by the ATC are more conservative than the VMC separations. As a result, an important area for supporting the potential air traffic growth is to improve the capacities of airports when weather deteriorates from Visual Meteorological Condition (VMC) to Instrument Meteorological Condition (IMC).
The repartition visibility – ceiling can be represented under the following graphic. This graph allows evaluating the authorized domains and the flight categories in relation with the visibility and the ceiling.

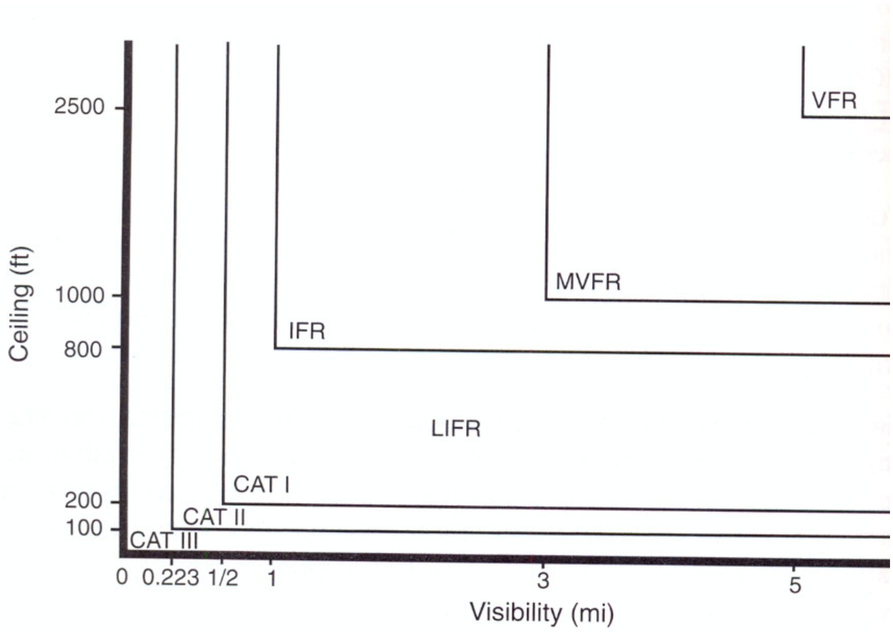

Figure 5: Weather conditions at an airport [Ref [3] page 388]

For instance, during bad weather period the capacity of the airport can be reduced to 50% or more. For example, the meteorological conditions at Frankfurt/Main airport are listed just below. This table gives an idea of the role of the weather for the traffic flow in an international airport and why it is important not to neglect this parameter.

Table 3: Meteorological conditions in FRA in 2005 [Ref [11] page 44]

CAT III	CAT II	CAT I	
IMC			VMC
1%		37%	62%
28 arrivals		38 - 41 Arrivals	> 43 Arrivals

1.4 GEOMETRIC LAYOUT OF THE RUNWAYS

"How the runway configurations influence the capacity of the airports?"

The aim of this chapter is to provide a layout sketch of the runway systems for many major airports. Runway designs are influenced by many sources: winds, topography, emplacement…
The geometric characteristic parameter is important for determining the throughput of the airport. For example, a comparison study of two airports using for the first airport two parallel runways and for the second airport two intersecting runways will show that the airports have two independent capacity values. In this practical case, only the orientation of the runway has been changed. That is why it appears important to study the levers caused by the geometric characteristics on the capacity determination.
Many types of airport layouts illustrate these geometrical characteristics, and the next subchapters are devoted to an overview of several basic configurations. Four basic configurations are highlighted in the chapter and their influence for the capacity is emphasized at the end of the dedicated subchapter.
Moreover the considered runways in the study are obviously longer as 2000m to accept Medium and Heavies movements without restrictions.

1.4.1 SINGLE RUNWAY

The single runway is the simplest case and has the highest capacity rate per runway. Aircraft follow the same track to land and they have to share the runway use with the departing aircraft whose need to take off. For that reason this airport configuration is limited with the regulations. The runway is often optimally positioned for prevailing principally winds, noise, and landing track. It is used for example in London Gatwick (UK).

Figure 6: Single runway [12]

1.4.2 PARALLEL RUNWAYS

The second solution consists of two parallel runways and is nowadays the runway systems of many major airports. The spacing between the centre-lines of the runways is another critical parameter for determining the throughput and the necessary separations between the runway operations. Airport can have close, medium-spaced or independent parallel runways. They are named according how closely they are placed next to each other and standards may differ from country to country.

Close parallel runways are generally those with centreline distances of less than 2500ft (762m). Under instrument flight rules, movements of aircraft on the two close parallel runways must be carefully coordinated. They have a higher capacity than only one runway (e. g. Düsseldorf airport). Some airports use exclusively one runway for the landings and the second for the departures while others airports don't use this dedicated use and propose a mix of operations on each runway (e. g. Frankfurt/Main Airport). [9]

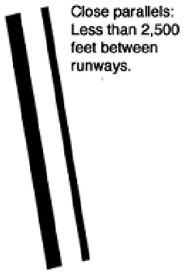

Figure 7: Close parallel runways [12]

Medium spaced runways allow independent departure or independent segregated parallel operations. That means that one runway is only used for arrival and the second runway is fully dedicated for departures. In this case, the capacity is also augmented in comparison with the close parallel runways. However arrivals on two medium spaced runways are not independent.

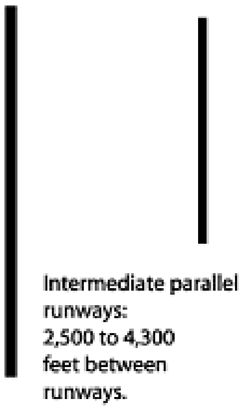

Figure 8: Medium spaced parallel runways [12]

Independent runways or far parallel runways are those whose centrelines are separated by distances greater than 3400 ft (1035 m), 4300 ft (1310 m) or 5000 ft (1525 m) [9]. The referenced distances depend of the local legislation. Aircraft do not need to be coordinated for the 5000 ft configuration. The independent runways make possible two simultaneous approaches. The far parallel runways have the best capacities (for example Munich Airport) of the four possibilities presented in this report.
It should be noted than close and medium spaced runways generate under visual flight rules and good weather equivalent capacities than independent runways.

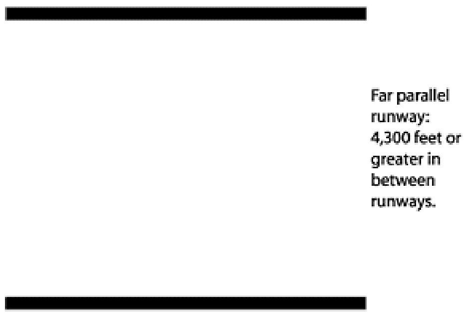

Figure 9: Independent parallel runways [12]

1.4.3 INTERSECTING RUNWAYS

The third possibility is the intersecting runways. In this case, two or more runways that cross each other define the intersecting runways categories (e. g. Hamburg Airport). This type of configuration is justified when relatively strong prevailing winds come from more than one direction during the year.
When the winds are strong from one direction, operations will be limited to only one runway.
With relatively light winds, both runways can be used simultaneously.
The greatest capacity is accomplished when the intersection is close to the take-off beginning and the landing threshold as shown below (configuration on the left). [9]

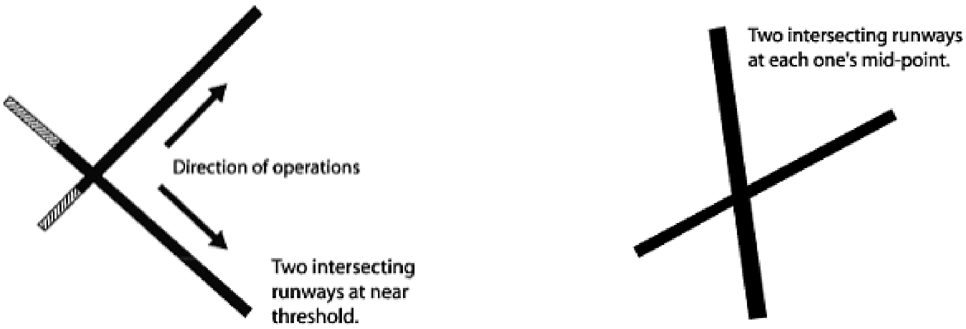

Figure 10: Intersecting runways [12]

1.4.4 OPEN V RUNWAYS

The fourth and last basic configuration is the open V runways.
Open V runways is made of two runways that diverge from different directions but do not intersect, so form a shape that looks like an "open-V" (e. g. Paris Orly Airport). This configuration is very useful without winds because both runways can be used at the same time.
When the winds become strong in one direction, then only one runway will be used. When take-offs and landings are made away from the two closer ends, the number of operations per hour significantly increases.
When take-offs and landings are made toward the two closer ends, the number of operations per hour can be reduced by 50%.

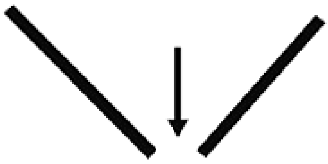

Figure 11: Open V runways [12]

1.4.5 GEOMETRIC LAYOUT SUMMARY

To summarize, the geometrical system has subsequently an influence on the capacity determination. As emphasized in this chapter, these characteristics are a decisive element in the runway capacity calculation.
Thus the parameter "Geometric characteristics" is an appropriate criterion for the development of the model. The geometric layout of the runway supplies to the study further questions, in particular to determine how this geometrical parameter is used with the runways scenarios. This dependence is solved in the next chapter, which is dedicated to runway separation scenarios for a single runway.

1.5 RUNWAY SEPARATION SCENARIOS

"What are the various scenarios existing between two traffics and how could they technically enhance the capacity?"

The runway separation scenario is a parameter influencing the throughput of the runway.
The chapter is consequently focused on the runway use. The runway use parameter is linked to the factors such as wake vortex or runway occupancy rule. Indeed, this parameter specifies the possible scenarios for using the runway (e. g. if the Wake Vortex has an impact on the Arrival Arrival spacing, it has no influence of the Departing Arrival scenario).

The case of a sole runway in function is examined to understand the impact on the factors. The major airport cases are made with several runways; complexes scenarios can be developed from this single use case.
This work considers additionally that both take-off and landing phases are unpredictable achieved one this runway (mix of two take-offs, two landings or take-off and landing). The single runway use can consequently be divided into four main scenarios of operation and each one is detailed in a dedicated subchapter.
In order to add the time differences between the runway operations for a throughput calculation, it is necessary to have a sole and unambiguous definition of the aircraft positions. In the literature, the definitions are varied and the selected ones come from the reference [3]. Measurement positions are different: the threshold is used for the landings whereas departs use the beginning of the take-off roll position as reference measure.

For a different application than used on this report, other definitions may be more appropriate.

An arrival followed by another arrival (Arr-Arr)

Figure 12: Arrival-Arrival scenario

In the Arrival-Arrival scenario, the time separation must be calculated between the passages of the aircraft noses over the threshold. This measurement of the approach spacing is possible on the whole airport. The touchdown position is variable from one aircraft to another aircraft and consequently is not used for this approach time measurements.

Other localisations have been identified during this study, but they have more drawbacks (D) than assets or could be difficult to achieve measurements for a landing operation.

- Flying over the blast pads,

D: Some runways are not equipped with blast pads

- Flying over the beginning of the runway,

D: This measure has an offset for runways with displaced runways threshold

- Touchdown zone (contact landing gear-runway),

D: This measure is strongly dependant of the pilots ability to touch down in the beginning of the runway. It is also used for the ROT calculations.

- Runway exit.

D: Various exit type can be considered. Pilots breaking policies (use of the slats, reverses, pedals, automatic brakes) in the landing sequence influence significantly the measurement in this position.

An arrival followed by a departure (Arr-Dep)

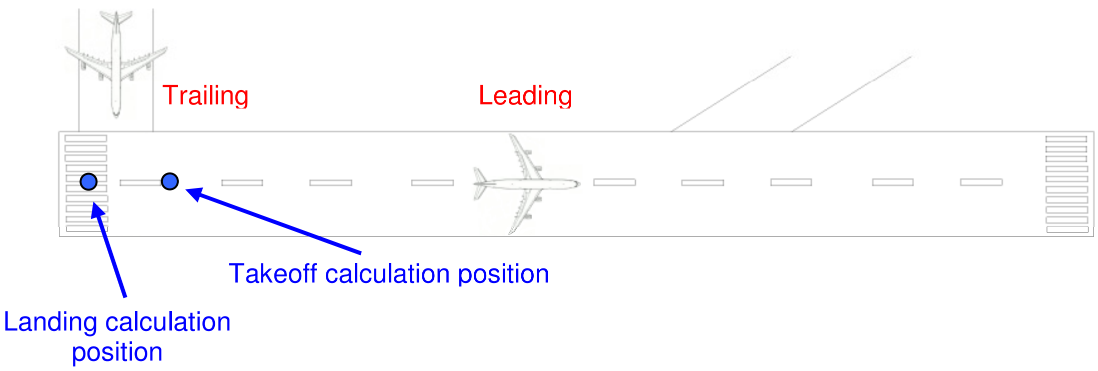

Figure 13: Arrival-Departure scenario

The time separation between 2 aircraft in the Arrival-Departure scenario starts when the leading (and landing) aircraft overflies the threshold. The time must be stopped when the trailing (and departing) aircraft starts his take-off roll.

A departure followed by an arrival (Dep-Arr)

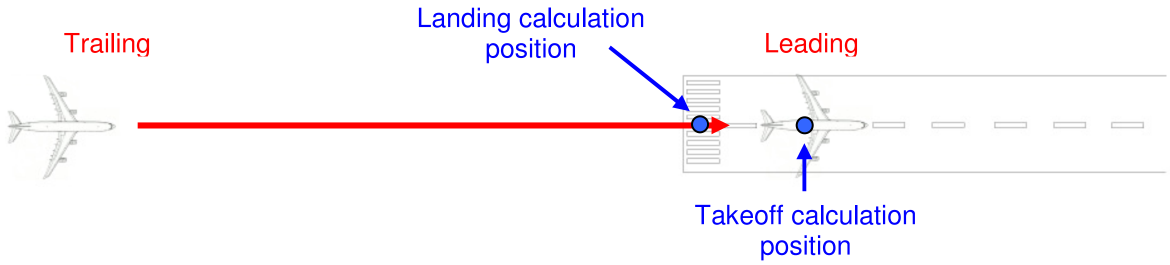

Figure 14: Departure-Arrival scenario

In the Departure-Arrival scheme, the time separation starts when the leading (and departing) aircraft begins his take-off roll and stops when the trailing (and landing) aircraft overflies the threshold of the runway.

A departure followed by a departure (Dep-Dep)

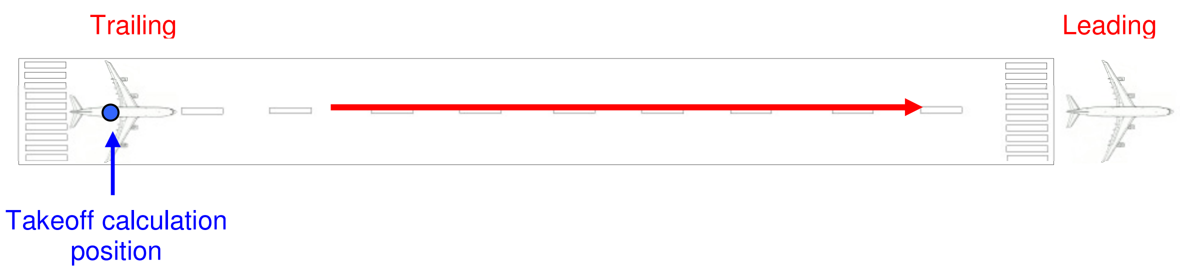

Figure 15: Departure-Departure Scenario

In this last single runway scheme, the time measurement begins when the leading (and departing) aircraft start his take-off roll. The time separation measurement must be stopped when the trailing (and departing) aircraft starts also his take-off roll. The advantage is that the times are independent of the departing route (Whatsoever same, diverging or different routes).

1.5.1 ARRIVAL ARRIVAL

The first scenario deals with two aircraft expected to land on a single runway. The separation between both aircraft concerns here only the longitudinal separation on the landing track.

The successive aircraft make their landing approaches and reduce their airspeed to prepare the landing configuration. In this case, the trailing aircraft must respect the longitudinal spacing with the preceding traffic.

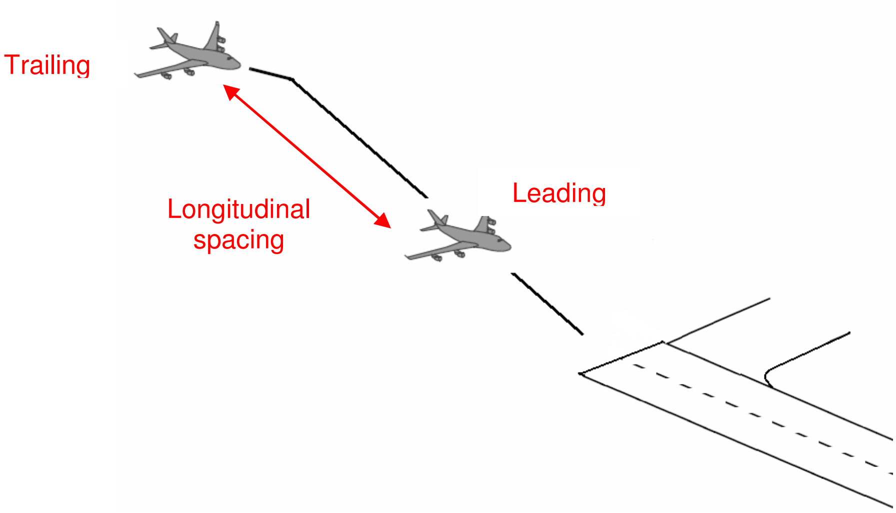

Figure 16: Arrival followed by another arrival sequence

Two regulations must be respected in this scenario:

- The two aircraft should not be on the same time in the runway (Runway occupancy rule). In any case, the trailing aircraft is not allowed to touch down before the runway is clear.
- The separation between the aircraft during the approach must respect the wake turbulence and radar regulations.

Table 4 presents the distance separations generally used during an Arrival – Arrival sequence in the same runway. Some cases of this table are into the reference value of 3 NM because there are no constraints due to wake turbulence (see subchapter 1.2.1). For example no extra distance separation is required when the trailing aircraft is heavier than the leading one.

Table 4: Distance separation between two arrivals in Nautical Miles [Ref [3] page 380 for FAA & [6] for ICAO values]

in NM		Trailing arrival			
		Small	Medium	Heavy	Super
ICAO Leading arrival	Small	2,5	3	3	3
	Medium	4 or 5	3	3	3
	Heavy	6	5	4	3
	Super	10	8	6	4
FAA Leading arrival	Small	2,5/3	2,5/3	2,5/3	2,5/3
	Large	3	2,5/3	2,5/3	2,5/3
	B757	5	4	4	4
	Heavy	5	5	5	4

The table 4 shows that the local legislations such as FAA use other separation requirements than those indicated in the ICAO standards. The FAA requirements are here smaller than the ICAO ones, and this reduction of the standard allows an augmentation of the capacity of the airport.
In any case, the absolute separation minimum as defined by the ICAO is three nautical miles for sufficient radar capability and two and a half nautical miles if the Runway Occupancy Time (ROT) is proven not to exceed 50 seconds (i. e. small- small).

Various guidelines for improving the airport runway separation parameters are selected in the technological papers, scientific publications and libraries. A listing of these proposals has been established through the SESAR and NextGen Air Traffic Management research programs ([13] & [14]). These main lines are showing the direction of the research programs in Air Traffic Management for the next decades. However, in order to demonstrate the relation between the parameters developed in this section and the method presented in the second section, some research guidelines are exposed in order to identify possible candidate for future improvements.

Among the various projects, three main axes have been developed.
In the wake vortex research, projects are focused on the study of the separation behind a B757 or Heavy (Next Gen) or on the study of a fixed reduced separation based on the wake vortex prediction (SESAR).
The researchers are also acting on the ATC improvements of the threshold delivery accuracy (Next Gen), and of operations in low visibility conditions through an enhanced ATC procedure (SESAR).
Procedures are additionally developed for Arrival-Arrival scenarios:

- The mixed independent and dependent parallel approaches (Next Gen),
- The paired approaches (Next Gen),
- The optimised dependant parallel operations (SESAR).

Moreover the maintaining of the visual contact through the approach, when an appropriate visual condition prevails, is a research axis for the MMC (Next Gen and SESAR). The use of a larger number of separation groups such as 2 – 3 -4 -5 -6 NM (Next Gen) is heading in the same direction.

1.5.2 ARRIVAL DEPARTURE

In this sequence, the leading aircraft is expected to land whilst the trailing aircraft hold position short to the runway until the leading traffic leaves the runway. Once the runway is cleared from the landing traffic, the departing aircraft can process to the departure sequence.

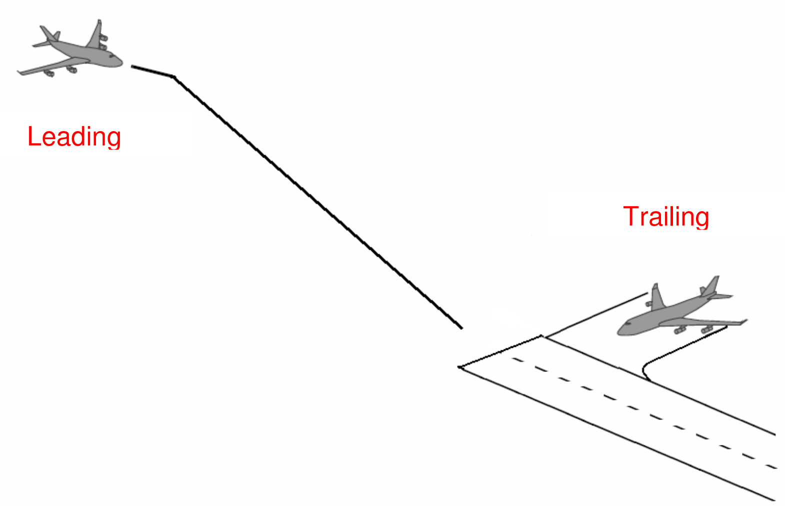

Figure 17: Arrival followed by a departure sequence

The exact time depends on the actual approach speed of the landing aircraft, this one being connected with the landings parameters (e. g. flaps settings) of the landing aircraft.

Projects are dealing mainly with the vacating of the landing aircraft such as the guidance assistance to the aircraft on the airport surface (SESAR), the use of the the Brake To Vacate (BTV) procedure (SESAR) or the use of the runway occupancy time (ROT) reduction techniques (SESAR). Other axes include the construction of intersecting taxiways (Next Gen), the reduction of the ILS sensitive areas (SESAR), the improvement of the low visibility operations using MLS (SESAR) or the Land and Hold Short Operations known as LAHSO (Next Gen) [15].
The ATC component of the research programs incorporates the situational awareness of an enhanced ground controller for every weather conditions (SESAR) and an integrated arrival-departure management for a full traffic optimisation, including the TMA airspace (SESAR).

1.5.3 DEPARTURE ARRIVAL

In this scenario, the leading aircraft is departing while the trailing aircraft wants to land after the take-off. Rules express that the runway must be clear and so the leading (and departing) aircraft must have taken off before the trailing (and landing) aircraft has overflown the threshold: the application of the runway occupancy has to be respected.

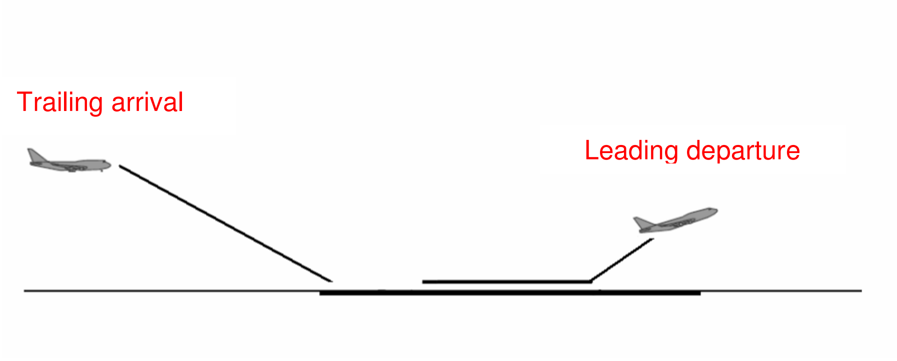

Figure 18: Departure followed by an arrival aircraft

Indeed this case can be problematic for the capacity when the time separation between both aircraft is too small: the arriving aircraft have to make a go around. The main factor affecting runway occupancy time is the response time to the line-up and take-off clearances, including the airlines standard operating procedures. The slot is also lost and the aircraft has to be reinserted later in the circuit. This solution includes extra cost (fuel cost) and delay for the arriving aircraft.
Moreover the pilot ability to move the departing aircraft from the holding position to the runway centreline and then to begin the take-off roll is clearly of critical importance to the departure runway occupancy time. When the aircraft is loaded with fuel and pax, the speed to safely negotiate the line up turn is slower. The pilots experience allows avoiding the stop on the holding point during taxiing and this action saves few seconds and enables the optimization of the ROT.

The research programs exploring the Departure – Arrival scenario improvements investigate on several topics. The most important of these are the reduction to 1,5 NM between a departure and a arrival separation under the IMC (Next Gen) or the creation of a new or extended runway (Next Gen). On the other side of the Atlantic Ocean, the SESAR programs propose to study the interlaced take-off and landing and the optimisation of the dependant parallel operations. [16]

1.5.4 DEPARTURE DEPARTURE

The last arrangement possible for a single runway use is the departure-departure sequence (See Figure 19). The two aircraft are holding short in the taxiway before entering in the runway. The first aircraft receives the clearance to enter to the runway and achieve the take-off. Then the second aircraft follows the departing aircraft but have to hold on the runway for the purpose of taking off, due to ensure the separations between the aircraft (the wake vortex is here the restricting factor).

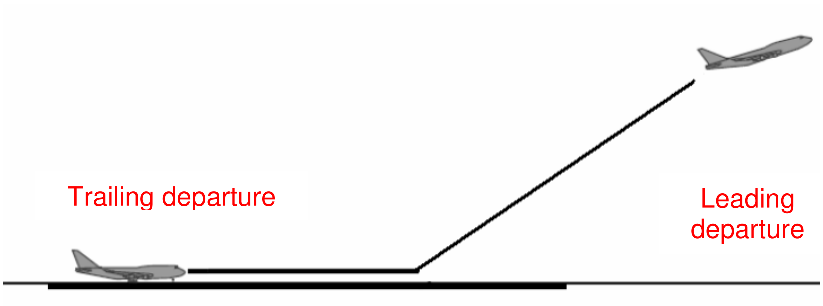

Figure 19: Departure-Departure arrangement

As during the arrival followed by a departing aircraft, the trailing departure can be authorized by ATC to line up and hold until the time separation with the leading aircraft is ensured.
The following table lists the approximate time to respect the departure separations rules.

Table 5: Departures minimum separation time [3] & [5]

in secondes		Trailing departure			
		Small	Medium	Heavy	Super
ICAO Leading departure	Small	45	45	45	-
	Medium	60	60	60	-
	Heavy	120	120	90	-
	Super	No information	No information	No information	No information
		Small	Large	B757	Heavy
FAA Leading departure	Small	45	45	45	45
	Large	60	60	60	60
	B757	120	90	90	90
	Heavy	120	120	120	90

Moreover the method of operation chosen by the airlines (checklist…) or specified by the aircraft and engine manufacturer will have an impact on the runway use.
In the case where the leading and departing aircraft is registered as a Heavy or B757, the take-off run of the trailing aircraft can start when one of the following conditions is validate:

- 2 min time separation separates the leading and the trailing aircraft.
- When the trailing aircraft become airborne, the distance separations in the table 6 are satisfied:

Table 6: Conditions to start the run for a heavy aircraft [3]

in NM		Trailing departure		
		Small	Large/B757	Heavy
Leading departure	B757	5	4	4
	Heavy	5	5	4

In any case, the less constraining of the 2 conditions have to be selected to conduct the departure sequence of the trailing aircraft. The Super class includes only A380 operations and are not really taken into consideration in this study due to the few aircraft in use.

Furthers improvements are working by the research teams to enhance the departure - departure scenario. Therefore, the Next Gen program is implicated on the reduction of the spacing to less than 2500ft between to take-off on the same runway. They also explore an enhancement of the standard departure – departure separation and the independent parallel departure under IMC. The SESAR teams have highlighted the study of the possibility to reduce the departure spacing by strong crosswind, and therefore to propose a fixed spacing based on the wake vortex prediction.

1.6 TIME SEPARATION ANALYSIS FOR ARRIVAL – ARRIVAL SCENARIO

This chapter is different to the other chapters detailing the parameters which influence the runway throughput. Actually, in order to analyse the possibility to transfer the longitudinal separation into time separation, the chapter is focused on the analysis of the arrival-arrival scenario. Thanks to a distribution of the time separation occurred on an arrival-arrival scenario, the study makes investigation about the variables that modify the time separation distribution.

1.6.1 SEPARATION ANALYSIS IN ARRIVAL-ARRIVAL SCENARIOS

The goal of the separation analysis subchapter is to highlight the influence of the distributions of the time separations for Arrival-Arrival scenarios. The separation analysis helps to understand the aim to change the distance separations into time separation.
The separation analysis can be approximated as a smoothed probability density curve. Arrival-Arrival scenario enhancements have two objectives:

- To reduce the value of the median closer as possible to the theoretical distance/time time) regulations presented in the chapter 1.1.
- To increase the height of the peak curve, that is to say to provide always the same distance/time separation.

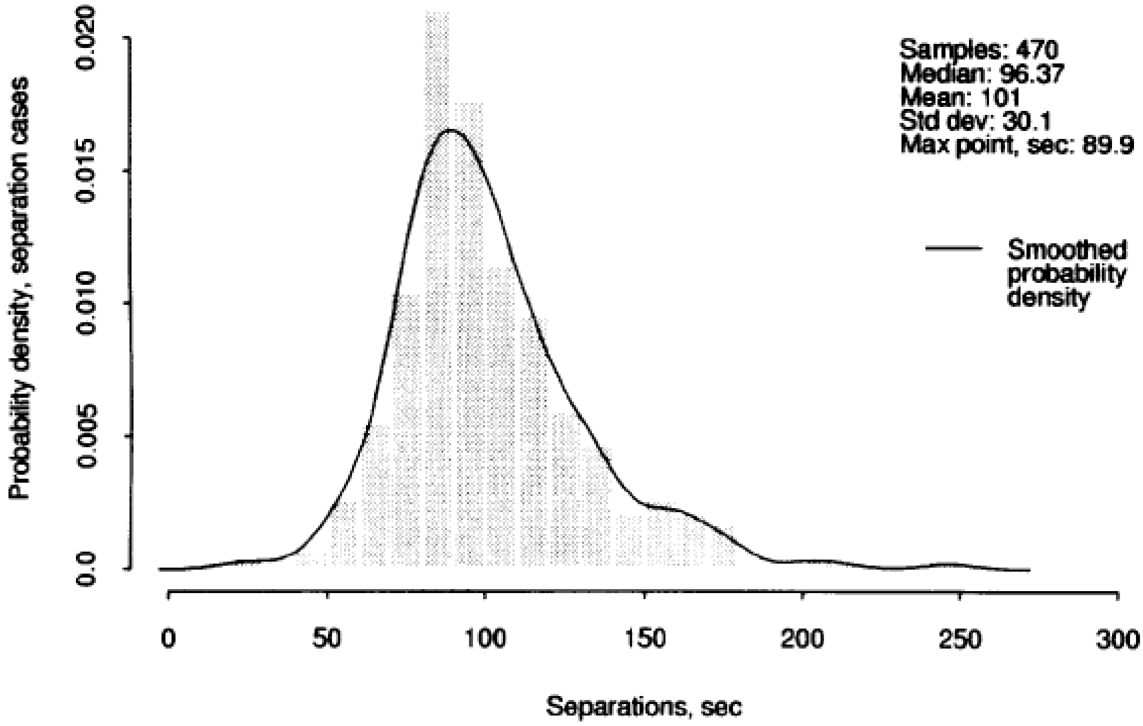

Figure 20: Distribution of time separations for all landing scenarios (2,5 NM required minimum separations). [17]

The main question is now to determine the variables that influence this distribution and how is it technically possible to develop new ATC concepts and separations regulations with the knowledge and the exploration of these variables. This exploration defines an order of importance between the variables which determinate the time separation and then the runway capacity.

1.6.2 TIME VARIATION VARIABLES

This part is devoted to the study of the influence of the variables on the time separation. In this domain, the pressure, temperature, aircraft mass and headwinds contribute to change the runway throughput value.
All the calculations have been effected on a 3 NM track, and the variables have been set to their nominal value (see Table 7).

Table 7: Initials variables

Pressure	1013,25	hpa
Airspeed	135	kt
Headwind	10	kt
Temperature	273,15	K
Distance to threshold	3	NM
Buffer	0	sec

Calculations are completed to give an evaluation of the time separation values. Selected values for the calculation can of course be discussed but they have been chosen to represent the standard range.

1.6.2.1 PRESSURE

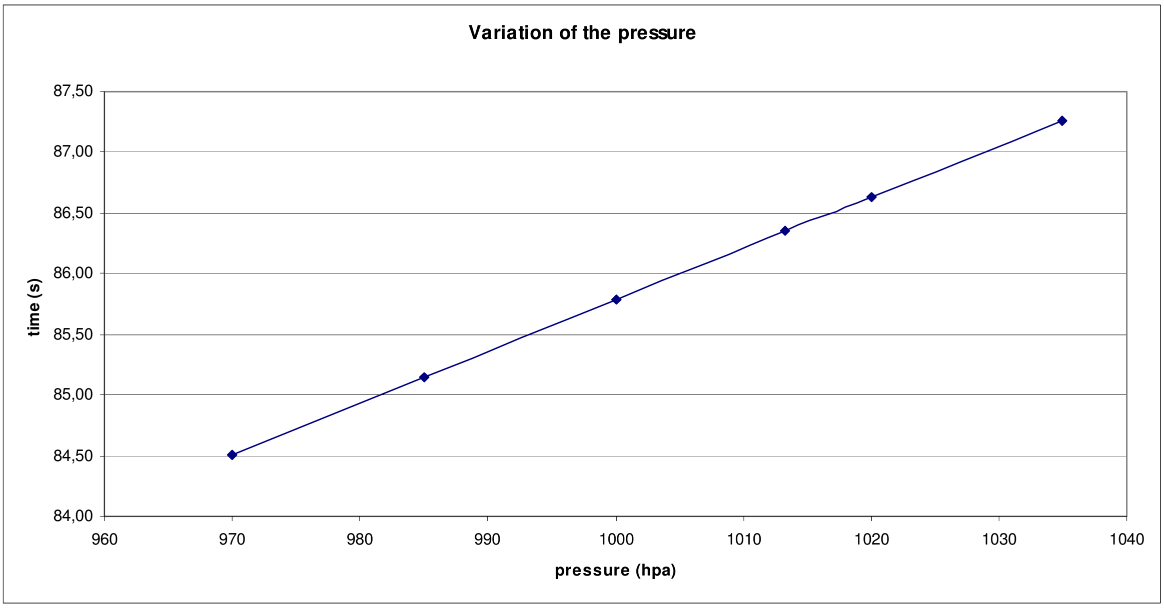

Figure 21: Pressure influence

The pressure ranges from 970 hPa up to 1030 Hpa. On this range, it is possible to see that the time variation evolutes from 84,5 seconds up to 87,5 seconds. The 3 seconds variation issue from the pressure variation has not really an influence in the evolution of the time separation.

1.6.2.2 TEMPERATURE

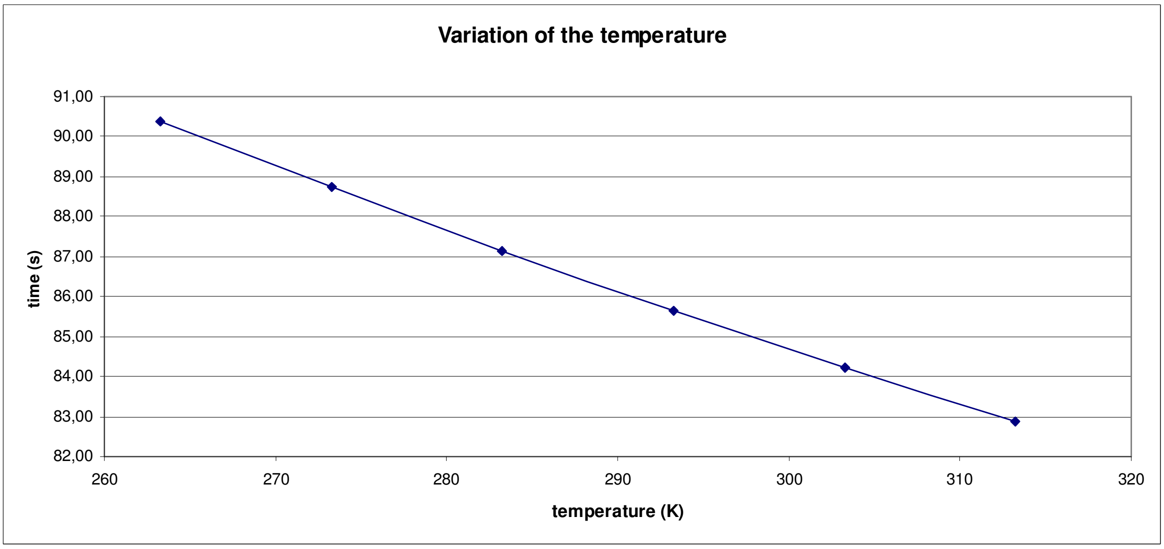

Figure 22: Temperature influence

For a same IAS, a high temperature induces a higher GS and consequently the time to fly the 3 NM is reduced. The temperature ranges from -10 Celsius degrees up to + 30 Celsius degrees. When the temperatures are under -10 degrees Celsius, several weather parameters such as snow and ice could reduce significantly the airport capacity. Their effects are furthermore more significantly than the temperature effect, because water, ice or snow conditions induce a level of contamination in the runway. This level affects the breaking management and modifies the ROT.
On the graph it is possible to see than the time to fly 3 NM changes approximately of 7 seconds on a 40 Celsius degrees range.
The temperature has also twice the influence of the pressure on the time to go all the 3 NM.

1.6.2.3 HEADWIND

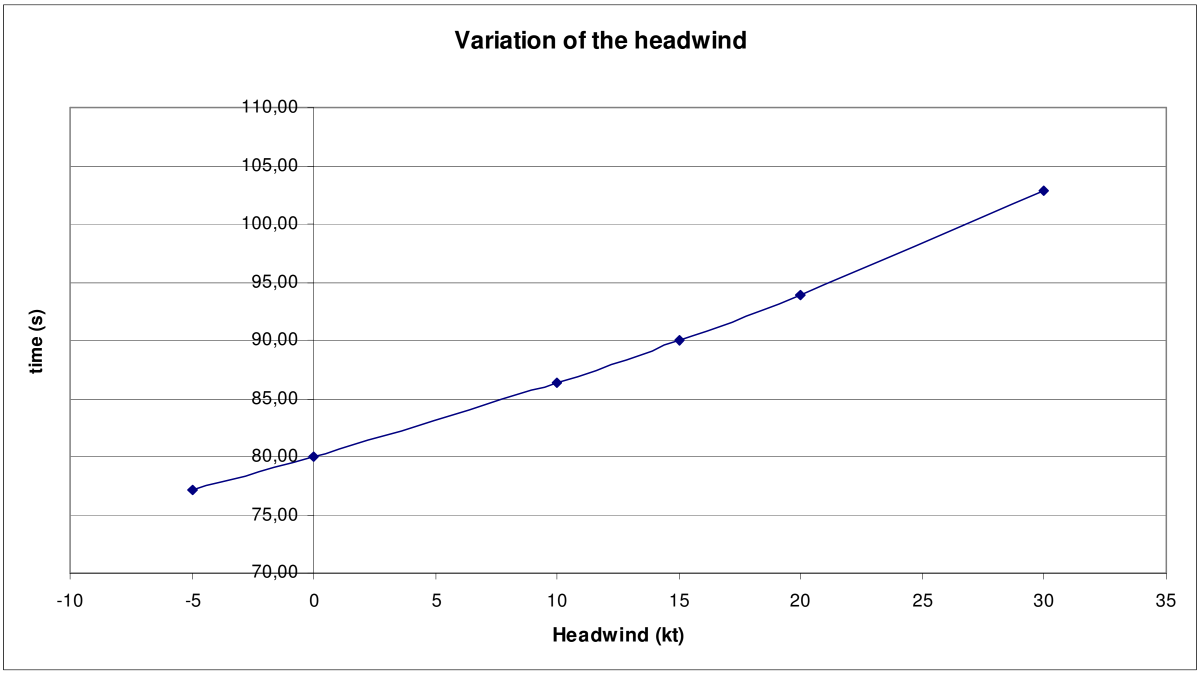

Figure 23: Headwind influence

The headwind seems to be a variable which has a high influence on the time to fly the 3 NM distance.
Indeed the time varies from 77 seconds up to 103 seconds for a headwind range getting from -5 knots up to 30 knots. This variation of 26 seconds can play a role in terms of airport capacity. Of course, a headwind augmentation induces an augmentation of the time to fly the 3 NM with as constant IAS.

Airlines manuals frequently authorize a headwind component of 40 knots during operation. On the other side, manufacturer manuals certify headwind component up to approximately 50 knots and a crosswind component of approximately 35 knots, gusting up to 40 knots. The values used for the calculation run are not out of order.

1.6.3 ANALYSIS & CONCLUSIONS

As a conclusion, mass (which influences the landing speed) and headwinds are the variable which influences the more the aircraft time to fly the 3 NM.
Temperature and pressure vary during the approach path in relation with the change of altitude. This variation could be calculated with the ISA table values.

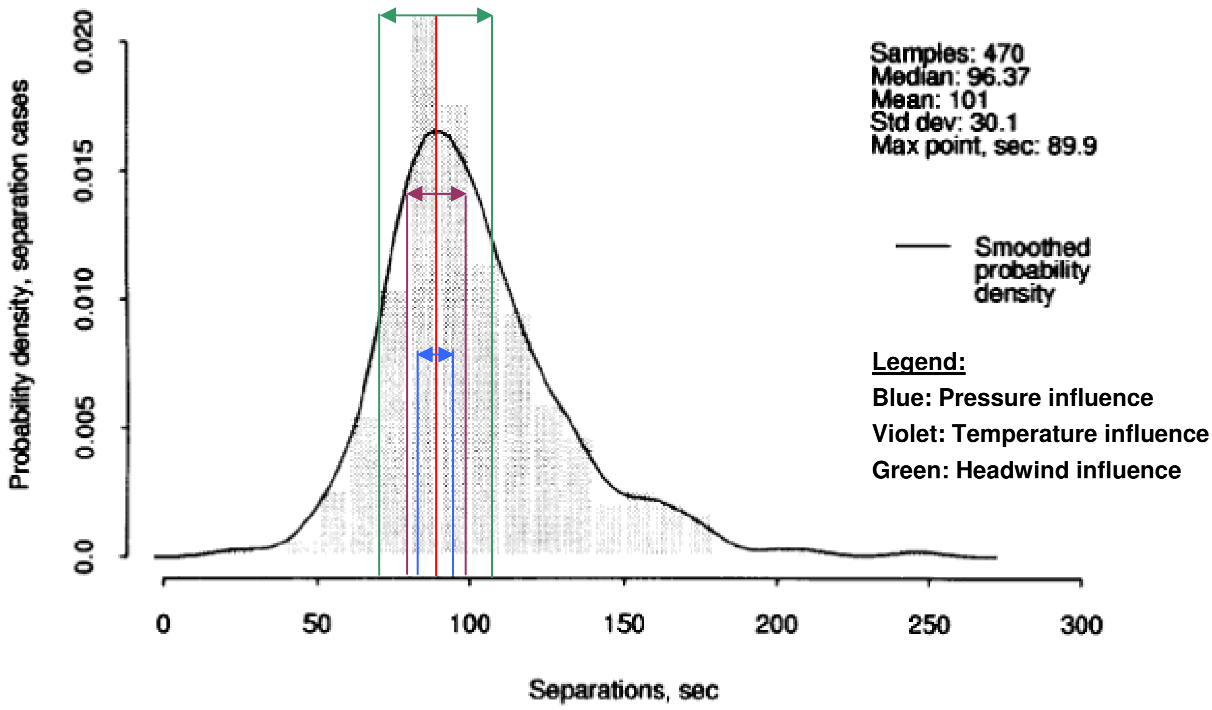

Figure 24: Influence of the variables on the distribution [initial curve [17]]

The figure 24 presents the influence of the variables on the arrival time distribution.
The headwind is the variable which influences the more the distribution. Then the second variable which influences the time to fly the last 3 NM is the variation of temperature. The pressure variation has no significant repercussion (variation of 3 seconds) on the spacing.
This conclusion opens the possibility to study more precisely the airspeed influence during the approach path because airspeed and winds are strongly rely and produce the main variations of the distribution.

1.6.4 AIRSPEED INFLUENCE

The goal of this part is to shows the significantly influence of the aircraft airspeed in the time separation during the approach phase.
During the last stage of the approach phases, the airspeed decreases in relation with the pilots policies to adapt the aircraft for the landing configuration. This configuration is different for each aircraft type, for each airline and remains in discretion of the pilots.
ATC do not have the possibility to modify this airspeed evolution on the last stage of the approach and consequently the airport capacity is closely dependant of the pilot airspeed

selection for the landing. This chapter aims to introduce the time variation due to the various aircraft classes and secondly the time variation for a particular aircraft but flying with various weights.

1.6.4.1 TIME GAP DUE THE AIRCRAFT CLASSES

Calculations shows that the time to fly a 3 NM track with a constant airspeed (120 knots; 130 knots; 136 knots; 145 knots; 155 knots; 165 knots) changes from 70 seconds up to 96 seconds. Speed values are selected to represent approximately the approach airspeed for a Small class (120 knots), Medium class (136 knots) and Heavy class aircraft (155 knots). The time variation between the 3 classes has consequently a relatively signification in the time separation. The following graph shows the evolution of the time in accordance to the landing airspeeds.

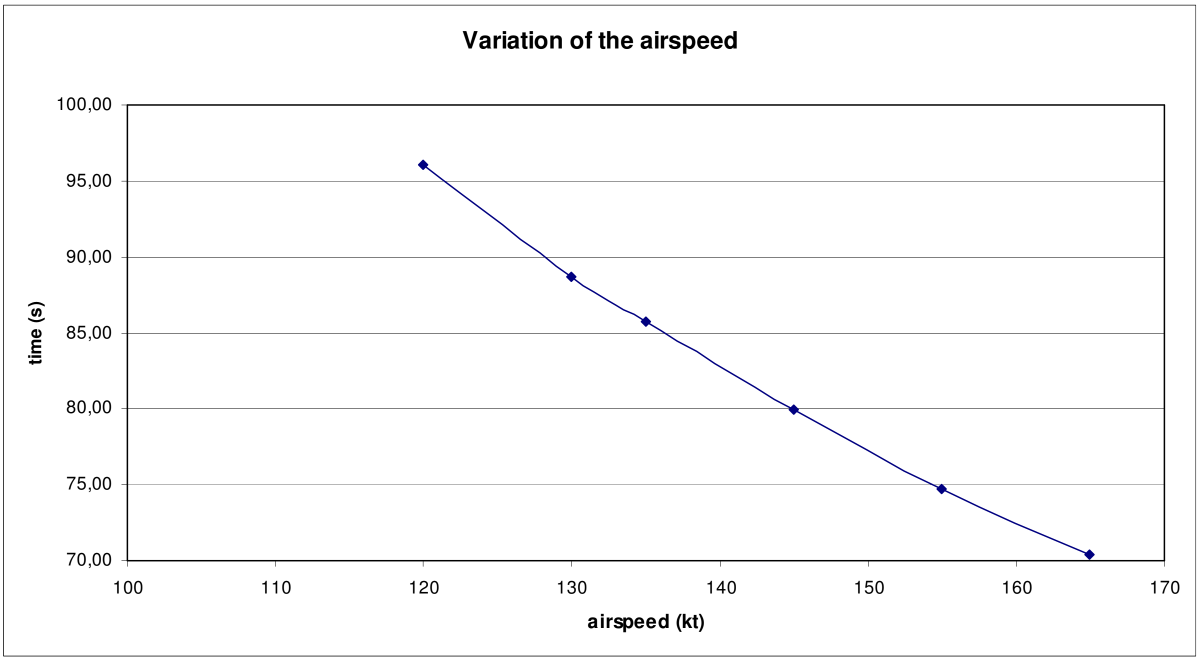

Figure 25: Airspeed influence on the approach track

This graph shows that an aircraft flying in 165 knots completes the 3 NM in 70 seconds whereas another aircraft in 120 knots needs 96 seconds to do the same track. As a first conclusion and to propose an evaluation of the gap, aircraft type induces about a 26 seconds gap.

1.6.4.2 TIME GAP DUE TO THE VARIATION OF THE MASS

An Airbus A319 is chosen for this study. The twinjet and single aisle aircraft can carry in a normal configuration 124 passengers. The following table presents the calculations issues from the variation of the masse (See Appendix 1 for the relation Masse/CAS).

Table 8: Landing CAS evolution in function of the aircraft weight

Passengers	Aircraft mass		CAS
	kg	lb	kt
0	57000	125663	126
62	63200	139332	134
124	69400	153000	140

The aircraft airspeed ranges from 124 knots up to 140 knots in relation with the variation of the aircraft passengers load. For this medium size aircraft, the induced time variation (See figure 25) ranges from 83 seconds up to 93 seconds. The analysis shows that the aircraft load influences more than the temperature range. The aim to reduce the smoothed probability density curve range should be concentrated on the first time on the airspeed lever. The futures improvements for the runway separation parameters could be easily connected with the airspeed enhancement.

1.7 SUMMARIZE OF THE CURRENT SITUATION

The thorough first section has emphasized the current air traffic management situation. For providing a global view of the situation to the reader, the section has been divided into four logical parts. A computation of the capacity has exposed the terms of the work in order to precise the working task. Then the separations rules which technically implement the capacity in the airport, have been established and the factors justifying the separations rules are highlighted through three main axes. They are concerning the regulation due to the wake turbulence separation, the limitation of the separation depending of the radar performance and the third factor deals with the runway occupancy rule.

Afterwards various parameters have attracted attention because they can modify the factors influencing the spacing rules. The separation rules are themselves the reason of the capacity restrictions. In this causes-effects relationship, the weather plays an important role. This role is all the more influencing that the weather is an independent parameter. That is to say that the action of the human in the weather parameter is totally limited: he must find technical solutions to reduce the dependence of the meteorological conditions.
The second parameter which can be used as a lever for the improvement of the capacity is the geometric layout of the runway. This more concrete parameter has a significant influence in the separation rules and is technically modifiable for enhance the air traffic separations.
In relation with the geometric layout of the runway, the runway separation scenarios are a mandatory parameter contributing to the runway throughput. The mix of operation is actually an improvable parameter and the four scenarios detail the possible improvements. The research is actively implicated to propose some technological solutions to enhance this parameter, and the taskforces is mainly concentrated on the Arrival- Arrival scenario.
Then, to get more deeply in the arrival-arrival scenario, the thinking concentrates on the influence of the meteorological variables such as temperature or pressure variation on the distance separation between two aircraft. The transformation of the distance separation into time separation is also discussed because this possibility could expend significantly the

runway throughput. However the efficiency and the ability to implement this transformation on the airport must be evaluated as soon as possible in order to save time and money.

Accordingly this approach paves the way for developing a robust method which is able to determine the optimal candidates for capacity improvement. For achieve objectively this task, the method has to sort the various candidates with a criteria system. The criteria system, which is also in the second section presented is totally connected with the parameters developed in the first section.

2 DEVELOPMENT OF THE PROCESS

"The airport I work at uses parallel runways with dedicated take-offs and landings. The traffic is mainly constituted of a mix of medium and heavy aircraft. I would like to increase the landing capacity during bad visibility for the next decade. What are your recommendations?"

This question comes from an airport administration and reveals a typical problem of capacity. Airport operators are looking for additional capacity and do their best to anticipate a possible increase or decrease of the traffic at their airports. They must be able to respond quickly to air traffic changes in order to stay competitive.
Moreover, this additional capacity can become a source of extra incomes to the airport.

In order to solve this problem of adding extra capacity, the following solution consisting of four steps can be offered:

- The first step consists of finding out and predicting the bottleneck of the airport. In this case the bottleneck can be only caused by a capacity problem. Usually this capacity problem means a saturated runway or congestion in the approach phase.
- The focus of the second step is on finding of one or several solutions for the elimination of possible problems with the bottleneck. Until now, the consultants were the ones responsible for proposing such solutions. The participation of consultants capable of identifying and proposing a solution can be considered as not totally efficient because of their subjective point of view. Therefore their point of view cannot represent the most optimal solution.
- The third step is connected with the investigation of the possible solutions that were selected in the second step as well as an evaluation of the expected gain that these solutions may bring.
- In the fourth step the best solutions for the improvement of airport needs is found. In the end of the process, this solution is implemented at the airport with the help of fast time simulation tools or analytical modelling.

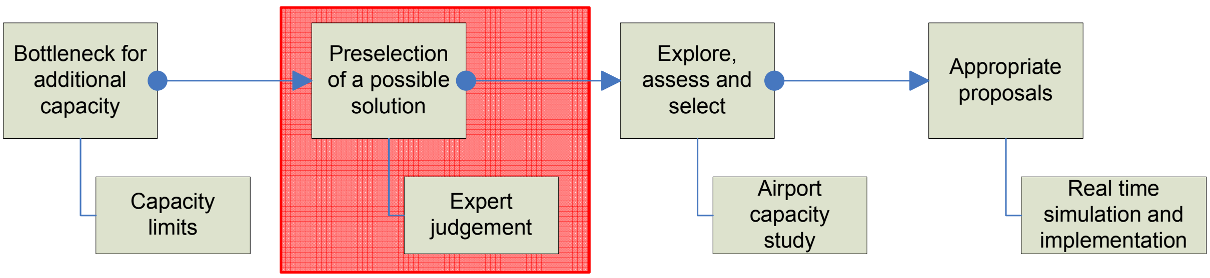

Figure 26: Process to enhance the runway capacity

A conclusion can be made that the biggest problem is connected with the second step. So it needs to be studied in depth.
As it has been already noticed, the search of the solutions depends on the subjective point of view of the experts involved in the process of improvement of the efficiency of the airport.

Moreover the latest technologies and effectiveness of research programs are rarely taken into consideration. For the research programs, the possible advantages cannot be easily estimated before the implementation of the system.

To solve these deficiencies, a method to evaluate the effectiveness of the new technologies on the airport runway separations has been developed. Its application area ranges between the bottleneck identification and the in-detail exploration/selection of phases for additional capacity.
Practically, the method must be divided into three main parts to solve this problem. It includes a database of candidates which is made up of systems and new procedures. The method is composed of several airport requests, also known as "Airport Queries", which aim to specify the particular needs of the considered airport. Then a matrix compares the database of candidates to the needs specified in the airport queries. The advantages of this method are:

- The database of candidates can be more meaningful than an expert's knowledge,
- It will be very fast, if the method is computerized,
- The proposed solutions are more neutral than those proposed by the experts.

The following figure illustrates the way of resolution of the problematic.

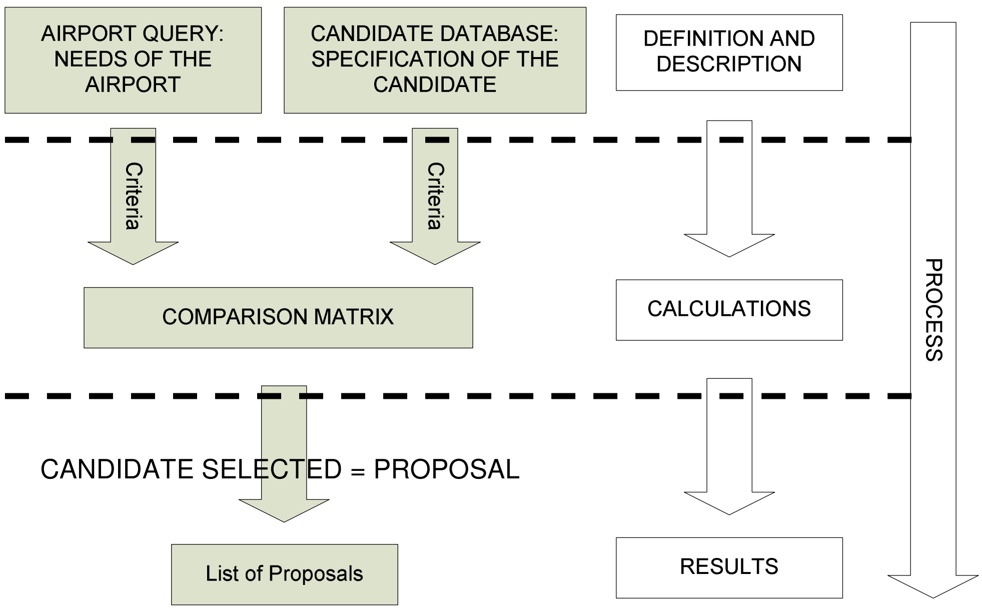

Figure 27: Structure of the method

For the purpose of easier understanding of the report, definitions of the specific words and expressions are given below (See figure 28).
The term "candidate" defines a set of systems, technologies, operational concepts, procedures and all the elements working to improve the airport runway separation parameters. The candidates are provided with the research guidelines. For instance, the candidate "Brake To Vacate" (see Appendix 4) aims to ameliorate a threshold delivery accuracy research program.

The proposals are equivalent of the candidates, but the name "Proposal" indicates that the candidates have passed the comparison matrix and have been selected for the depth in study. This name is consequently used to describe the output variable of the method (see figure 26).
The parameters, factors and capacity have been presented in the first section of this report and the explanation of the use of the terms is available in the beginning of the section one.
Process is used in this report as a synonym of method and defines the way to conduct the resolution of the problematic. (See figure 27)

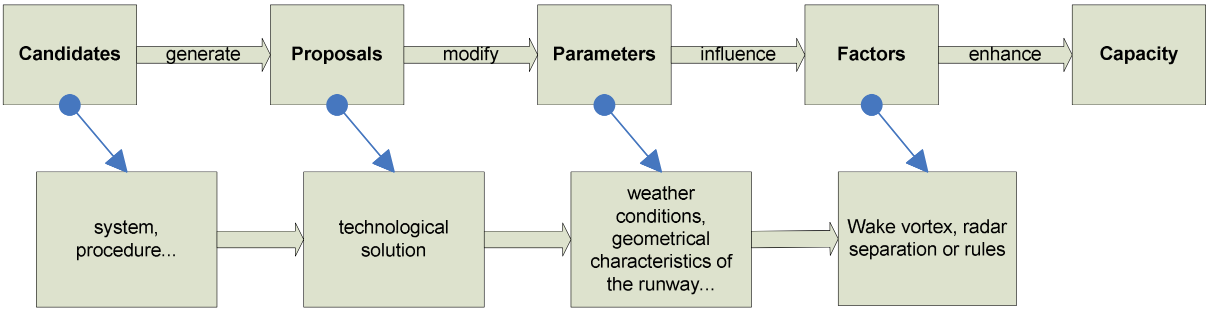

Figure 28: Vocabulary description

<u>Discussion of the choice of the method</u>

The framework for assessing these candidates prior to a detailed capacity study has been thought and ameliorates during a large period of this time.
Several plans of actions have been studied but they did not propose a broad panel capable to propose the possible candidates like this method.

For instance, after the determination of the research programs and the possible candidates dealing with the airport congestion, a linear description composed of paragraphs of text could have taken place.
Nevertheless, this choice presents more drawbacks than assets. It could provide nice and traditional pages of descriptions but it do not move away from the ideas of the publication. Textual descriptions look with difficulties at the objectively capacities of the possible candidate. Indeed the view of this description is dependant of the source of the information and how was written the paper describing the candidate. Furthermore, it could difficultly have a so structured frame than the one which is proposed in the next pages of this report.

The airport request provides an important asset to the method. The possible candidates take part to the enhancement of the airport capacity, but their range is difficult to evaluate and above all, nothing proves that the possible candidate is the proposition answering the best to the needs of the airport. Indeed, the research programs are implicated to provide wide ranging solutions increasing the capacity of airports. The individual needs of the airport are not taken into consideration in these wide ranging solutions and in any case this is the goal of the research.
In order to compensate this lack, the airport request main line has been to propose an interface capable to take into consideration the particularities of the airport. In this way, a

developed strategy was to propose an interface keeping always close to the individual needs of the airport.

2.1 FORMAL DESCRIPTION OF THE DATABASE OF CANDIDATES

"How may I take into account the new technologies and operational concepts?"

The focus of the chapter is to provide the user with a formal description of the database of candidates. The first subchapter deals with the objectives of the database. The focus of the second subchapter is to characterize the parts of which the database of candidates is constituted. They are respectively devoted to the presentation of the candidates, the sources, the criteria and the conclusions. The third subchapter illustrates the database of candidates with a concrete form. The requirements formulated in the subchapter two are highlighted in this example and the reader becomes familiar with the graphic interface of the database of candidates.

2.1.1 OBJECTIVES

Initially, the following purposes motivate the building up of a formal description for the candidates:

- This is the optimal solution to order various systems with a unique arrangement. The listing of the system specifications is achieved using dedicated criteria.
- A database of the different projects can be a powerful tool for the DLR researchers. The whole projects of the institute could be listed on the database.
- In order to be compared with the request of the airport operator, the candidate must share a common structure with the airport operator. A formal description of the candidate can easily allow the comparison with the request of the airport operator.
- The form offers the possibility to support a structured description by assuming always the same shape.

The database of candidates must provide the user with all the information about the function of the system.

2.1.2 ELEMENTS CONSTITUTING THE DATABASE OF CANDIDATES

Four paragraphs describe the main topics of the database of candidates. A short description, which aims to briefly introduce the candidate, takes place in the top of the form. Then the form should include the sources of information and the link to the publications. The main paragraph of the database describes the specifications of the candidate. These specifications are detailed with the help of criteria. Finally, the conclusion summarizes the advantages for the selection of the particular candidate and the possible gains of the candidate are emphasized.

2.1.2.1 DESCRIPTION OF THE CANDIDATES

This part must explain the function of the candidate in a few sentences. The user has the possibility to watch the scope of application of the candidate. This clarification of the range of the candidate has to be positioned on the top of the form. The research main lines coming from the SESAR or NextGen research programs have to be filled in this description of the candidate. This ensures that the candidates are involved in the ATM improvements.

2.1.2.2 SOURCES OF THE DOCUMENT

This paragraph of the form is dedicated to the determination of the sources of the information with the purpose to make easier furthers exploration about the candidate. This demonstrates the efficiency and the reliability of the candidate because the absence of sources is equivalent to a lack of reliability.

The name of the publication, the date of the edition of the publication and the authors of the publication are the three mandatory elements of this paragraph.
Several points necessary to the understanding of the sources of the information must be included in the paragraph of the form. For example, topics such as a link to a publication, a connection with a website mentioning the firm developing the candidate, an email of a project leader provide to the interface user with the possibility to contact an expert for further information about the candidate.
Another part of the sources paragraph must give the possibility to link the candidate with an airport or aircraft test bed. The goal is to give the possibility to find again the system environment because the user sometimes remembers the airport where survey have been conducted but not the name of the candidate.
Furthermore, the manufacturer name has to be inserted in the database for the candidates which are now available or in production phase.
In order to manage the database and the various candidates, the date of the composition of the form provides to the reader the possibility to update the database.
A technical prerequisite form is justified when the system needs simultaneously the use of additional systems. The additional systems are not included in the candidate package but the candidate is not able to work without the addition systems. This note located in the end of the source paragraph orientates the user to be extremely careful to extra costs concerning the retrofitting and to the adaptation of the additional systems with the candidate requirements.

2.1.2.3 CRITERIA PARAMETERS

A code made of criteria provides with a frame of reference in order to describe the specifications of each candidate. Considering the fact that the origins of the candidates are heterogeneous (procedures, systems…), this code has the advantage to compare what is comparable.
The criteria characterize technically the candidates specifying notably the maturity, the introduction dates, the weather conditions, the airport scenarios which are allowed by the candidate and the expected time gain. A review of all the criteria is now carried out.

Maturity
The maturity criterion gives an assessment of the candidate in the technological lifecycle.
The position of the candidate in the developing process scale provides an estimation of the feasibility and reliability of the candidate. In this domain, the Technology Readiness Level

TRL developed by the NASA and the European Operation Concept validation methodology E OCVM are the most used scales to describe the maturity of the project.

The Technology Readiness Level scale is divided into nine levels [18]:

- TRL 1. Basic principles observed and reported
- TRL 2. Technology concept and/or application formulated
- TRL 3. Analytical & experimental critical function and/or characteristic proof-of-concept
- TRL 4. Component and/or breadboard validation in laboratory environment
- TRL 5. Component and/or breadboard validation in relevant environment
- TRL 6. System/subsystem model or prototype demonstration in a relevant environment (ground or space)
- TRL 7. System prototype demonstration in a space environment
- TRL 8. Actual system completed and "Flight qualified" through test and demonstration (ground or space)
- TRL 9. Actual system "Flight proven" through successful mission operations

The interdependency of the EOCVM scale with the TRL scale is defined as follow:

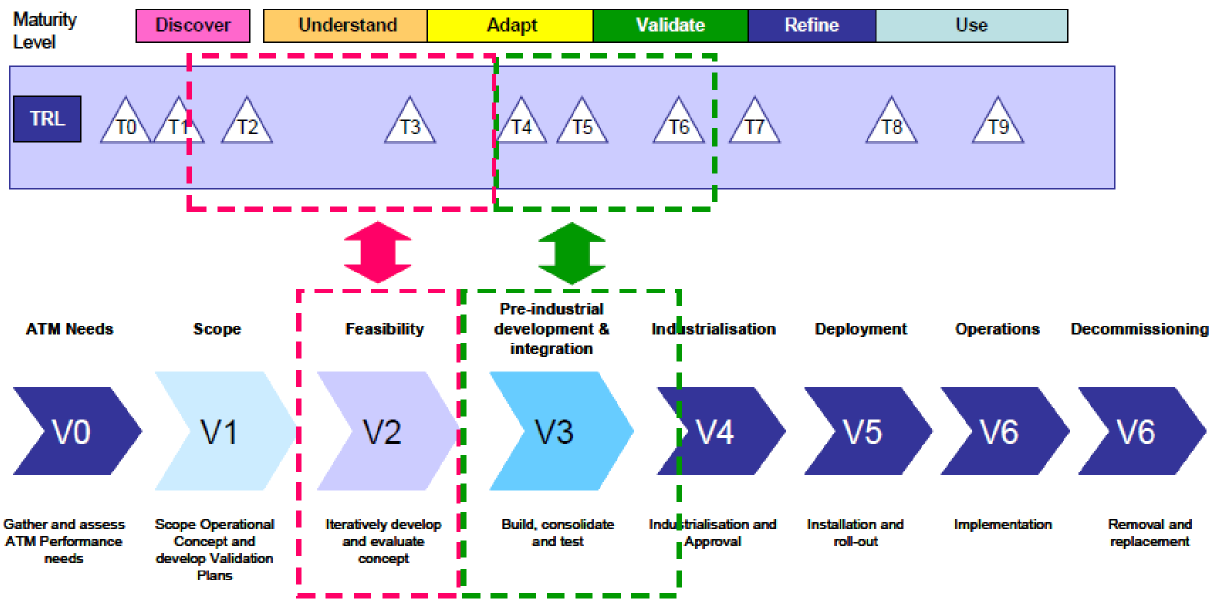

Figure 29: Comparison EOCVM and TRL levels [19]

Given that the determination of the maturity level is frequently confusing, it could be interesting to write some remarks characterising the maturity of the candidate or justifying the maturity choice. For example, if the maturity is not clearly explained, if the publication is not recent or if the candidate is improved, these remarks have to be taken into account in a small sentence.

Dates

This criterion indicates to the user the dates concerning the temporal introduction of the candidate. It enables the preparation in advance of the deadlines and to manage the planning.
This criterion has to be separate into two main lines in order to be powerful.
The progress of a candidate provided by the research has to be defining with a sentence. Like the maturity, the progress is an indicator of the feasibility and success of a research project. For example, a well planed starting project has more chances to rise up than another which has not a time projection or deadlines for the developing phases.
The date of introduction is indicated by a scale getting from 2010 to 2030. This scale gives a sufficient visibility for the research programs.

Weather

The aim of this criterion is to highlight the weather conditions which are allowed for using the candidate. The criterion indicates the weather conditions (VMC or IMC) as well as the flight category (CATI, CATII, CATIII) where the candidate performs.
The visibility parameter gives information of the required or expected visibility. Values can be inserted for the horizontal visibility as well as for the vertical visibility.
The wind requirement values should be filled in. The form should include the possibility to maximize of minimize a wind value (> or <) and also to indicate if the candidate is working with the crosswind situations.
They are particularly useful for the systems concerning the wake turbulence reduction during special meteorological and wind conditions (e.g. strong crosswind and headwind shift the wake turbulence corridors). In this case, the candidates gain is strongly linked with the presence of strong crosswinds and therefore a wake turbulence reduction candidate who increases the throughput in an airport could be totally limited or even pointless in another place.
As the weather is not only limited to the visibility and the winds characteristics, a place should be reserved to write a sentence or keywords (e. g. Working with snowfalls).

Airport

The form must be able to describe the airport structure where the candidate performs.
The criterion airport aims to differentiate the configurations and the mix of operation of the airports allowed by the candidate. Thus the four configurations should be available (Single/Crossing/Parallel/Open V) as well as the runway use (Arrival-Arrival, Arrival-Departure, Departure-Arrival, Departure-Departure).
Given that this criterion should be blurry, the form must include a line dedicated to write a sentence establishing the particularity of the airport structure.

Costs

Airport operators must generate benefits adding extra capacity and at the same time control the operating costs. Hence the cost criterion is a relevant indication for the candidate form.
To be accurate as much as possible with the reality, the cost criterion have been divided into four payer stakeholders:

- ATC or air traffic control provider service,

- Airlines,
- Airports,
- Other contributors.

The cases of other contributors give information when an associate payer is implicated in the development of the solution (e. g. the aircraft manufacturer).
During the first stage of the development of the form, the cost values had to be filled in a dedicated cell. Nevertheless values and indications of the price are never clearly written. In order to make up this lack, the costs of the candidate are assessed with two indicators describing the cost qualitatively or quantitatively.

<u>Localisation</u>
The localisation informs the user of the geographical position of the candidate. The analysis of various candidates has found several places where the candidate should be implemented. Three main places have caught the attention and a sentence should be available to detail the exact position of the candidate. (i. e. Aircraft: display in cockpit and calculator box in the avionic bay). There are:

- Airport,
- Aircraft,
- Tower.

As the candidate should be not positioned on one of these three places, the form should include a fourth place known "Other".
The criterion opens the possibility to wonder whether the candidate will be easily or not implemented because the interactions coming into sight between the candidates and the other systems are easier highlighted thanks to this criterion. (e. g. extra display in cockpit. Interference with a HUD?)

<u>Applicability (period of application)</u>
The applicability is defined as the period in which the candidate is active. The applicability should be mandatory described by a sentence, which mainly include value or assessments.
This criterion can demonstrate the need to introduce a candidate on an airport and the uselessness of the same candidate on another airport (e. g. candidate improving the landing capacity during snowfalls).

<u>Gain</u>
One of the selected criteria is the expected time gain. It is evaluated per operation and indicates the time or the expected gain when the candidate is active (e. g. expected gain: three seconds per landing movement). This criterion is a mandatory input for the studies taken part of exploration of the proposal (See figure 26). This criterion has a drawback, because the papers mainly avoid the question or talk about an "expected time gain" with care.

<u>Technical risk</u>
A small paragraph describes the technical risks issue from a candidate. The paragraph should be completed with keywords. They indicate the possible elements reducing the

expected gain or even able to reject the candidate (e. g. implementation of Galileo influences the candidates using the GPS?).
This criterion should also include a remarks line dedicated to the systems and technologies developed by a unique firm and as a result patent rights restrict the candidate use.

2.1.2.4 CONCLUSION

The conclusion paragraph of the form can be resumed through three elements: the gain, extra gain and remarks.
The first one indicates the generated gain for the airport runway separation. It should be close to the expected time gain generated in the criteria part. The extra gain lists the advantages without interests for the capacity improvements. This element contains advantages such as an environmentally benefit, a noise reductions or a safety improvement. The additional gain is not the aim of the form but they may become a parameter to distinguish the suitable solution of the database. The part remarks should be filled in with general observations related to the candidate and in particular when the candidate research has been stopped before the closure of the project.

2.1.3 EXAMPLE OF A FORM DESCRIBING THE CANDIDATE

In order to illustrate the definitions of the last chapter, a frame has been created. It relays the structure based on the four axes and it organizes the criteria.
Further forms have been filled in to build up the database of candidates. The following systems and procedures have been selected as possible candidate:

- Brake To vacate (BTV)
- Ground Markers
- Wake Vortex Avoidance System (WVAS)
- Closely Spaced Parallel Runway Arrival (HALS/ DTOP)
- Wake Independent Departure and Arrival Operation (WIDAO)
- Time based separation (TBS) for arriving aircraft
- Crosswind Reduced Separation for Departures Operations (CREDOS)
- Reduction of the CATIII ground restriction areas
- Ground based Augmentation System (GBAS) for CAT I operations
- ROT Reduction through pilot/control awareness
- Intersecting Take-off
- Airborne Information for Lateral Spacing (AILS)

This presentation is not thorough and all the tables of candidates are located in the appendix 4.

Table 9: Example of a candidate form

I. CANDIDATE												
Name	p	Crosswind Reduced Separation for Departures Operations (CREDOS)										
Short description	p	Crosswind procedure which consists to suspending (Time and distance) wake turbulence separation under specific crosswind conditions. Sufficient crosswind transport any hazardous turbulence out of the track of a following aircraft.										
SESAR-NextGen topic	p	Crosswind reduced separations for departures and arrivals										
II. SOURCES												
Name, authors	p	Wakenet 3 Europe - Dr. Debbie Mittchell										
Date of the document	p	01.08.2009										
Website	p	http://www.greenwake.org/Links/Overview.pdf										
Contact	p	http://www.eurocontrol.int/eec/credos/public/subsite_homepage/homepage.html										
Airport-aircraft testbed												
Composition date	p	July 2010										
Manufacturer-Developper	p	AIRBUS, Berlin Technical University, DFS, DLR, EUROCONTROL, INECO, M3 SYSTEMS										
Technical prerequesite												
III. CRITERIA												
MATURITY	o	TRL	0	1	2	3	4	5	6	7	8	9
	o	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	o	Demonstration of the feasability not executed										
DATES												
Progress		Due to be completed at the end of 2009										
		Fully completed in 2012										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	o	<	>	Strong crosswind							Crosswind	
Notes												
AIRPORT												
Runway system	o	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use		Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	p	Only for the Departure -Departure scenarios										
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	o	Airport										
		Aircraft										
	o	Tower										
	o	Other	Develop a procedure									
Applicability												
Expected gain time/ops	p	Absorbs capacity peaks and reduces departure delays										
Technical risk	o	No knowledge about wake Vortex during initial climb										
IV. CONCLUSION												
Gain	p	Temporarily increase the departure runway throughput										
Extra gain												
Remarks	p	Can be used for all aircraft types but only on the D-D sequence. The gain is mainly seen after a heavy departure. Need a documentation and ICAO standart changes.										

Presentation of the candidate

Code p and o (See chapter 2.4)

Description of the sources

Yellow cells indicate that the case is considered

Criteria part

Part to be completed with sentences or keywords by the user

frame

Conclusions

2.2 FORMAL DESCRIPTION OF THE AIRPORT REQUEST

"My airport is constituted of 2 parallel runways whose one with a dedicated landing operations and the second one with a mix operations. How could I enhance the staggered approach and take advantage of my airport specificities?"
How answer correctly to this problematic? Before to decide something, listen all the particular needs of the airport operator could not be wrong. In this way, the process proposes to list all the needs in a dedicated request form.

2.2.1 GOAL OF THE REQUEST FORM

The feature of the request form is to provide to the airport operator the ability to describe the specific needs of the airports. They are described with the help of some criteria, chosen to be so far as closer to the criteria expressed in the database of candidates. Using the same criteria will allow for a quick and robust research of the possible candidates accordingly to the airport operator's wishes.
The structure of the form is divided into three main chapters to propose a global and simple view of the airport needs. Firstly, a short description gives a general overview of the airport. Secondly, the criteria which have to be used for the comparison are listed. Finally the expected capacity needs can be indicated.

2.2.2 CONSTITUTION OF THE REQUEST FORM

The structure to build up a request form answering to the needs of the airport operator is explained in this subchapter. The form to fill in presents a lot of similarities with the database of candidates, and these are a real asset for the creation of the comparison matrix because it allows more easily the connection of the two forms.
The paragraphs concerning the presentation of the candidate is changed into a paragraph describing the airport particularities. The criteria used to characterise the specifications of the candidate have been modified into criteria used to designate the user needs. Then the part serving as a conclusion stays unchanged.

2.2.2.1 AIRPORT OVERVIEW

The general presentation gives information to the airport and his environment.
This should include the airport name, the ICAO and IATA codes. A line should be dedicated to write the date when the airport request has been fill in or upgraded.
A line of the form designated Overview – AIP Chart is conceiving to link the airport request with a description chart of an airport such as JEPPESEN charts.
The last entry of the first paragraph of the form should indicate the number of runways available in the airport.

2.2.2.2 CRITERIA USED FOR THE REQUEST

This paragraph of request form deals with the choice of criteria selected to define the airport needs. The idea is to develop a similar model in order to generate cohesion between the request and the database of candidates. The simplest way to generate cohesion is to develop the same model and that means technically the use of the same criteria.

Maturity
The maturity appears to be the first criteria on the questioning form. The maturity delivers an overview of the candidate developing stage. The expected maturity for the candidate is written in the request form while the actual maturity of the candidate is available in the form developed to describe the candidate.
The graphic interface of this criterion should include the same scale than the form dealing with the description of the candidate. The explanation related to the maturity scale proposed in the form is available in the candidate chapter. The TRL and OECVM comparability is also conducted in the chapter 2.2.2.

Dates
Airport operator should have the possibility to insert the date when he wants to introduce the candidate to the airport. This criterion aims to plan the next dates and steps for the capacity improvements. Named effective date, this criterion highlights the airport deadline for the introduction of the candidate. A time scale ranging from 2010 until 2030 appears to be in agreement with the actual research programs.

Weather
The weather parameters are also taken into consideration in the request. The user should be able to describe in the request form the expected meteorological conditions. Thanks to this information about the weather, the form would be able to propose a compatible solution to solve the throughput problems occurring under specific weather. To be comparable with the form of candidates, the choice between VMC and IMC conditions is proposed. The ILS categories (CAT I, CAT II, CATIII) come also in consideration, for example for the candidates dealing with the Arrival-Arrival scenarios (See chapter 1.5.1). The subcategories of the CAT III (A; B; C) do not have any significant influence in this situation (criterion too much specialized for the situation and then a very restrictive use in the process). The subcategories should not be included in the airport request.
The horizontal and vertical visibility is very useful criterion for the selection of the appropriate candidate.
As the wind parameters are specific for each airport, the required minimum or maximum values of winds have to be quoted in a line of the request form. This line should also specify if the airport operator is looking for a candidate affected by the crosswinds. For example, the scope for the introduction of a WV reduction candidate can be discussed with the help of the local meteorological centre and the weather statistics in the considered airport.

Type of operations
Lots of candidates are working optimally with a sole airport configuration or scenario. These criteria describing the airport aim to specify the configuration and runway use that are required by the airport operator. Within the scope of improving the airport capacity, the runway systems are detailed point by point in the request form to be sure that the candidate will be the optimal proposal for the airport runway enhancement.

The data related to the type of operations deals with the runway configuration cases (single runway, crossing runways, parallel runways and open V) and the runway use (Arrival-Arrival, Departure-Arrival, Arrival-Departure, Departure-Departure cases).
A line should be inserted in order to precise with one sentence an airport particularity.
The type of traffic is also taken into consideration. This criterion deals with the three main categories of traffic and a dedicated line should be filled in with the percentage of the traffic repartition (e. g. Small = 10 %, Medium =70 %, Heavy = 20 %).

Costs
The criterion of cost is the last criterion to be proposed for the request form. As the user wants to determine the payer of the candidate, the criterion is organised in two parts.
The first one deals with the assessment of the cost (Qualitative or Quantitative aspects) whereas the second one try to answer on the question: who have to pay for the candidate?
The user has the possibility to insert a maximum price value for the four considered domains (ATC, airport, airlines and other) like as the form of the candidates.

2.2.2.3 CONCLUSION

The last part of the request form is dedicated to fulfil the capacity needs by the airport. This paragraph could be divided into two main lines, which are the actual capacity and the expected needs.

2.2.3 EXAMPLE OF A REQUEST FORM

A graphic interface including all the elements described in the subchapter 2.2.2 have been created. As proposed, the structure of the request form is divided into three parts, the first one presenting the airport, the second one is required to define the airport particular needs and the last paragraph of the form is conceive to inform the expected capacity.

The contents of the airport request would be organized in accordance with the following table:

Table 10: Example of an airport request form

Frankfurt/Main Runways parallels close 25 L and 25R											
I. AIRPORT											
Airport name	Flughafen Frankfurt am Main										
ICAO - IATA name	EDDF						FRA				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	3	07L/25R		07R/25L		18/36					
Notes	Runway 18/36 is only used as depart on the 18.										
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	**6**	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	**V3**	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	**2014**	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	**IMC**							CAT I	**CAT II**	**CATIII**
Visibility	Horizontal		2 NM			Vertical					
Wind	<	**>**	10 m/s							**Crosswind**	
Notes	Winds coming from the North East										
Ice - Snow											
TYPE OF OPERATIONS											
Runway system	Single		Crossing		**Parallel**		Open V		All cases		
			Close	Middle	**Close**	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		**All cases**		
Notes	Dependant arrivals runways 25L and 25R										
Runway traffic (%)	Small	5		Medium		65		Heavy		30	
COST											
Value	Quantitative									€	$
	Qualitative		5 millions							**€**	$
Cost Stakeholder	**ATC**	DFS implication		**Airport**	Fraport GmbH		Airlines			**Other**	
III. CONCLUSION											
Capacity needs	Now: 79 mov/h Objectives: 82 mov/h										

Presentation of the airport

Definition of the airport needs

Expression of the capacity needs

2.2.4 ARRANGEMENT FOR THE MULTIPLE REQUESTS

As every airport is unique and needs a specific answer to its difficulties, the method is developed to simultaneously complete several airport request forms. This option has the asset to increase the number of criteria and consequently gives a more accurate vision thanks to the multiple airport requests.

The following figure introduces the architecture developed to increase the performance of the method.

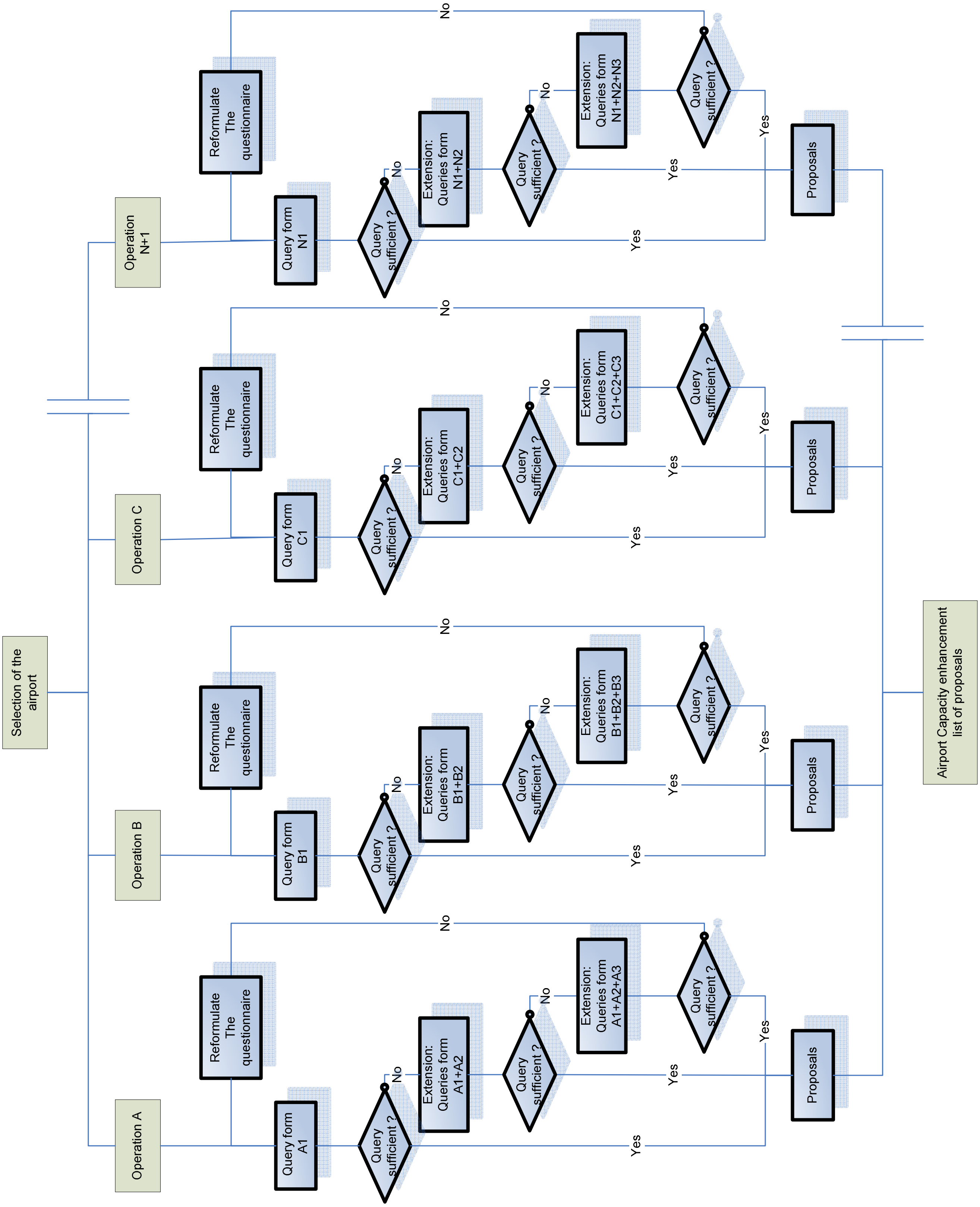

Figure 30: Architecture of the request

The start of this enhancement is to focus the subject to the specific needs of the airport. The second stage is to separate the airport into various modes of operation. This phase of separation has to be defined according to the needs of the airport. It could be interesting to divide the mode of operations into the interest dedicated to the runway. That is to say that the several request will only be focused on a runway use. Otherwise, another strategy consists to define the needs with various meteorological conditions (e. g. first request dealing with the icing conditions, second request dealing with the summer conditions), etc…The strategy to organize the multiple request is left free to the user. This mode of operation is summarized with a letter (A, B, C) to avoid the mistakes with the different levels.
Once the mode of operation is defined, the third level of the process of the multiple requests is related to put in order the queries. The process of the multiple requests defines architecture able to support three consecutive queries. The consecutives queries are defined with a number. They are justified by the case where the first stage of queries (queries referenced *.1) does not give a positive answer. Indeed the user fills in the request form and sends his request to the matrix achieving the comparison. From that moment, two possibilities are predicted:

- If the request is sufficient, the user receives directly a list of proposals.
- If the request is too restrictive for the database of candidates and none of the candidate has been proposed by the comparison matrix, a second request should be proposed in order to receive a list of proposals.

Then this loop can be repeated one more time. If the third request replies without any proposals, the process of the multiple requests must offer to the user to order another questionnaire form. The loop is consequently closed.

2.3 CONNECTION BETWEEN THE DATABASE AND THE REQUEST: THE COMPARISON MATRIX

2.3.1 GOAL OF THE MATRIX

The goal of the comparison matrix is to create the list of possible candidates exploring the similarities between the airport requests and the database of candidates. With the purpose to take advantage of the connections between the requests and the database interfaces, the comparison matrix made know the candidates replying correctly to the airports queries.
This scheme is facilitated because most of the criteria taken in the database of candidates have the same function and designation than these in the airport request.

2.3.2 ELEMENTS LINKING: THE CRITERIA

Prior to present the graphic interface created to link the airport request and the database, the report justifies the use of the criteria in order to achieve the comparison.
The first goal of the criteria is to order the specifications of the candidates or the needs of the airport into a formal structure. This point has been strongly detailed in the two preceding chapters. The second role of the criteria is to associate the airports needs with the candidate specifications.

The following figure shows the links between the airport request and the database of candidates. To facilitate the comprehension of the connection between the airport request and the database of candidates, questions from each side have been asked.
The database of candidates has more criteria than the airport request proposes, but this point is justified by the necessity to describe the most accurately the candidate. The method is using the description with the criteria (instead of writing paragraphs), and more criteria have to be used to define the candidate than the airport request need.

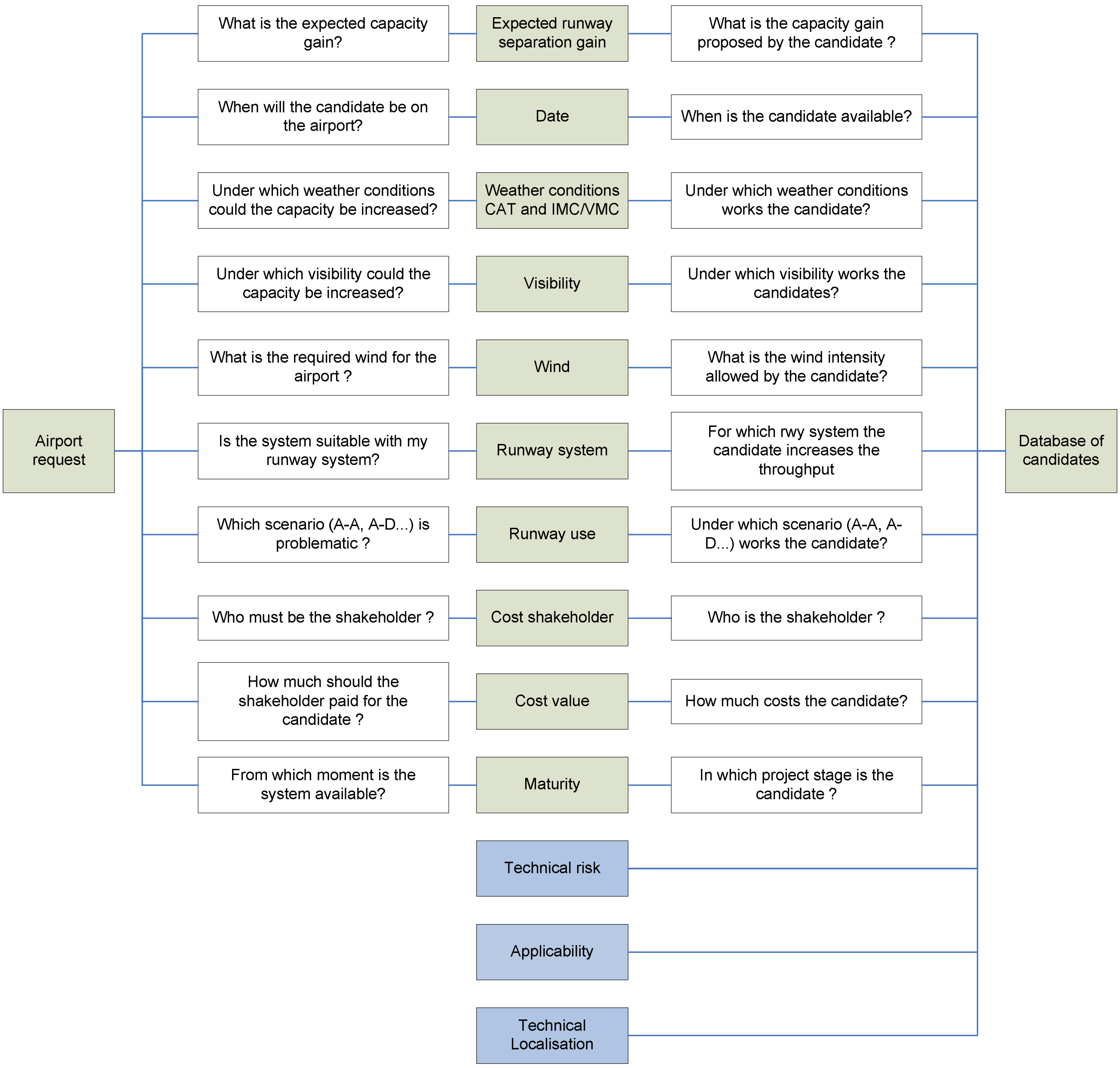

Figure 31: Links between the request and candidates criteria

2.3.3 EXAMPLE OF THE COMPARISON MATRIX

In order to illustrate how the matrix takes effect, the following table present the particularities of this tool. Each candidate has a dedicated matrix to make the comparison between the (multiple) requests and the criteria of the candidates.

As in the figure 31 shows, ten criteria are selected for the calculations. They are described in the left part of the table whereas the multiple requests are located on the top of the table (See Table 11). That allows the addition of many requests in the right side of the table as the user wishes without difficulties.
Four possibilities can be filled in the case dedicated to the answer:

1. Yes: The candidate criterion answers correctly to the query
2. No: The candidate criterion does not answer positively to the query
3. NI (Not Inquiry): the point in the request form is not formulated.
4. NC (Not in the Candidate form): the information is not fulfilled in the candidate criterion and in view of this, it is impossible to answer correctly to the request requirements.

When the candidate answers positively to one of the four possibilities, the value of the table should be shifted into “1”. A “1” in the No column indicates that the candidate does not answer to the query and is directly considered as eliminated the candidate from the proposal list. The value is highlighted in red and allows the user to identify at first sight the no validate criterion and maybe to take some corrections on his request.
As a conclusion, the matrix identifies all the No answers and delete the candidate from the list of proposal for a certain request. After this first selection, the computations must compare the “Yes” answers of the candidates answering to a particular request.
When this stage is achieved, this tool generates the list of possible proposals with in first position the candidates having the highest rate of “Yes” answers and followings, by decreasing number of “Yes” answers.

To be as close as possible to the users needs, the table includes the possibility to add a weighting system to the criteria. The weighting system goal is once again to give to the user the possibility to balance the criteria. The variation of the weighting would be seen as an option working to accommodate more accurately the user.
To maintain the logic, the weighting system is only expressed one time for the entire comparison process (the whole candidates of the database). Otherwise, the comparison has no more meaning because the candidates compared are not balanced in the same way. The example in the section three of the report will detail more precisely how to use optimally the weighting system.

Table 11: Example of the matrix comparing two queries A.1 and B.1 to the candidate

CANDIDATE			A.1				B.1			
Criterion	Designation	Weighting	A23D23				A05.D05			
			Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1								
B	Introduction Date	1								
C	Weather conditions IMC/VMC	1								
D	Weather conditions CAT I/ II/ III	1								
E	Weather conditions Visibility	1								
F	Weather conditions wind Crosswind	1								
G	Runway System	1								
H	Runway Use	1								
I	Cost value	1								
J	Cost Payer	1								
Total	Yes (Y)		0				0			
1	No (N)			0				0		
	Not Inquiry (NI)				0				0	
	Not Candidate (NC)					0				0
Total	Yes (Y)		0				0			
1	No (N)			0				0		
+	Not Inquiry (NI)				0				0	
weighting	Not Candidate (NC)					0				0

This comparison table is divided into two parts. On one hand, the criteria of the candidate are compared with the airport request. On the other hand, the points are calculated in order to list the candidates answering correctly to a particular request. An example with fulfilled matrix is presented in the section three of the work and the appendix 7 includes all the comparison matrices.

2.4 REMARKS ABOUT THE PROCESS

All the illustrations of the forms can be modifying using MS EXCEL because this tool is optimal to create the form and the enhancements are quickly achieved. Besides, the form is the first step of the developing of a database programming, which can increase the power of the process.

In the database of candidates, the second column of the form is reserved to a source guideline. Letters p and o, respectively meaning Paper and Own could be written in this case: This indicator informs the user that the information comes literally from the paper or has been estimate by the person whose fulfil the database.
To describe the request form, the word query is frequently used.
A three colour code has been built up in the database of candidates and in the airport request sheet. This colour code aims to define if the criterion in the case can be considered as true, false or unknown

- White background: false, the case in the case is not considered.
- Yellow background: true, the case in the case is considered.
- Orange background: unknown, there is no idea of the influence of the candidate in this criterion (only for the database of candidates).

Furthermore the package of the planned improvements SESAR and NEXT GENERATION is available in the datasheet known “information” in the EXCEL files.

It should be noted that the entire form is sometimes not fully fulfilled.
The information is not available in the publication or simply has not been evaluated. This lack of information is really problematic for the sequencing of the process. It influences notably the further calculations and makes more complex the computation to obtain the list of proposal.
Indeed, the possibility not in Candidate “NC” is totally dependant of the lack of information in the candidate form.

3 IMPLEMENTATION EXAMPLE

The section 3 is dedicated to the illustration of the method in order to accentuate the produced advantages. This aims to propose a concrete example with an airport which experiences capacity difficulties. All the thinking steps are detailed here to justify the feasibility and the contribution to the capacity improvement process.
To respect the sequence of the method, an imaginary capacity problem has been identified.
Up this starting point, a request specifying the needs of the airport has been written. Then the matrix compares the needs of the airport with the candidates constituting the database of candidates. The process to obtain the list of possible proposals is practically explained. A list answering to the specified needs is proposed and the technological solutions issues from the list are described.

Hamburg airport is chosen to illustrate the method. This German airport knows some extension difficulties due to the saturation of the area close to the airport facilities. The airport is included in the suburbs area of Hamburg. Extensions projects like the construction of a new runway are considered but difficult to be achieved in short terms. Consequently, the airport operator must find some alternative solutions to increase temporary the air traffic and the airport capacity in Hamburg.

3.1 DEFINITION OF THE PARTICULAR AIRPORT NEEDS

The strategy for the Hamburg Fuhlsbüttel example is to compose four requests, each one being dedicated to a specific runway scenario (See Appendix 6 for detail about Hamburg Airport).
Subsequently the first form deals with the use of the runway 23 in single operations. The second is concentrated on the single use of the runway 05. The third form deals with the crossing operations using the runway 15 for arrivals and the runway 23 for departures. The fourth request is focused on the crossing operations with the runway 33 dedicated for departures while arrivals are conducted on the runway 05. An analysis of the airport shows that runway 33 in single use has an occurrence close to zero.

3.1.1 QA.1: RUNWAY 23 IN SINGLE USE

The first request identifies the particularities of the runway 23. In this case, the airport operator is looking for:

- a mature candidate because he needs a system having reach the TRL 9,
- an available candidate,
- a candidate working with the IMC conditions,
- a candidate taking effect under the CAT III category,
- a candidate working with visibility of 1 nautical mile,
- a candidate able to optimally work with crosswind situations defined with winds stronger than 10 m/s. This specification has been made with the help of the weathers data coming from the airport statistics.

- The snow or the icing is not taken into consideration in this request,
- The required configuration scheme is a single use of the runway 23,
- All four types of scenario are taken into consideration (Arrival-Arrival, Arrival-Departure, Departure-Departure, Departure-Arrival).
- The traffic in the runway is the following: 15 % Small, 70 % Medium, 15% Heavy
- The costs are expressed quantitatively and a candidate who cost few million of euros answers positively to this request.
- The Deutsche Flugsicherung (DFS) has not implication in the program to enhance the capacity of the runway 23. The stakeholder is the company supervising the operation in Hamburg Airport, that is to say Flughafen Hamburg GmbH.

Hamburg airport runway capacity team has identified that the runway is at 12,3 % of the time used in single use. In this scheme, the airport operator wishes to obtain 50 movements per hour, adding two movements.

Table 12: HAM runway 23 single use and crosswind configuration request

Hamburg Fuhlsbüttel rwy 23 single											
I. AIRPORT											
Airport name	Hamburg Fuhlsbüttel										
ICAO - IATA name	EDDH						HAM				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	2	05/23		15/33							
Notes											
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	6	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	IMC							CAT I	CAT II	CATIII
Visibility	Horizontal		1 NM			Vertical					
Wind	<	>	10 m/s							Crosswind	
Notes	Strong winds reduce operations to single runway use.										
Ice - Snow	No information										
TYPE OF OPERATIONS											
Runway system	Single		Crossing		Parallel		Open V		All cases		
			Close	Middle	Close	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	Single use: rwy23 = 12,3 %										
Runway traffic (%)	Small	15		Medium		70		Heavy		15	
COST											
Value	Quantitative									€	$
	Qualitative		Few millions							€	$
Cost Stakeholder	ATC	without DFS implication		Airport	Flughafen Hamburg		Airlines			Other	
III. CONCLUSION											
Capacity needs	Now: 48 mov/h Objectives: 50 mov/h										

3.1.2 QB.1: RUNWAY 05 IN SINGLE USE

The second request is dedicated to the runway 05 for take-off and landing. In this configuration, the airport operator requirements are very similar to the ones of the runway 23:

- Maturity is reduced to level 5 on the TRL scale (V3 on EOCVM),
- The effective date of introduction is pushed back to 2020,
- The candidate must work with the IMC and under CAT III conditions,
- The candidate must work with a visibility of 1 nautical mile,
- He has to be able to enhance the capacity with winds higher than 10 m/s and during crosswind conditions,
- The runway considered in use is the runway 05 in single use,
- The candidate must specifically propose improvements for arrival-arrival scenarios.
- Cost requirements should not exceed 10 Millions euros.
- The expected gain with the candidate must be able to add two movements per hour.

However operations on this runway on single use scheme are less frequent than on runway 23 configuration (9,5% of the time).

Table 13: HAM runway 05 single use and crosswind configuration request

Hamburg Fuhlsbüttel rwy 05 single											
I. AIRPORT											
Airport name	Hamburg Fuhlsbüttel										
ICAO - IATA name	EDDH						HAM				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	2	05/23		15/33							
Notes											
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	6	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	IMC							CAT I	CAT II	CATIII
Visibility	Horizontal		1 NM			Vertical					
Wind	<	>	10 m/s							Crosswind	
Notes	Strong winds reduce operations to single runway use.										
Ice - Snow	No information										
TYPE OF OPERATIONS											
Runway system	Single		Crossing		Parallel		Open V		All cases		
			Close	Middle	Close	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	Single use: rwy05 = 9,5 %										
Runway traffic	Small	15		Medium		70		Heavy		15	
COST											
Value	Quantitative		10 Millions							€	$
	Qualitative									€	$
Cost Stakeholder	ATC	without DFS implication		Airport	Flughafen Hamburg		Airlines			Other	
III. CONCLUSION											
Capacity needs	Now: 44 mov/h Objectives: 46 mov/h										

3.1.3 QC.1: ARRIVAL RUNWAY 15 AND DEPART RUNWAY 23

As the strategy is to divide the airport request into particular runway requests, the third case is related to the runway 15 operations. The runway 15 is rarely used in single use. That is why, in order to answer correctly to the individual needs of the airport, runway 23 is added for departures while the runway 15 achieves the landings.

The request indicates that the searched candidates must respect the following conditions:

- The candidates must add at least 4 movements per hour.
- A maturity of level 8 or 9 (TRL scale) is required, that is to say that only the candidates with a maturity of 8 or those why a maturity of 9 could be selected.
- An effective date of delivery from 2016 is required,

- No weather conditions or restrictions are noted, only the VMC are required,
- The candidate have to work in crossing situations, so in this case with the runway 05/23 in duty.
- It should be cost less than 10 Millions of Euros.
- Like the other queries, the costs have to be paid by the airport operator and the DFS should not have any implication in the costs.

All these conditions are noted in the request D.1 and the Table 14 illustrates the questioning.

Table 14: HAM crossing Arrival runway 15 and Depart runway 23 request

Hamburg Fuhlsbüttel crossing Arr 15 Dep 23											
I. AIRPORT											
Airport name	Hamburg Fuhlsbüttel										
ICAO - IATA name	EDDH						HAM				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	2	05/23		15/33							
Notes											
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	6	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	IMC							CAT I	CAT II	CATIII
Visibility	Horizontal					Vertical					
Wind	<	>								Crosswind	
Notes	Strong winds reduce operations to single runway use.										
Ice - Snow	No information										
TYPE OF OPERATIONS											
Runway system	Single		Crossing		Parallel		Open V		All cases		
			Close	Middle	Close	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	Depart RWY 23 and Arrival RWY 15										
Runway traffic (%)	Small	15		Medium		70		Heavy		15	
COST											
Value	Quantitative		10 Millions							€	$
	Qualitative									€	$
Cost Stakeholder	ATC	without DFS implication		Airport	Flughafen Hamburg		Airlines			Other	
III. CONCLUSION											
Capacity needs	Now: 40 mov/h Objectives: 44 mov/h										

3.1.4 QD.1: ARRIVAL RUNWAY 05 AND DEPART RUNWAY 33

The fourth request describes the runway 33 use. Nevertheless, the runway 33 is hardly ever used in a single situation (close to 3% per year). Consequently, it is more interesting to consider the configuration when dual runways (33 and another runway) are working. The runway 05 has been chosen for the landing operations and the needs related to this runway are the following:

- The enhancement would be from the year 2016 available,
- A system which is totally developed (maturity level 8 or 9).
- The system has to work with the VMC conditions. No ILS categories are requested for the landing approach, although the runway 05 is equipped with an ILS CATIII.
- The type of operation describes the crossing configuration and indicates the runways 05 for the landings and the runway 33 is dedicated to departures.
- No specifications about the weather conditions are specified in this request.
- The costs of the candidate should not exceed 5M Euros
- Cost specifications are not clearly specified, the request indicates only that the payer is the airport operator.

The candidate must enhance the runway capacity of four traffics per hour to reach 48 movements per hour with this configuration

Table 15: HAM Arrival runway 05 and Depart runway 33 request

Hamburg Fuhlsbüttel crossing Arr rwy 05 Dep 33											
I. AIRPORT											
Airport name	Hamburg Fuhlsbüttel										
ICAO - IATA name	EDDH						HAM				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	2	05/23		15/33							
Notes											
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	6	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	IMC							CAT I	CAT II	CATIII
Visibility	Horizontal					Vertical					
Wind	<	>								Crosswind	
Notes	Strong winds reduce operations to single runway use.										
Ice - Snow	No information										
TYPE OF OPERATIONS											
Runway system	Single		Crossing		Parallel		Open V		All cases		
			Close	Middle	Close	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	Depart RWY 33 - Arrival RWY 05										
Runway traffic	Small	15		Medium		70		Heavy		15	
COST											
Value	Quantitative		5 Millions							€	$
	Qualitative									€	$
Cost Stakeholder	ATC	without DFS implication		Airport	Flughafen Hamburg		Airlines			Other	
III. CONCLUSION											
Capacity needs	Now: 44 mov/h in single use Objectives: 48 mov/h										

<u>Summarize:</u>

The four queries created to describe the needs of the airport of Hamburg are now defined with the criteria. The next step of the work consists to compare the data (values) of these criteria with the values written in the database of candidates. To achieve correctly this step, 12 candidates coming from various research projects have been studied. This range of candidates aims to furnish one or several candidates answering correctly to the four requests.

3.2 MATRIX DETERMINING THE OPTIMAL PROPOSALS

As explain in theory in the chapter 2.3, the various queries and the candidates have to be linked together. The extraction of (a list of) proposals is carried out with a matrix which adds up the queries and the candidates. The calculations should be later automated with the development of the database.
An example, following the four requests is here suggested to give a good understanding of the powerful of the process.

3.2.1 COMPARISON WITHOUT WEIGHTING CALCULATIONS

Values are calculated in the bottom part of the matrix. This total is divided into two parts: The first part presents the results without weighting whereas the second part of the table includes the candidates weighting system.
The totals are also sent to another table, which summarizes the results for all the candidates. The following table presents the results for the candidate n°6 "Ground Markers".

Table 16: Matrix comparing the intersecting take-off candidate with the request

CANDIDATE 6: Ground markers			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1		1			1					1				1		
B	Introduction Date	1		1			1				1				1			
C	Weather conditions IMC/VMC	1	1				1					1				1		
D	Weather conditions CAT I/ II/ III	1	1				1						1				1	
E	Weather conditions Visibility	1	1				1					1				1		
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	1	1				1					1				1		
H	Runway Use	1		1			1					1			1			
I	Cost value	1				1				1			1				1	
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		6				9				2				3			
1	No (N)			3				0				5				4		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					1				1				0				0
Total	Yes (Y)		6				9				2				3			
1	No (N)			3				0				5				4		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					1				1				0				0

The addition of the "1" without weighting is calculated in the first part of the Total table. As all the weighting (second column) are selected with the 1 value, both totals are here equals.
A "No" answer in the table is highlighted in red to easily show which criterion eliminates the candidate of the future proposal list.
The Candidate 6 "Ground Marker" case answers correctly to the query B.1 with a result of 9.0.0.1 (code Yes.No.NI:NC). He is consequently noted in the final table which lists the candidates who answer correctly to one of the four queries.
The candidate answers not particularly well to the three other requests. (results in the table 6.3.0.1; 2.5.3.0 and 3.4.3.0).

3.2.2 COMPARISON WITH WEIGHTING CALCULATIONS

In this second example, the weighting is added to the matrix. It aims to reinforce a criterion influence or to delete (weighting = 0) the criterion from the criterion list.
The following figure shows the same candidate as in the previous paragraph but the table includes components different from 1 in the weighting column.

Table 17: Weighting added to the matrix

CANDIDATE 6: Ground markers			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1		1			1					1				1		
B	Introduction Date	2		1			1				1				1			
C	Weather conditions IMC/VMC	1	1				1					1				1		
D	Weather conditions CAT I/ II/ III	1	1				1						1				1	
E	Weather conditions Visibility	1	1				1					1				1		
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	2	1				1					1				1		
H	Runway Use	3		1			1					1			1			
I	Cost value	1				1				1			1				1	
J	Cost Payer	1	1				1				1				1			

Total	Yes (Y)		6				9				2				3			
1	No (N)			3				0				5				4		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					1				1				0				0
Total	Yes (Y)		7				13				3				6			
1	No (N)			6				0				8				5		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					1				1				0				0

In this scheme, the introduction date (weighting 2), the runway system (weighting 2) and the runway use (weighting 3) are considered more important than the other criteria (weighting 1). Any criterion is considered not required for the calculation (weighting = 0).
With the use of weighting, candidates total is modified: the query A.1 and C.1 have their "No" values which increase and this point reinforces the idea that the candidate does not answer correctly to the queries.
The candidate is strongly reinforced as a good answer to the request B.1 with 13 "Yes" instead of 9 positive answers.

3.3 LIST OF PROPOSALS

The next step of the process consists in a table showing the results of the comparison matrix between the database of candidates and the queries. The aim is to sort the candidates which get the maximum of "Yes" values, the absence of "No", the minimum of "Not Inquiry" or "Not Candidate" answers for each candidate.

For this example, the sorting has been effected with the weighting system and the following figure illustrates the ranking issue from the comparison.

Table 18: Candidates sorting

candidates sorting:				
Query A.1	7			
Query B.1	6	7	8	3
Query C.1	7			
Query D.1	7	1	2	

<u>Request A.1</u>
Only the candidate 7 Brake to Vacate can be selected as possible candidate. The eleven other candidates have a criterion including a "No" and they are excluded of the process for this request.

<u>Request B.1</u>
In this way, four candidates are presented as possible proposals because they do not have a "No" answer. The selection step must then define which candidate gives the best answer to the query. As a result of which, the ranking depends of the number of "Yes" obtained during the calculations.

The ranking proposes the following candidates:

- Candidate 6: Ground Markers
- Candidate 7: Brake to Vacate
- Candidate 8: WVAS
- Candidate 3: Rapid Exit Taxiway

The candidates Brake to Vacate, WVAS and Rapid Exit Taxiway obtain the same values of "Yes" answers. In order to enhance the calculation, it could be interesting to change one of the criteria of the needs of the airport, and to achieve another comparison. The ranking result could be different and therefore the listing of the possible proposals more useful.
Otherwise, it could be interesting to propose a combination of the proposals. Implemented several systems totally independent but working for the same goal could provide more results, in terms of capacity increasing than the implementation of only one system.

<u>Request C.1:</u>
As in the query A.1, only the candidate 7 Brake to Vacate can be selected as possible candidate.

<u>Request D.1:</u>
Three candidates are selected in the first sight:

- Candidate 7: Brake to Vacate
- Candidate 1: Intersecting take-off
- Candidate 2: ROT Reduction through pilot/control awareness

After this process, the airport operator has now in hands the proposals which are designated to increase the airport capacity and following the queries expressed in the paragraph 3.3.2. Until now, these proposals could be used as input for the exploration, assessment and selection part in the airport studies (See figure 26).

3.3.1 QA.1: BRAKE TO VACATE PROPOSAL

The brake to vacate system is a candidate which should be seriously considered because it answers correctly to the four queries A.1, B.1, C.1 and D.1. Experimentations have shown that the BTV system plays an important role for the landing ROT optimization and generates time gain during landings.

Moreover the mature and currently available technology is a real asset for this candidate.

Table 19: Brake to vacate proposal

I. CANDIDATE												
Name	p	Brake To Vacate (BTV)										
Short description	p	BTV gives pilots real-time visibility on realistic braking distances to reach their prefered exit. When the pilot chooses a runway exit point, the system indicates the estimated runway occupancy time and the minimum turnaround time. during low visibility conditions, the system optimise the landing roll and brake just necessary to vacate the runway										
SESAR-NextGen topic	p	Brake To Vacate procedure										
II. SOURCES												
Name, authors	p	Brake to vacate, Airbus										
Date of the document	p	2008										
Website	p	http://www.airbus.com/fileadmin/media_gallery/files/brochures_publications/FAST_magazin										
Contact	p	fabrice.villaume@airbus.com										
Airport-aircraft testbed	p	TLS	A346	A388								
Composition date	p	July 2010										
Manufacturer-Developper	p	Airbus System Engineering										
Technical prerequesite	p	GPS - Airport Navigation Autoflight - Autobrake systems										
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	EASA certified										
DATES												
Progress		Available on the A380 - soon available on the A320 family										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	o	<	>								Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes		None										
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
											Manufa	
Technical localisation		Airport										
	p	Aircraft	system incorpored on the aircraft									
		Tower										
		Other										
Applicability	o	No information										
Expected gain time/ops		tbd										
Technical risk	o	Airbus patent rights Only available for certain Airbus aircraft										
IV. CONCLUSION												
Gain	o	Expecting AIB answer										
Extra gain	o	Gain for the maintenance										
Remarks	o	Manufacturer Boeing works on a similar topic										

3.3.2 QB.1: GROUND MARKERS PROPOSAL

This Ground Markers candidate answers the request B.1. This new technology aims to reduce the occupation of the runway and facilitate the vacating of the runway. Ground markers are also expected to reduce significantly the landing ROT, especially during bad weather. This solution includes a voice presentation of the next runway exit distance. The pilots can optimize the braking sequence in the runway according to the exits distance and this solution could consequently allow a ROT gain.
However, the current maturity stage could disqualify the candidate for others queries.

Table 20: Ground Markers proposal

I. CANDIDATE												
Name	p	Ground Markers										
Short description	p	The goal of the aircraft Marker Receivers is to reduce the landing ROT. Under reduced visibility, landing pilots have difficulties to reach runway exits at the optimum ground speed. Throught low powered transmitters and taxiways embedded antennas, aircraft Marker Receivers can provide clear voice airfield positional information to taxiing pilots. Pilots are vocally advised of the "distance to go" to runway exits.										
SESAR-NextGen topic	p	Guidance assistance to aircraft on the airport surface										
II. SOURCES												
Name, authors	p	Reduced Runway Occupancy Times, Nigel Corrigan										
Date of the document	p	June 2005										
Website												
Contact	p	groundmarker@axis-electronics.com										
Airport-aircraft testbed												
Composition date	o	June 2010										
Manufacturer-Developper	p	Axis Electronics										
Technical prerequesite	p	FAA Runway Incursion Prevention Programme										
III. CRITERIA												
MATURITY	o	TRL	0	1	2	3	4	5	6	7	8	9
	o	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	o	Flight simulator trials achieved but with a instructor pilot voice to prevent the exit distance instead of the automatic voice like GPWS.										
DATES												
Progress	p	10 initial assesment trials were conducted using a B737 flight simulator. No avancement dates are stipuled.										
Date of introduction	o	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	p	<	>	Solution independant of the wind characteristics							Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	p	Reduce the ROT singnificatly for single runway operations										
COST												
Value		Quantitative										
		Qualitative		to be define								
Cost Stakeholder		ATC			Airport	not clearly explained		Airlines	not clearly explained		Other	Aircraft manuf
Technical localisation	p	Airport	Runway lateral equipment									
	p	Aircraft	Voice system									
		Tower										
		Other										
Applicability	o	No information										
Expected gain time/ops	p	From 10 up to 20 seconds per landing ROT.										
Technical risk	p	Occupancy times expected in the simulator are not reached in the real trials.										
IV. CONCLUSION												
Gain	p	During CATIII B Conditions, gain is expected to be similar to the ROT during a clearly weather conditions: a graphic shows a ROT reduction from 70 seconds (without Voice Advisoy) to approximatively 50 seconds (with Voice Advisory)										
Extra gain	p	Furthermore it bringt a reduction for the noice emission and brake maintenance										
Remarks	o	Paper not really clear. No changes are required on aircraft or equipment. The ATC can also propose the exit which they would prefer a landed aircraft to vacate the runway										

3.3.3 QB.1: WVAS PROPOSAL

The second possible answer to the request B.1 is the Wake Vortex Avoidance System. This system is an old system (research in 1988) and has never been in service due to several failures during the tests. Nevertheless he answers correctly to the request and as a result is presented in the list of proposals. It could be used to look for recent systems closer to the principle of this one.

Table 21: Wake Vortex Avoidance System proposal

I. CANDIDATE												
Name	p	Wake Vortex Avoidance System (WVAS)										
Short description	p	The WVAS is developped to provide a significant gain in airport capacity through reduced approach and departure times. This system combines the Vortex Advisory system (VAS) and the Vortex Warning System (VWS) to solve the wake vortex problems. The VAS is designed to take advantage of the wind direction criterion and via a simple display indicates when wake vortex separation need no longer to be applied.										
SESAR-NextGen topic	p	Fixed reduced separation based on wake vortex prediction										
II. SOURCES												
Name, authors	p	ICAO - Air traffic services planning Manual (II -5 -3 -12)										
Date of the document	p	03.11.1988										
Website												
Contact												
Airport-aircraft testbed	p	ORD										
Composition date	p	july 2010										
Manufacturer-Developper												
Technical prerequesite	p	Meteo sensor - ATC runway monitor - Ground Wind Vortex Sensing System Doppler Acoustic Vortex Sensing System										
III. CRITERIA												
MATURITY	o	TRL	0	1	2	3	4	5	6	7	8	9
	o	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes												
DATES												
Progress		Project closed : have been tested operationnaly in Chicago O´Hare Airport										
Date of introduction	o	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind		<	>								Crosswind	
Notes												
AIRPORT												
Runway system	o	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	o	Airport	Sensors									
		Aircraft										
	o	Tower	Tower Monitor									
		Other										
Applicability	o	No information										
Expected gain time/ops	p	aircraft spacing on approach of less than 3NM and 2NM could be used 86% of the time.										
Technical risk												
IV. CONCLUSION												
Gain	p	Not selected for further use										
Extra gain												
Remarks	p	The incidence of transitions through red/green warning lights do not provide sufficient time for the controller to change separation minima applied between various type of aircraft in a already established approach sequence										

3.3.4 QB.1: RAPID EXIT TAXIWAY PROPOSAL

The Rapid Exit Taxiway is another candidate form the list which has been selected. This proposal consists in analyzing the runway exits and taxiways possibilities in order to add the rapid exit taxiway solutions to the airport.

Table 22: Rapid Exit Taxiway proposal

I. CANDIDATE												
Name	p	Rapid Exit Taxiway										
Short description	p	The Rapid Exit Taxiway aims to reduce the ROT Landing. This reduction is generated with the construction of news taxiways, which with an acute angle make possible to vacate the runway with a high speed.										
SESAR-NextGen topic	p	Improved runway capacity accuracy										
II. SOURCES												
Name, authors	p	Airport capacity enhancement						Praha Ruzyne Airport				
Date of the document	p	2005										
Website	p	http://www.eurocontrol.int/airports/gallery/content/public/pdf/Prague%20leaflet%20Phase%2										
Contact	p	petr.hlousek@csl.cz										
Airport-aircraft testbed	p	LKPR										
Composition date	p	Aug 10										
Manufacturer-Developper												
Technical prerequesite												
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	Mature technology										
DATES												
Progress	p	Available										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	o	<	>								Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative		High cost compared to an 90° exit								
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	p	Airport	Taxiways									
		Aircraft										
		Tower										
		Other										
Applicability	p	For more than 30 peak period movements period										
Expected gain time/ops	o	not defined										
Technical risk	p	Difficult to use more than 3 rapid exit taxiways on each runway side if the runway, if the runway is already equiped with 90 degrees taxiways.										
IV. CONCLUSION												
Gain												
Extra gain												
Remarks	o	Solution easily implementable										

3.3.5 QD.1: INTERSECTING TAKE-OFF PROPOSAL

The intersecting take-off is the second proposal issue from the questioning form D.1. This proposal consists to predict the scheduling of the departing aircraft and to propose them alternative intersections to enter in the runway in order to save time during the take-off phases. Unfortunately, gains coming from this proposal have not been studied in the publication.

Table 23: Intersecting take-off proposal

I. CANDIDATE												
Name	p	Intersecting Take Off										
Short description	p	This procedure consists to propose to the pilots alternatives intersections for take off runs. It generates a high intensity runway operations, in particular when the airport traffic is constitued of commuter and turboprop aircraft.										
SESAR-NextGen topic	p	Improved threshold delivery accuracy										
II. SOURCES												
Name, authors	p	Airport capacity enhancement						Praha Ruzyne Airport				
Date of the document	p	2005										
Website	p	http://www.eurocontrol.int/airports/gallery/content/public/pdf/Prague%20leaflet%20Phase%2										
Contact	p	petr.hlousek@csl.cz										
Airport-aircraft testbed	p	LKPR										
Composition date	p	Aug 10										
Manufacturer-Developper												
Technical prerequesite												
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	Mature technology										
DATES												
Progress	p	Available										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind		<	>								Crosswind	
Notes												
AIRPORT												
Runway system	o	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	o	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes		The airport should have several runway entries										
COST												
Value		Quantitative										
		Qualitative		few millions								
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	o	Airport	news taxiways									
		Aircraft										
		Tower										
		Other										
Applicability	o	Each runway										
Expected gain time/ops	p	Reduce ROTD										
Technical risk												
IV. CONCLUSION												
Gain	o	Information not in the paper										
Extra gain												
Remarks	o	Not interesting if the traffic mix is not diversified										

3.3.6 QD.1: ROT REDUCTION THROUGH PILOT/CONTROL AWARENESS PROPOSAL

The ROT Reduction through pilot/control awareness is the last proposal coming from the request D.1. On the appendix, the matrix shows that this candidate receives less “Yes” answers than the other proposals but it passes the “No Go” sorting and consequently has to be inserted as a possible proposal.

Table 24: ROT reduction proposal

I. CANDIDATE												
Name	p	ROT Reduction through pilot/control awareness										
Short description	p	This airport dedidacted procedure provides an efficient use of the runway. It reduces delays, airlines costs (fuel savings), ROT and reaction times. This project requires close cooperation between pilots and controllers, particularly during peak periods. The pilots make their operations predictable to controllers by exiting at the recommended Rapid Exit Taxiway, for example.										
SESAR-NextGen topic	p	Use of runway occupancy time (ROT) reduction techniques										
II. SOURCES												
Name, authors	p	Lisbon Airport airport capacity enhancement						Lisbon airport				
Date of the document												
Website	p	http://www.eurocontrol.int/airports/gallery/content/public/pdf/Lisbon%20Awareness%20Leaf										
Contact	p	oliveirahall@ana-aeroportos.pt										
Airport-aircraft testbed	p	LPPT										
Composition date	p	Aug 10										
Manufacturer-Developper	o	Airports operators and airlines										
Technical prerequesite	o	Analysis of the taxiway system and measurements of the ROT Arrival and ROT Departure										
III. CRITERIA												
MATURITY		TRL	0	1	2	3	4	5	6	7	8	9
		EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	Mature technology										
DATES												
Progress	p	Available										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions		VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind		<	>								Crosswind	
Notes	p	May be dificult to be applied by the pilots under IMC										
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative		few millions								
Cost Stakeholder		ATC			Airport			Airlines			Other	
Technical localisation	o	Airport	eventually new RET									
		Aircraft										
		Tower										
	o	Other	procedure									
Applicability	p	All the time										
Expected gain time/ops		Not defined										
Technical risk	p	Pilots agreements for reacting promptly to all clearances, taxing directly and without delay to the centreline when cleared to line up, applying speed control accurately										
IV. CONCLUSION												
Gain	o	Information not in the paper										
Extra gain	p	Fuel savings										
Remarks	o	The "general" case must be adapted to the airport specificities.										

To summarize this section, the practical example has shown the three parts constituting the framework for assessing the candidates. The particulars needs of the airport have been presented into the airport query, while the matrix has compared the needs with the specifications of the candidates. As four queries have taken part to the process, the comparison has obtained several candidates which can be used as input for a detailed capacity study.

4 CONCLUSION

This conclusion is divided into three parts. The first part summarizes the work carried out in this report. The second one discusses the advantages of the method designed to enhance the runway throughput while the third part focuses on the further improvements which could increase the performance of the method.

The report presents a methodology which aims to solve runways capacity problems. This methodology consists of three main parts: a database of candidates, a request form specifically suited to the airport specificities and a matrix linking the database of candidates and the requirements of the airport operator that were determined through the request.
All the points coming from the methodology find their origins in the first section which aims to explain the challenges of the improvements for the runway separation parameters. Indeed, the current situation in runway time separation was outlined through the study of the runway rules and the parameters influencing these rules. This section has shown that limits such as wake vortex or radar separations restrict the field of improvements. Nevertheless the research works actively to enhance these limits with the development of new operational concepts presented in the part dedicated to the use of the runways.

At first sight the entire process may appear to be a complex scenario but the proposed method provides the user with the opportunity to determine the optimal solution for his individual airport scheme. In fact, the request form can adapt to all the needs and requirements of the airports. On one hand, this highly accurate approach is advantageous for the user because the database of candidate is able to provide sufficient technical knowledge and information, which eliminates the need to consult the subjective opinion of an expert. On the other hand, this approach saves a great amount of time, and may be achieved online during business meetings. The results are laid out in an explicit and comprehensible format for the participants of the business meetings.
The implementation of the proposal may even be discussed during the short timeframe of a business meeting. This aspect of the method is considered to be a real advantage to business managers during discussions with the airport authorities or operators.
The list of proposals facilitates the exploration for the airport studies. The data in the list of proposals are described so far as with facts, therefore the airport study already contains factual elements before the analysis in detail and the real time simulations begin.

The method describing the way of achievement some proposals solving a capacity problem is sufficient to work independently, however it can also be enhanced by incorporating several modifications.
For instance, the database of candidates could include more explicit values such as the percentage of use of the system in relation to the meteorological conditions. However these facts are really difficult to determine and the process will require significant upgrades before being able to include these indicators.
During the development of the methodology, a small database of candidates was set up. An enhancement of the method could consist to add several candidates in the database. The

variety of the database could be an enhancement, bringing diversity and the ability to provide a more precise list of proposals. The list of proposals gives a ranking of the systems that the user would be not able to identify independently.

The study was always centralized on the enhancement of the approach throughput and increasing the runway capacity. Moreover the method has been developed with a broad scope in order to allow for its application with other studies performed by the flight guidance institute of the DLR. For example, the capabilities of the process permit the selection of proposals for other flight phases. Other domains concerning the airport simulations can be taken into consideration without difficulty by the method. It could be able to perform with other themes such as security enhancements or environmental concerns related to the aeronautics.

Another possible modification would be to enhance the calculation of the weighting. This could be achieved through the implementation of an initial survey design to determine the most important criterion and thus generate the optimal weighting scenarios.

5 FRENCH SUMMARY

Malgré les récentes fluctuations dans le monde du transport, le trafic aérien européen est en augmentation et continue de croître d´une manière importante.

Actuellement, les aéroports européens sont confrontés à court ou moyen terme aux problèmes de saturation de trafic aux abords des aéroports. Alors que l´augmentation de la capacité de l´aéroport telle que des constructions de pistes est un processus à long terme, les compagnies aériennes ont une visibilité sur leurs activités sur des périodes beaucoup plus restreintes. Les solutions recherchées par les opérateurs des aéroports doivent donc résoudre les problèmes de capacité pour un futur proche tout en anticipant le trafic aérien des prochaines décennies.
Certaines places aéroportuaires, incluses aujourd´hui dans un environnement urbain dense sont directement confrontées à ces difficultés. Elles ne peuvent plus augmenter leur capacité d´accueil d´aéronefs par des expansions et de nouvelles infrastructures. Des solutions alternatives, respectant les critères actuels de sécurité et d´espacement entre les aéronefs en approche doivent de ce fait impérativement être trouvées.

Ce projet de fin d´études de cycle ingénieur intervient donc dans le processus d´amélioration des capacités de piste des plateformes aéroportuaires. Il se concentre sur la recherche des solutions améliorant la capacité piste pour les opérateurs des aéroports.
Le travail a été divisé en plusieurs domaines d´études. Tout d´abord, un état des lieux des problèmes de saturation des pistes a été entrepris. Il présente la situation du trafic aérien actuel et les différents paramètres qui le régulent et le restreignent.
A partir de cette problématique, le cœur du travail consiste à créer un outil permettant aux opérateurs des aéroports de sélectionner la solution adéquate pour résoudre leurs problèmes de capacités d´aéroports. Une illustration consistant à implémenter un aéroport d´une solution vient conclure ce travail.

5.1 FACTEURS INFLUENCANT LA CAPACITE PISTE

Il s´agit de connaître les limites des facteurs qui interviennent dans la détermination du débit de la piste. Le débit d´avions sur un aéroport est directement dépendant de la notion de vitesse de l´avion, du temps d´occupation des organes aéroportuaires (pistes, circuit d´approche) et au volume (masse) de l´avion. Cinq facteurs ont été recensés comme ayant une forte implication dans la détermination de la capacité des aéroports.

5.1.1 LES WAKE VORTEX

Les wake vortex sont des perturbations aérodynamiques issues du passage de l´avion dans l´air. Ces turbulences de sillages obligent les avions en vol à maintenir une distance de sécurité entre eux afin de ne pas se retrouver perturbés ou dépendant du flux issu de l´avion précédent. Aujourd´hui cette contrainte est une contrainte de type distance entre les 2 avions. Cette distance varie selon les législations des pays (voir table 25). Il est proposé de modifier ce paramètre en un temps fixé entre les deux machines qui se trouvent dans une phase d´approche des pistes des aéroports.

Table 25: Distances de séparation dues au Wake Vortex lors des phases d´approches

in NM		Trailing arrival			
		Small	Medium	Heavy	Super
ICAO Leading arrival	Small	2,5	3	3	3
	Medium	4 or 5	3	3	3
	Heavy	6	5	4	3
	Super	10	8	6	4
FAA Leading arrival	Small	2,5/3	2,5/3	2,5/3	2,5/3
	Large	3	2,5/3	2,5/3	2,5/3
	B757	5	4	4	4
	Heavy	5	5	5	4

5.1.2 LA SEPARATION RADAR

La séparation radar est une restriction qui intervient principalement dans les scénarios de type Arrivée-Arrivée. Le contrôle aérien (ATC), n´ayant pas de visuel sur l´avion, est restreint à suivre les informations de son écran radar. En fonction du type, de la résolution du radar et du rafraîchissement des données, la représentation radar des avions induit un flou sur la position exacte de l´avion. De ce fait, une condition de distance minimum entre 2 aéronefs est à maintenir pour éviter tout abordage. Cette séparation est elle aussi actuellement donnée en distance, et est généralement de valeur égale à 3 NM.

5.1.3 L´OCCUPATION DE LA PISTE

Une règle définit qu´il est impossible d´autoriser un avion à atterrir ou à entrer sur la piste tant qu´un autre appareil est situé sur la piste.

5.1.4 LES PARAMETRES METEOROLOGIQUES

La météo est un facteur influençant particulièrement la capacité des aéroports. Le trafic peut se retrouver perturbé en cas de mauvaises conditions météorologiques car les équipages des aéronefs n'ont plus de contact visuel sur les autres avions et ils doivent rester particulièrement vigilent en augmentant leurs distances de sécurité. Il convient d´étudier le levier agissant sur la possibilité d´augmenter la capacité lors de conditions météorologiques particulières et qui, avec les systèmes embarqués et les équipements actuels pourraient être résolus aujourd´hui.

5.1.5 LE SYSTEME DE PISTE

Les aéroports ont une structure différente: Le nombre de pistes varie généralement de une à six. Ces pistes peuvent être uniques, parallèles éloignées, parallèles adjacentes, sécantes. Elles peuvent aussi être utilisées de façon dédiée (Seulement atterrissage ou seulement décollage) ou alternés (mix atterrissage-décollage). Toutes ces configurations font évoluer la capacité d´accueil des aéroports.

5.1.6 LE TYPE DE SCENARIO ETUDIE

Le scenario est le mot employé pour définir les configurations existantes entre les avions et les séquences de décollage et atterrissage.
En fonction du type de scenario, les 2 appareils ne sont pas séparés par le même temps ou la même distance. Les quatre cas sont présentés ci joint.

- Une Arrivée suivie par une Arrivée (Arr-Arr)
- Une Arrivée suivie par un Départ (Arr-Dep)
- Un Départ suivit par une Arrivée (Dep-Arr)
- Un Départ suivit par un Départ (Dep-Dep)

5.2 PROCESS DE RESOLUTION DES PROBLEMES DE SATURATION DE PISTE

Afin d´augmenter la capacité des aéroports, un outil a été conçu pour améliorer la phase de présélection de solutions techniques. Il doit permettre à l´utilisateur (opérateur d´un aéroport) de déterminer le candidat (système ou procédure) le plus adéquat à ses besoins capacitaires.
Ces phases sont décrites a travers le schéma suivant qui indique les quatre étapes de résolution d´un problème de trafic aérien.
Le premier point consiste à déterminer les limites en capacité aéroportuaire. Le second axe est centré sur la recherche de solutions. Une fois le candidat déterminé, une étude plus approfondie constituée notamment de simulations explore la faisabilité des solutions et a pour but de valider ou non l´emploi de la solution. En quatrième phase, la solution a été sélectionnée et son implémentation au sein de l´aéroport est analysée.

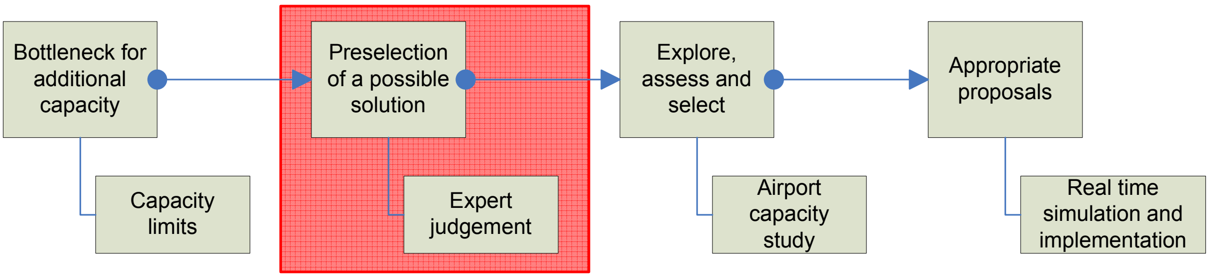

Figure 32: Développement d´une méthode pour amélioration des capacités aéroportuaires

La tache a accomplir au cours de ce PFE est uniquement centrée sur la présélection des candidats probables.
Au sein de cette phase, deux supports de type formulaire ont été mis en place. Le premier formulaire, appelé „Airport Request“ permet de qualifier les besoins spécifiques de l´aéroport étudié: les points faibles/forts et les exigences de la plateforme doivent y être établis par l´utilisateur. Le second formulaire „Database of candidates“ caractérise les spécifications des candidats intervenant pour augmenter le trafic aérien.

La transcription sous un système de gestion de bases de données est par la suite facilitée par ces deux formulaires.

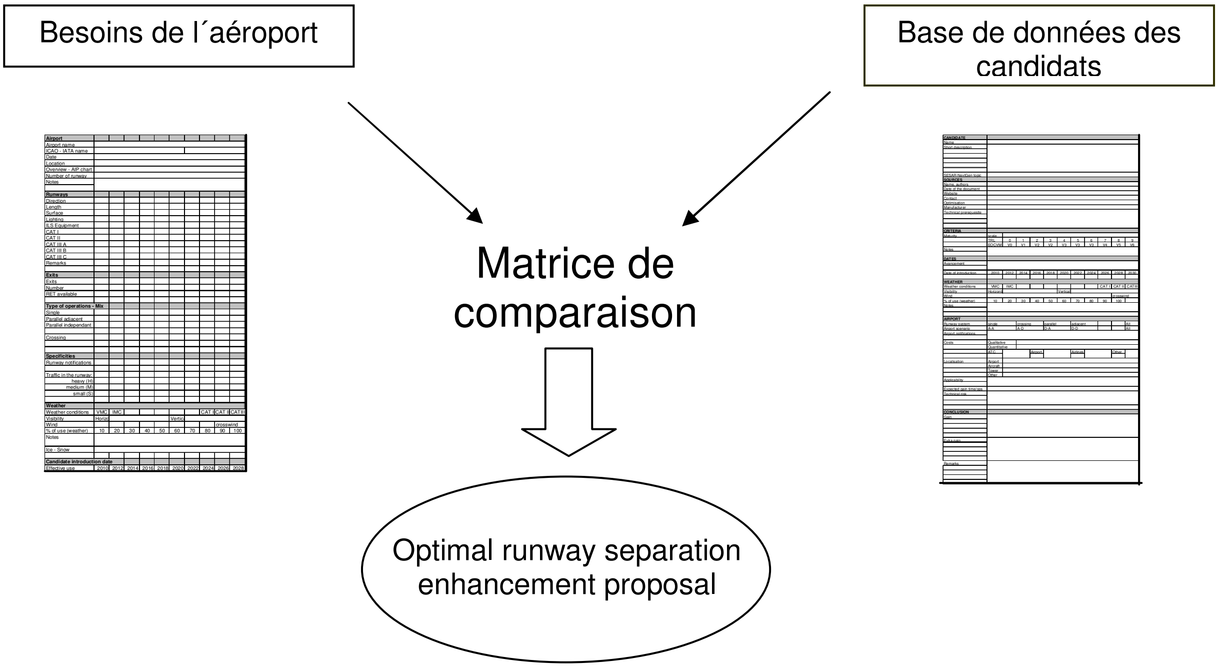

Figure 33: Structure mise en œuvre pour présélectionner une solution

Les candidats sont caractérisés et différenciés à la fois par une étude du trafic aérien, mais aussi par une évaluation des coûts par exemple. Ils sont à la fois présents au sein de la base de données de candidats et du formulaire de questionnement.
Les critères exploités dans les formulaires sont disponibles en annexe de ce dossier.
Une fois ces deux supports établis, une matrice vient comparer les besoins indiqués dans le formulaire de questionnement avec les performances proposées par la base de données de candidats. Il ressort de cette analyse une liste de probables candidats pouvant résoudre les problèmes de capacité pour l´aéroport considéré.

5.3 EXEMPLE

Afin de s´assurer de la faisabilité et de la pertinence de ce processus, un exemple concret a été développé. Cette étude a pris pour modèle les besoins de l´aéroport de Hamburg Fuhlsbüttel. Quatre formulaires de questionnement caractérisant les besoins de la plateforme ont été établis.
Fort d´une base de données de douze candidats (voir annexes) la méthode d´identification de la meilleure proposition a été entreprise. Les candidats ne répondant pas à un des critères des besoins de l´aéroport sont directement éliminés de la liste de candidats. Ensuite les points requis par l´opérateur de l´aéroport et présents au sein des candidats sont comptés et ordonnés dans un tableau. Ces candidats seront ensuite analysés plus en détail afin de déterminer s'ils peuvent être implémentés au sein de l´aéroport.

5.4 CONCLUSION

Ce travail de projet de fin d´études a pour but de concevoir un processus de résolution de problèmes de capacité de piste.
Une méthode incluant trois axes de travail a été développée. Elle inclue une partie définissant les besoins particuliers de l´aéroport considéré, une partie recensant les caractéristiques de systèmes et procédures apportant une solution totale ou partielle aux problèmes de saturation. La dernière partie consiste à comparer les deux organes précédant et de générer une liste de candidats potentiels dont leurs performances seront ensuite analysées au cours des simulations en temps réel.

Ce procédé a de nombreux avantages, notamment celui de proposer une solution au plus proche des besoins particuliers de l´aéroport analysé. Les « airport queries » sont de véritables outils s´adaptant très facilement aux particularités des aéroports. Ce degré de liberté est par ailleurs avantageux pour les personnes qui vont l´exploiter. La recherche peut être effectuée directement lors de meetings par des personnes non expertes du domaine d´application du système. Elle génère par ailleurs un gain de temps et est présenté selon un format clair et exploitable pour les analyses ou simulations en temps réel.
Des améliorations peuvent aussi être entreprises sur cette ligne de travail. Par exemple, l´exploitation des données des candidats pourrait être quantifiée de manière à connaitre exactement l´implication du candidat sur l´aéroport. Une autre amélioration consisterait à étendre les capacités de la méthode pour une exploitation plus générale au sein de l´institut de recherche. Cette ouverture se traduirait par la possibilité de traiter des phases autres que les approches et les congestions de piste. De plus ce point permettrait d´intervenir sur des sujets tels que l´environnement ou l´amélioration de la sécurité.
Enfin la base de données de candidats pourrait s´étoffer de manière à pouvoir présenter des propositions plus pertinentes aux requêtes particulières des aéroports.

6 ANNEX

6.1 Abbreviations

A/C	Aircraft
AIR	
CAA	Civil Aviation Authority
CAT	Category
CSPR	Closely Spaced Parrallel Runways
DGAC	Direction Générale de l´Aviation Civile
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DFS	Deutsche Flugsicherung
DH	Decision Height
FAA	Federal Aviation Administration
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
IMC	Instrument meteorological Conditions
KT	knot
LLZ	Localizer
NATS	UK Air Navigation Service Provider
NM	Nautical mile
PR	Parallel Runway
ROT	Runway Occupancy Time
RWY	Runway
SHA	Simplified Hazard Area
TAS	True Air Speed
TMA	Terminal Control Area
VMC	Visual meteorological Conditions

<u>Subscript:</u>

W	Wind
WV	Wake Vortex

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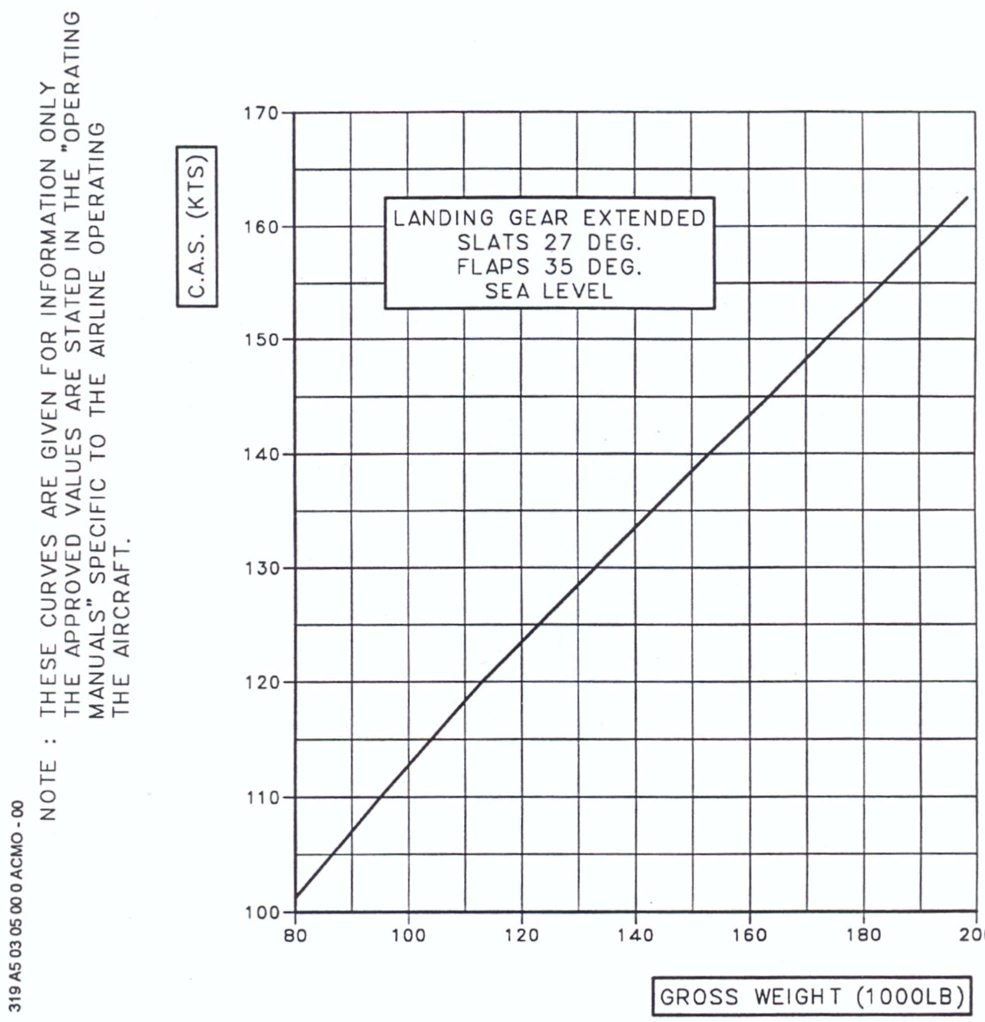
6.3 List of Figures

6.4 List of Tables

APPENDIX 1: AIRBUS A319 LANDING SPEED CURVE

A319
AIRPLANE CHARACTERISTICS



3.5 FINAL APPROACH SPEED
CFM56-5A ENGINES

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Printed in France

Figure 34: Airbus A319 Airspeed - Weight graphic [21]

APPENDIX 2: TYPICAL RUNWAY OCCUPANCY TIME

Typical ROT Values vs. Runway Exit Types

Scenario Number	Scenario	Runway Exits Description Exit Location (m.) Exit Type						Weighted Average ROT (s.)
		Exit # 1	Exit # 2	Exit # 3	Exit # 4	Exit # 5	Exit # 6	
1	Baseline	390 90 deg.	1154 90 deg.	1614 90deg.	2159 90 deg.	2713 90 deg.	3042 90 deg.	54.50
2	Wide Throat	390 90 deg.	950 WT	1225 WT	1425 WT	1900 WT	3042 90 deg.	51.20
3	30 Degree Standard FAA	390 30 deg.	950 30 deg.	1200 30 deg.	1400 30 deg.	1925 30 deg.	3042 90 deg.	44.63
4	30 Degree FAA Modified Exit[a]	390 90 deg.	900 30 deg. modified	1150 30 deg. modified	1350 30 deg. modified	1875 30 deg. modified	3042 90 deg.	43.00
5	REDIM 3030[b]	390 90 deg.	875 RE 3020	1125 RE 3020	1325 RE 3020	1825 RE 3020	3042 90 deg.	40.80
6	REDIM 3530[c]	390 30 deg.	825 RE 3520	1050 RE 3520	1250 RE 3520	1650 RE 3520	3024 90 deg.	36.80

a.The FAA modified 30 degree, acute angle geometry includes a 457 m. (1400 ft.) transition spiral.
b.The designation RE 3030 implies a high-speed exit designed for 30 m/s entry speed and a 30 degree exit angle.
c.The designation RE 3530 implies a high-speed exit designed for 35 m/s entry speed and a 30 degree exit angle.

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Table 26: ROT values estimation [20]

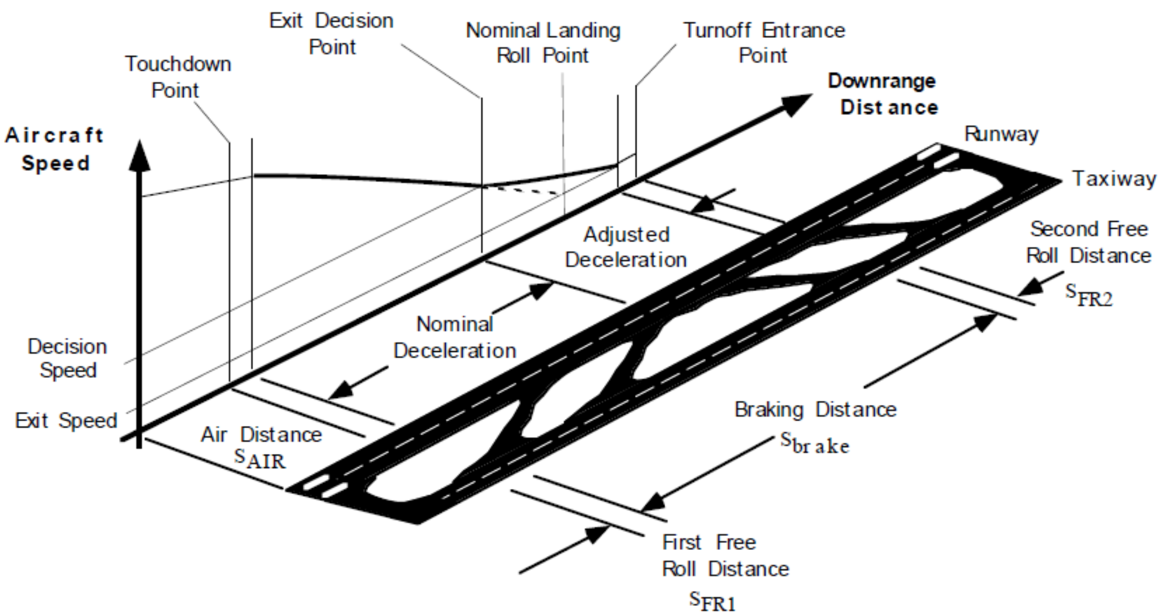
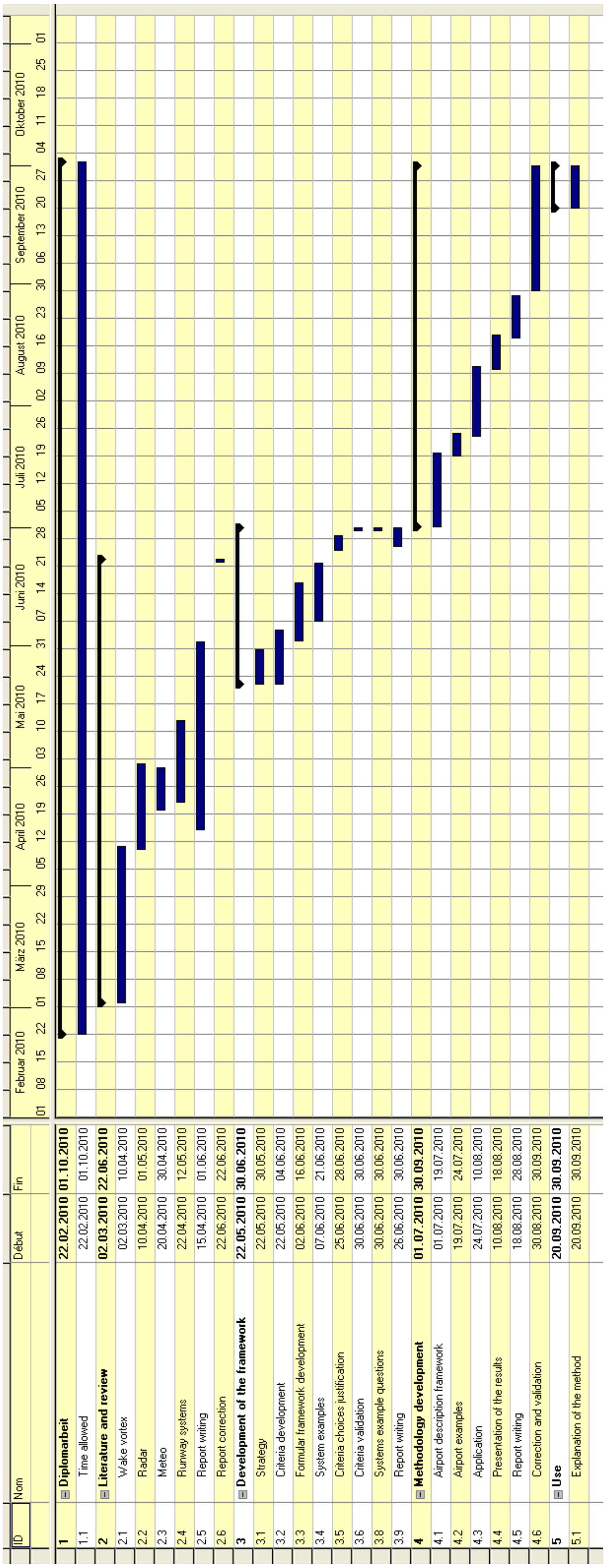


Figure 35: Aircraft landing roll profile [20]

APPENDIX 3: DIPLOMARBEIT PROJECT MANAGEMENT



APPENDIX 4: DATABASE OF CANDIDATES

This Appendix lists all the candidates whose are involved in the enhancement of the runway throughput. As explain in the chapter 2, 12 candidates are available in database.

Table 27: Ground Based Augmentation System

I. CANDIDATE												
Name	p	Ground Based Augmentation System GBAS										
Short description		GBAS is a system that supports augmentation through the use of terrestrial radio messages. GBAS are constitued of several surveyed ground stations and radios transmitters, which transmit the information directly to the end user. The GBAS provides enhanced integrity, accuracy, availability and continuity over and above the GPS.										
SESAR-NextGen topic	p	Use of runway occupancy time reduction techniques										
II. SOURCES												
Name, authors		Installation and Validation of a GBAS ground statio						Robert Geister / Thomas Ludwig				
Date of the document		01.07.1905										
Website												
Contact	p	helmut.toebben@dlr.de										
Airport-aircraft testbed	p	EDVE										
Composition date		Aug 10										
Manufacturer-Developper	p	Thales / honeywell (ground) and Rockwell Collins (aircraft)										
Technical prerequesite	p	Multi Modes Receivers (MMR)										
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes												
DATES												
Progress	p	Only CAT I developped and available in 2010 CAT II/ CAT III available in 2015/2020										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	p	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind		<	>								Crosswind	
Notes		Available just for CATI - CATII/CATIII in development										
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	p	ATC			Airport	1 Million €		Airlines	100 000€		Other	
Technical localisation	p	Airport	4 GPS antennas and 1 GPS ground station									
	p	Aircraft	1 Multi modes receiver (MMR)									
		Tower										
		Other										
Applicability	p	Just for the CATI conditions										
Expected gain time/ops	o	Not in the Paper										
Technical risk	p	Galileo development -Dependence of GPS										
IV. CONCLUSION												
Gain	o	Survey in the begin of september 2010 in EDVE										
Extra gain	p	Few calibration campaign - Absence of ILS ground restrictions areas Noice reduction -Fuel consumption reduction										
Remarks	o	A form for the GBAS for the CAT III should be independantly fill in.										

Table 28: Rapid Exit Taxiway

I. CANDIDATE												
Name	p	Rapid Exit Taxiway										
Short description	p	The Rapid Exit Taxiway aims to reduce the ROT Landing. This reduction is generated with the construction of news taxiways, which with an acute angle make possible to vacate the runway with a high speed.										
SESAR-NextGen topic	p	Improved runway capacity accuracy										
II. SOURCES												
Name, authors	p	Airport capacity enhancement						Praha Ruzyne Airport				
Date of the document	p	2005										
Website	p	http://www.eurocontrol.int/airports/gallery/content/public/pdf/Prague%20leaflet%20Phase%2										
Contact	p	petr.hlousek@csl.cz										
Airport-aircraft testbed	p	LKPR										
Composition date	p	Aug 10										
Manufacturer-Developper												
Technical prerequesite												
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	Mature technology										
DATES												
Progress	p	Available										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	o	<	>								Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative		High cost compared to an 90° exit								
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	p	Airport	Taxiways									
		Aircraft										
		Tower										
		Other										
Applicability	p	For more than 30 peak period movements period										
Expected gain time/ops	o	not defined										
Technical risk	p	Difficult to use more than 3 rapid exit taxiways on each runway side if the runway, if the runway is already equiped with 90 degrees taxiways.										
IV. CONCLUSION												
Gain												
Extra gain												
Remarks	o	Solution easily implementable										

Table 29: Airborne Information for Lateral Spacing

I. CANDIDATE												
Name	p	Airbone Information for Lateral Spacing (AILS)										
Short description	p	Transfert the lateral separation responsability to the flight deck during parallel approaches. AILS research has focused on the development of an airborne centered approach for independent instrument approaches to parallel runways as close as 2,500 ft. The system provides to the pilot the capability to detect and avoid possible encroaching traffic while flying closely spaced parallel instrument approaches.										
SESAR-NextGen topic	p	Optimised dependant parallel operations										
II. SOURCES												
Name, authors	p	Nasa Research for Instrument approaches to closely spaced parallel runways, Dawn M. Elli										
Date of the document	p	2000										
Website	p	paper										
Contact												
Airport-aircraft testbed												
Composition date	o	Aug 10										
Manufacturer-Developper	p	Nasa Langley Research Center - Honeywell										
Technical prerequesite	p	Navigation using DGPS - Datalink using ADS-B AILS Alert hosted in the TCAS box - Operational procedures										
III. CRITERIA												
MATURITY	o	TRL	0	1	2	3	4	5	6	7	8	9
	o	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes												
DATES												
Progress												
Date of introduction	o	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	p	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	p	<	>								Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
	p			Close	Middle	Close	Far					
Runway use	o	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation		Airport										
		Aircraft										
		Tower										
		Other										
Applicability	o	No information										
Expected gain time/ops	o	Not defined										
Technical risk												
IV. CONCLUSION												
Gain	o	Not defined										
Extra gain												
Remarks	p	Pilots appreciate the clarity of the alerts and the simplicity of the operational procedures Aircraft EADI and ND instruments have to be modified to host AILS alerts.										

Table 30: ROT reduction through pilot/control awareness

I. CANDIDATE												
Name	p	ROT Reduction through pilot/control awareness										
Short description	p	This airport dedidacted procedure provides an efficient use of the runway. It reduces delays, airlines costs (fuel savings), ROT and reaction times. This project requires close cooperation between pilots and controllers, particularly during peak periods. The pilots make their operations predictable to controllers by exiting at the recommended Rapid Exit Taxiway, for example.										
SESAR-NextGen topic	p	Use of runway occupancy time (ROT) reduction techniques										
II. SOURCES												
Name, authors	p	Lisbon Airport airport capacity enhancement						Lisbon airport				
Date of the document												
Website	p	http://www.eurocontrol.int/airports/gallery/content/public/pdf/Lisbon%20Awareness%20Leaf										
Contact	p	oliveirahall@ana-aeroportos.pt										
Airport-aircraft testbed	p	LPPT										
Composition date	p	Aug 10										
Manufacturer-Developper	o	Airports operators and airlines										
Technical prerequesite	o	Analysis of the taxiway system and measurements of the ROT Arrival and ROT Departure										
III. CRITERIA												
MATURITY		TRL	0	1	2	3	4	5	6	7	8	9
		EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	Mature technology										
DATES												
Progress	p	Available										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions		VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind		<	>								Crosswind	
Notes	p	May be dificult to be applied by the pilots under IMC										
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative	few millions									
Cost Stakeholder		ATC			Airport			Airlines			Other	
Technical localisation	o	Airport	eventually new RET									
		Aircraft										
		Tower										
	o	Other	procedure									
Applicability	p	All the time										
Expected gain time/ops		Not defined										
Technical risk	p	Pilots agreements for reacting promptly to all clearances, taxing directly and without delay to the centreline when cleared to line up, applying speed control accurately										
IV. CONCLUSION												
Gain	o	Information not in the paper										
Extra gain	p	Fuel savings										
Remarks	o	The "general" case must be adapted to the airport specificities.										

Table 31: Intersecting Take-off

I. CANDIDATE												
Name	p	Intersecting Take Off										
Short description	p	This procedure consists to propose to the pilots alternatives intersections for take off runs. It generates a high intensity runway operations, in particular when the airport traffic is constitued of commuter and turboprop aircraft.										
SESAR-NextGen topic	p	Improved threshold delivery accuracy										
II. SOURCES												
Name, authors	p	Airport capacity enhancement						Praha Ruzyne Airport				
Date of the document	p	2005										
Website	p	http://www.eurocontrol.int/airports/gallery/content/public/pdf/Prague%20leaflet%20Phase%2										
Contact	p	petr.hlousek@csl.cz										
Airport-aircraft testbed	p	LKPR										
Composition date	p	Aug 10										
Manufacturer-Developper												
Technical prerequesite												
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	Mature technology										
DATES												
Progress	p	Available										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind		<	>								Crosswind	
Notes												
AIRPORT												
Runway system	o	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	o	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes		The airport should have several runway entries										
COST												
Value		Quantitative										
		Qualitative		few millions								
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	o	Airport	news taxiways									
		Aircraft										
		Tower										
		Other										
Applicability	o	Each runway										
Expected gain time/ops	p	Reduce ROTD										
Technical risk												
IV. CONCLUSION												
Gain	o	Information not in the paper										
Extra gain												
Remarks	o	Not interesting if the traffic mix is not diversified										

Table 32: Ground Markers

I. CANDIDATE												
Name	p	Ground Markers										
Short description	p	The goal of the aircraft Marker Receivers is to reduce the landing ROT. Under reduced visibility, landing pilots have difficulties to reach runway exits at the optimum ground speed. Throught low powered transmitters and taxiways embedded antennas, aircraft Marker Receivers can provide clear voice airfield positional information to taxiing pilots. Pilots are vocally advised of the "distance to go" to runway exits.										
SESAR-NextGen topic	p	Guidance assistance to aircraft on the airport surface										
II. SOURCES												
Name, authors	p	Reduced Runway Occupancy Times, Nigel Corrigan										
Date of the document	p	June 2005										
Website												
Contact	p	groundmarker@axis-electronics.com										
Airport-aircraft testbed												
Composition date	o	June 2010										
Manufacturer-Developper	p	Axis Electronics										
Technical prerequesite	p	FAA Runway Incursion Prevention Programme										
III. CRITERIA												
MATURITY	o	TRL	0	1	2	3	4	5	6	7	8	9
	o	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	o	Flight simulator trials achieved but with a instructor pilot voice to prevent the exit distance instead of the automatic voice like GPWS.										
DATES												
Progress	p	10 initial assesment trials were conducted using a B737 flight simulator. No avancement dates are stipuled.										
Date of introduction	o	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	p	<	>	Solution independant of the wind characteristics							Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	p	Reduce the ROT singnificatly for single runway operations										
COST												
Value		Quantitative										
		Qualitative		to be define								
Cost Stakeholder		ATC			Airport	not clearly explained		Airlines	not clearly explained		Other	Aircraft manuf
Technical localisation	p	Airport	Runway lateral equipment									
	p	Aircraft	Voice system									
		Tower										
		Other										
Applicability	o	No information										
Expected gain time/ops	p	From 10 up to 20 seconds per landing ROT.										
Technical risk	p	Occupancy times expected in the simulator are not reached in the real trials.										
IV. CONCLUSION												
Gain	p	During CATIII B Conditions, gain is expected to be similar to the ROT during a clearly weather conditions: a graphic shows a ROT reduction from 70 seconds (without Voice Advisoy) to approximatively 50 seconds (with Voice Advisory)										
Extra gain	p	Furthermore it bringt a reduction for the noice emission and brake maintenance										
Remarks	o	Paper not really clear. No changes are required on aircraft or equipment. The ATC can also propose the exit which they would prefer a landed aircraft to vacate the runway										

Table 33: Brake to Vacate

I. CANDIDATE												
Name	p	Brake To Vacate (BTV)										
Short description	p	BTV gives pilots real-time visibility on realistic braking distances to reach their prefered exit. When the pilot chooses a runway exit point, the system indicates the estimated runway occupancy time and the minimum turnaround time. during low visibility conditions, the system optimise the landing roll and brake just necessary to vacate the runway										
SESAR-NextGen topic	p	Brake To Vacate procedure										
II. SOURCES												
Name, authors	p	Brake to vacate, Airbus										
Date of the document	p	2008										
Website	p	http://www.airbus.com/fileadmin/media_gallery/files/brochures_publications/FAST_magazin										
Contact	p	fabrice.villaume@airbus.com										
Airport-aircraft testbed	p	TLS	A346	A388								
Composition date	p	July 2010										
Manufacturer-Developper	p	Airbus System Engineering										
Technical prerequesite	p	GPS - Airport Navigation Autoflight - Autobrake systems										
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	EASA certified										
DATES												
Progress		Available on the A380 - soon available on the A320 family										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	o	<	>								Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes		None										
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
											Manufa	
Technical localisation		Airport										
	p	Aircraft	system incorporated on the aircraft									
		Tower										
		Other										
Applicability	o	No information										
Expected gain time/ops		tbd										
Technical risk	o	Airbus patent rights Only available for certain Airbus aircraft										
IV. CONCLUSION												
Gain	o	Expecting AIB answer										
Extra gain	o	Gain for the maintenance										
Remarks	o	Manufacturer Boeing works on a similar topic										

Table 34: Wake Vortex Avoidance System

I. CANDIDATE												
Name	p	Wake Vortex Avoidance System (WVAS)										
Short description	p	The WVAS is developped to provide a significant gain in airport capacity through reduced approach and departure times. This system combines the Vortex Advisory system (VAS) and the Vortex Warning System (VWS) to solve the wake vortex problems. The VAS is designed to take advantage of the wind direction criterion and via a simple display indicates when wake vortex separation need no longer to be applied.										
SESAR-NextGen topic	p	Fixed reduced separation based on wake vortex prediction										
II. SOURCES												
Name, authors	p	ICAO - Air traffic services planning Manual (II -5 -3 -12)										
Date of the document	p	03.11.1988										
Website												
Contact												
Airport-aircraft testbed	p	ORD										
Composition date	p	july 2010										
Manufacturer-Developper												
Technical prerequesite	p	Meteo sensor - ATC runway monitor - Ground Wind Vortex Sensing System Doppler Acoustic Vortex Sensing System										
III. CRITERIA												
MATURITY	o	TRL	0	1	2	3	4	5	6	7	8	9
	o	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes												
DATES												
Progress		Project closed : have been tested operationnaly in Chicago O´Hare Airport										
Date of introduction	o	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind		<	>								Crosswind	
Notes												
AIRPORT												
Runway system	o	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	o	Airport	Sensors									
		Aircraft										
	o	Tower	Tower Monitor									
		Other										
Applicability	o	No information										
Expected gain time/ops	p	aircraft spacing on approach of less than 3NM and 2NM could be used 86% of the time.										
Technical risk												
IV. CONCLUSION												
Gain	p	Not selected for further use										
Extra gain												
Remarks	p	The incidence of transitions through red/green warning lights do not provide sufficient time for the controller to change separation minima applied between various type of aircraft in a already established approach sequence										

Table 35: Wake Independent Departure and Arrival Operation

I. CANDIDATE												
Name	p	Wake Independant Departure and Arrival Operation (WIDAO)										
Short description	p	Crosswind procedure which relax the constraints limiting the effiency of closely-spaced parallel runways CSPR operations. The aim of the concept is to allow aircraft to entry at the start of the runway by demonstrating that wake vortex from aircraft landing on the adjacent runway does not present a significant risk on the departure aircraft.										
SESAR-NextGen topic	p	Crosswind reduced separations for departures and arrivals										
II. SOURCES												
Name, authors	p	Wakenet 3 Europe - Dr. Debbie Mittchell										
Date of the document	p	01.08.2009										
Website	p	http://www.greenwake.org/Links/Overview.pdf										
Contact												
Airport-aircraft testbed	p	CDG										
Composition date	p	july 2010										
Manufacturer-Developper	p	Eurocontrol -DNSA										
Technical prerequesite	p	Windtracer on the airport (measure of the wake vortices and the headwinds) on the airport during 12 months - Lidar analyse -WAKE4D modelisation										
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes												
DATES												
Progress	p	Should be completed by the end of 2009										
Date of introduction	o	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	o	<	>								Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use	o	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	o	Airport	Campaign to determine the wake vortices									
		Aircraft										
		Tower										
		Other										
Applicability	o	No information										
Expected gain time/ops	p	to be define										
Technical risk	p	Lost of throughput due to complex runway management										
IV. CONCLUSION												
Gain		To be defined										
Extra gain												
Remarks												

Table 36: Closely Spaced Parallel Runway Arrival

I. CANDIDATE												
Name	p	Closely Spaced Parralel Runway Arrival (HALS/ DTOP)										
Short description	p	This crosswind procedure allows that two aircraft land simustaneously on CSPR at Frankfurt/Main airport. The runway includes a second threshold, shifted by 1500m that generate a 83m higher glidepath track for this ILS CAT 1										
SESAR-NextGen topic	p	Interlaced takeoff and landing/Crosswind reduced separations for departure and arrivals										
II. SOURCES												
Name, authors	p	Wakenet 3 Europe - Dr. Debbie Mittchell										
Date of the document	p	01.08.2009										
Website	p	http://www.greenwake.org/Links/Overview.pdf										
Contact												
Airport-aircraft testbed												
Composition date	p	july 2010										
Manufacturer-Developper	p	Fraport AG										
Technical prerequesite	p	Second threshold strongly displaced Adequat runway lighting										
III. CRITERIA												
MATURITY	p	TRL	0	1	2	3	4	5	6	7	8	9
	p	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	p	Tested and available in runway 25L at Fankfurt/Main Airport before the new runway pavement (2008)										
DATES												
Progress	p	Project closed and available										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind	o	<	>	headwind							Crosswind	
Notes												
AIRPORT												
Runway system	p	Single		Crossing		Parallel		Open V		All cases		
	p			Close	Middle	Close	Far					
Runway use	p	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes												
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	p	Airport	Runway lighting									
		Aircraft										
	o	Tower	Training									
	o	Other	Procedures and documentations									
Applicability												
Expected gain time/ops	o	information not in the paper										
Technical risk	p	Increased pilot workload										
IV. CONCLUSION												
Gain	p	To be defined										
Extra gain												
Remarks	p	Pilots appreciate the clarity of the alerts and the simplicity of the operational procedures Aircraft EADI and ND instruments have to be modified to host AILS alerts.										

Table 37: Crosswind Reduction Separation for Departure Operations

I. CANDIDATE												
Name	p	Crosswind Reduced Separation for Departures Operations (CREDOS)										
Short description	p	Crosswind procedure which consists to suspending (Time and distance) wake turbulence separation under specific crosswind conditions. Sufficient crosswind transport any hazardous turbulence out of the track of a following aircraft.										
SESAR-NextGen topic	p	Crosswind reduced separations for departures and arrivals										
II. SOURCES												
Name, authors	p	Wakenet 3 Europe - Dr. Debbie Mittchell										
Date of the document	p	01.08.2009										
Website	p	http://www.greenwake.org/Links/Overview.pdf										
Contact	p	http://www.eurocontrol.int/eec/credos/public/subsite_homepage/homepage.html										
Airport-aircraft testbed												
Composition date	p	July 2010										
Manufacturer-Developper	p	AIRBUS, Berlin Technical University, DFS, DLR, EUROCONTROL, INECO, M3 SYSTEMS										
Technical prerequesite												
III. CRITERIA												
MATURITY	o	TRL	0	1	2	3	4	5	6	7	8	9
	o	EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes	o	Demonstration of the feasability not executed										
DATES												
Progress		Due to be completed at the end of 2009										
		Fully completed in 2012										
Date of introduction	p	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal		Vertical								
Wind	o	<	>	Strong crosswind							Crosswind	
Notes												
AIRPORT												
Runway system	o	Single		Crossing		Parallel		Open V		All cases		
				Close	Middle	Close	Far					
Runway use		Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	p	Only for the Departure -Departure scenarios										
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation	o	Airport										
		Aircraft										
	o	Tower										
	o	Other	Develop a procedure									
Applicability		No information										
Expected gain time/ops	p	Absorbs capacity peaks and reduces departure delays										
Technical risk	o	No knowledge about wake Vortex during initial climb										
IV. CONCLUSION												
Gain	p	Temporarily increase the departure runway throughput										
Extra gain												
Remarks	p	Can be used for all aircraft types but only on the D-D sequence. The gain is mainly seen after a heavy departure. Need a documentation and ICAO standart changes.										

Table 38: Time Based Separation for arrival Aircraft

I. CANDIDATE												
Name	p	Time based separation (TBS) for arriving aircraft										
Short description	p	The weather induces huge airport delays. 60% are due to wind. Currently, the distance based separation maintain the a constant distance between the two aircraft. Time based separation proposes to remain constant the time between two aircraft in headwind conditions										
SESAR-NextGen topic	p	Time based separation for arrivals										
II. SOURCES												
Name, authors	p	Time based separation (TBS) ; Dave Booth - Eurocontrol										
Date of the document	p	09.11.2009										
Website	p	http://www.eurocontrol.int/corporate/gallery/content/public/event_docs/2009_11_09wakevor										
Contact												
Airport-aircraft testbed												
Composition date	p	july 2010										
Manufacturer-Developper												
Technical prerequesite	p	Instructed airspeed										
III. CRITERIA												
MATURITY		TRL	0	1	2	3	4	5	6	7	8	9
		EOCVM	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes												
DATES												
Progress		1/applying WV time based separation minima 2/investigate the radar TBS minima 3/transition phase: applying a fixed reduction in the distance based radar										
Date of introduction	o	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER												
Weather conditions	o	VMC	IMC							CAT I	CAT II	CATIII
Visibility		Horizontal					Vertical					
Wind		<	>	15 kts Headwind							Crosswind	
Notes												
AIRPORT												
Runway system	o	Single		Crossing		Parallel		Open V			All cases	
				Close	Middle	Close	Far					
Runway use	o	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep			All cases	
Notes		Single runway track necessary										
COST												
Value		Quantitative										
		Qualitative										
Cost Stakeholder	o	ATC			Airport			Airlines			Other	
Technical localisation		Airport										
		Aircraft										
	o	Tower	Display									
		Other										
Applicability	o	No information										
Expected gain time/ops	p	0,5 NM										
Technical risk	p	Transition distance <> time can be confusing This project is efficient for H-H and H-M configurations										
IV. CONCLUSION												
Gain	o	to be defined										
Extra gain												
Remarks												

APPENDIX 5: AIRPORT REQUEST

This appendix presents the four queries which have been generating for the example.

Table 39: Request for Hamburg Fuhlsbüttel runway 23

Hamburg Fuhlsbüttel rwy 23 single											
I. AIRPORT											
Airport name	Hamburg Fuhlsbüttel										
ICAO - IATA name	EDDH						HAM				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	2	05/23		15/33							
Notes											
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	6	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	IMC							CAT I	CAT II	CATIII
Visibility	Horizontal		1 NM			Vertical					
Wind	<	>	10 m/s							Crosswind	
Notes	Strong winds reduce operations to single runway use.										
Ice - Snow	No information										
TYPE OF OPERATIONS											
Runway system	Single		Crossing		Parallel		Open V		All cases		
			Close	Middle	Close	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	Single use: rwy23 = 12,3 %										
Runway traffic (%)	Small	15		Medium		70		Heavy		15	
COST											
Value	Quantitative									€	$
	Qualitative		Few millions							€	$
Cost Stakeholder	ATC	without DFS implication		Airport	Flughafen Hamburg		Airlines			Other	
III. CONCLUSION											
Capacity needs	Now: 48 mov/h Objectives: 50 mov/h										

Table 40: Request for Hamburg Fuhlsbüttel runway 05

Hamburg Fuhlsbüttel rwy 05 single											
I. AIRPORT											
Airport name	Hamburg Fuhlsbüttel										
ICAO - IATA name	EDDH						HAM				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	2	05/23		15/33							
Notes											
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	6	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	IMC							CAT I	CAT II	CATIII
Visibility	Horizontal		1 NM			Vertical					
Wind	<	>	10 m/s							Crosswind	
Notes	Strong winds reduce operations to single runway use.										
Ice - Snow	No information										
TYPE OF OPERATIONS											
Runway system	Single		Crossing		Parallel		Open V		All cases		
			Close	Middle	Close	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	Single use: rwy05 = 9,5 %										
Runway traffic	Small	15		Medium		70		Heavy		15	
COST											
Value	Quantitative		10 Millions							€	$
	Qualitative									€	$
Cost Stakeholder	ATC	without DFS implication		Airport	Flughafen Hamburg		Airlines			Other	
III. CONCLUSION											
Capacity needs	Now: 44 mov/h Objectives: 46 mov/h										

Table 41: Request for Hamburg Fuhlsbüttel runway 15 for arrivals and runway 23 for departures

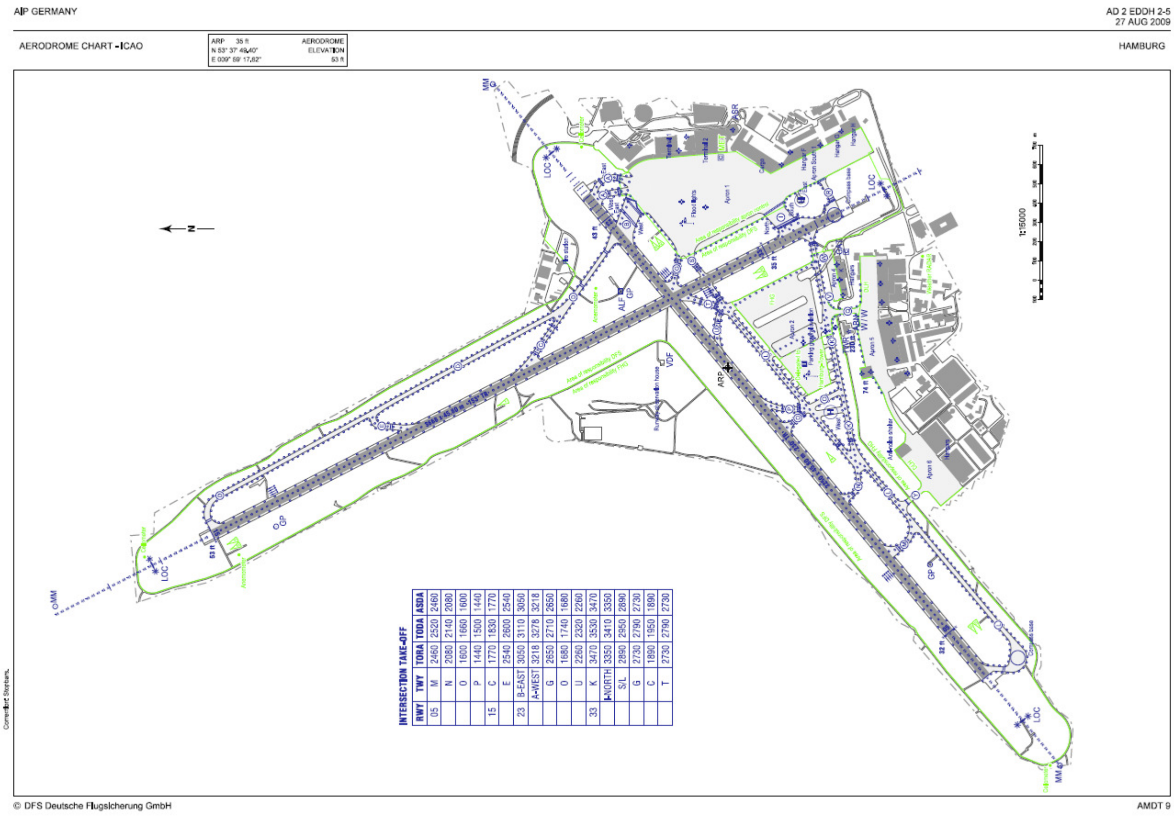
Hamburg Fuhlsbüttel crossing Arr 15 Dep 23											
I. AIRPORT											
Airport name	Hamburg Fuhlsbüttel										
ICAO - IATA name	EDDH						HAM				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	2	05/23		15/33							
Notes											
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	6	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	IMC							CAT I	CAT II	CATIII
Visibility	Horizontal					Vertical					
Wind	<	>								Crosswind	
Notes	Strong winds reduce operations to single runway use.										
Ice - Snow	No information										
TYPE OF OPERATIONS											
Runway system	Single		Crossing		Parallel		Open V		All cases		
			Close	Middle	Close	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	Depart RWY 23 and Arrival RWY 15										
Runway traffic (%)	Small	15		Medium		70		Heavy		15	
COST											
Value	Quantitative		10 Millions							€	$
	Qualitative									€	$
Cost Stakeholder	ATC	without DFS implication		Airport	Flughafen Hamburg		Airlines			Other	
III. CONCLUSION											
Capacity needs	Now: 40 mov/h Objectives: 44 mov/h										

Table 42: Request for Hamburg Fuhlsbüttel runway 05 for arrivals and runway 33 for departures

Hamburg Fuhlsbüttel crossing Arr rwy 05 Dep 33											
I. AIRPORT											
Airport name	Hamburg Fuhlsbüttel										
ICAO - IATA name	EDDH						HAM				
Date	Aug 10										
Location	Germany										
Overview - AIP chart	\\sda\AIP-GERMANY\localhost\public\dfsaip.nsf\readergermanopenframeset.h										
Number of runways	2	05/23		15/33							
Notes											
II. CRITERIA											
MATURITY	TRL	0	1	2	3	4	5	6	7	8	9
	EOCV	V0	V1	V2	V2	V3	V3	V3	V4	V5	V6
Notes											
INTRODUCTION DATE											
Effective date	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
WEATHER											
Weather conditions	VMC	IMC							CAT I	CAT II	CATIII
Visibility	Horizontal					Vertical					
Wind	<	>								Crosswind	
Notes	Strong winds reduce operations to single runway use.										
Ice - Snow	No information										
TYPE OF OPERATIONS											
Runway system	Single		Crossing		Parallel		Open V		All cases		
			Close	Middle	Close	Far					
Runway use	Arr-Arr		Arr-Dep		Dep-Arr		Dep-Dep		All cases		
Notes	Depart RWY 33 - Arrival RWY 05										
Runway traffic	Small	15		Medium	70		Heavy		15		
COST											
Value	Quantitative	5 Millions								€	$
	Qualitative									€	$
Cost Stakeholder	ATC	without DFS implication		Airport	Flughafen Hamburg		Airlines			Other	
III. CONCLUSION											
Capacity needs	Now: 44 mov/h in single use Objectives: 48 mov/h										

APPENDIX 6: HAMBURG AIRPORT CHART

Chart of Hamburg Airport in order to achieve the request forms.



RWY	TWY	TORA	TODA	ASDA
05	M	2460	2520	2460
	N	2080	2140	2080
	O	1600	1660	1600
	P	1440	1500	1440
15	C	1770	1830	1770
	E	2540	2600	2540
23	B-EAST	3050	3110	3050
	A-WEST	3218	3278	3218
	G	2650	2710	2650
	O	1680	1740	1680
	U	2260	2320	2260
33	K	3470	3530	3470
	I-NORTH	3350	3410	3350
	S/L	2890	2950	2890
	G	2730	2790	2730
	C	1890	1950	1890
	T	2730	2790	2730

Figure 36: Hamburg Airport information [22]

APPENDIX 7: COMPARISON MATRIX

Table 43: Matrix for Intersecting Take-off

CANDIDATE 1: Intersecting takeoff			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1	1				1				1				1			
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1		1				1					1				1	
E	Weather conditions Visibility	1				1				1				1				1
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	2	1				1				1				1			
H	Runway Use	3		1				1				1			1			
I	Cost value	1	1							1				1				1
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		7				6				5				6			
1	No (N)			2				2				1				0		
	Not Inquiry (NI)				0				0				2				2	
	Not Candidate (NC)					1				2				2				2
Total	Yes (Y)		9				8				7				10			
1	No (N)			4				4				3				0		
+	Not Inquiry (NI)				0				0				2				2	
weighting	Not Candidate (NC)					1				2				2				2

Table 44: Matrix for ROT Reduction through pilot/control awareness

CANDIDATE 2: ROT Reduction through pilot/control aware			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1	1				1				1				1			
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1		1				1					1				1	
E	Weather conditions Visibility	1				1				1				1				1
F	Weather conditions wind Crosswind	1		1				1					1				1	
G	Runway System	2	1				1				1				1			
H	Runway Use	3		1			1					1			1			
I	Cost value	1	1							1				1				1
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		6				6				5				6			
1	No (N)			3				2				1				0		
	Not Inquiry (NI)				0				0				2				2	
	Not Candidate (NC)					1				2				2				2
Total	Yes (Y)		8				10				7				10			
1	No (N)			5				2				3				0		
+	Not Inquiry (NI)				0				0				2				2	
weighting	Not Candidate (NC)					1				2				2				2

Table 45: Matrix for Rapid Exit Taxiway

CANDIDATE 3: RET			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1	1				1				1				1			
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1	1				1						1				1	
E	Weather conditions Visibility	1				1				1				1				1
F	Weather conditions wind Crosswind	1	1				1					1				1		
G	Runway System	2	1				1				1				1			
H	Runway Use	3		1			1					1			1			
I	Cost value	1				1				1				1				1
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		7				8				5				6			
1	No (N)			1				0				2				1		
	Not Inquiry (NI)				0				0				1				1	
	Not Candidate (NC)					2				2				2				2
Total	Yes (Y)		9				12				7				10			
1	No (N)			3				0				4				1		
+	Not Inquiry (NI)				0				0				1				1	
weighting	Not Candidate (NC)					2				2				2				2

Table 46: Matrix for Ground Based Augmentation System

CANDIDATE 4: GBAS			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1	1				1				1				1			
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1					1				1		
D	Weather conditions CAT I/ II/ III	1		1				1					1				1	
E	Weather conditions Visibility	1				1				1				1				1
F	Weather conditions wind Crosswind	1		1				1					1				1	
G	Runway System	2	1				1				1				1			
H	Runway Use	3	1				1				1				1			
I	Cost value	1	1				1				1				1			
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		7				7				6				6			
1	No (N)			2				2				1				1		
	Not Inquiry (NI)				0				0				2				2	
	Not Candidate (NC)					1				1				1				1
Total	Yes (Y)		11				11				10				10			
1	No (N)			2				2				1				1		
+	Not Inquiry (NI)				0				0				2				2	
weighting	Not Candidate (NC)					1				1				1				1

Table 47: Matrix for AILS

CANDIDATE 5: AILS			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1		1			1					1				1		
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1				1				1			1				1	
E	Weather conditions Visibility	1				1				1			1				1	
F	Weather conditions wind Crosswind	1	1				1					1				1		
G	Runway System	2		1				1				1				1		
H	Runway Use	3		1			1					1				1		
I	Cost value	1				1				1				1				1
J	Cost Payer	1		1				1				1				1		

Total	Yes (Y)		3				5				2				2			
1	No (N)			4				2				5				5		
	Not Inquiry (NI)				0				0				2				2	
	Not Candidate (NC)					3				3				1				1
Total	Yes (Y)		4				8				3				3			
1	No (N)			7				3				8				8		
+	Not Inquiry (NI)				0				0				2				2	
weighting	Not Candidate (NC)					3				3				1				1

Table 48: Matrix for Ground Markers

CANDIDATE 6: Ground markers			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1		1			1					1				1		
B	Introduction Date	2		1			1				1				1			
C	Weather conditions IMC/VMC	1	1				1					1				1		
D	Weather conditions CAT I/ II/ III	1	1				1						1				1	
E	Weather conditions Visibility	1	1				1					1				1		
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	2	1				1					1				1		
H	Runway Use	3		1			1					1			1			
I	Cost value	1				1				1			1				1	
J	Cost Payer	1	1				1				1				1			

Total	Yes (Y)		6				9				2				3			
1	No (N)			3				0				5				4		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					1				1				0				0
Total	Yes (Y)		7				13				3				6			
1	No (N)			6				0				8				5		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					1				1				0				0

Table 49: Matrix for Brake To Vacate

CANDIDATE 7: BTV			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1	1				1				1				1			
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1	1				1						1				1	
E	Weather conditions Visibility	1				1				1			1				1	
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	2	1				1				1				1			
H	Runway Use	3	1				1				1				1			
I	Cost value	1				1				1				1				1
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		8				8				6				6			
1	No (N)			0				0				0				0		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					2				2				1				1
Total	Yes (Y)		12				12				10				10			
1	No (N)			0				0				0				0		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					2				2				1				1

Table 50: Matrix for WVAS

CANDIDATE 8: WVAS			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1		1			1					1				1		
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1	1				1						1				1	
E	Weather conditions Visibility	1				1				1			1				1	
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	2	1				1				1				1			
H	Runway Use	3		1			1					1				1		
I	Cost value	1				1				1				1				1
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		6				8				4				4			
1	No (N)			2				0				2				2		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					2				2				1				1
Total	Yes (Y)		8				12				6				6			
1	No (N)			4				0				4				4		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					2				2				1				1

Table 51: Matrix for HALS/DTOP

CANDIDATE 9: HALS/DTOP			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1	1				1				1				1			
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1		1				1					1				1	
E	Weather conditions Visibility	1				1				1			1				1	
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	2		1				1				1				1		
H	Runway Use	3		1			1					1				1		
I	Cost value	1				1				1				1				1
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		5				6				4				4			
1	No (N)			3				2				2				2		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					2				2				1				1
Total	Yes (Y)		6				9				5				5			
1	No (N)			6				3				5				5		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					2				2				1				1

Table 52: Matrix for WIDAO

CANDIDATE 10: WIDAO			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1		1			1				1				1			
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1	1				1						1				1	
E	Weather conditions Visibility	1				1				1			1				1	
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	2		1				1				1				1		
H	Runway Use	3		1				1				1			1			
I	Cost value	1				1				1				1				1
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		5				6				4				5			
1	No (N)			3				2				2				1		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					2				2				1				1
Total	Yes (Y)		6				7				5				8			
1	No (N)			6				5				5				2		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					2				2				1				1

Table 53: Matrix for Time Based Separation

CANDIDATE 11: TBS			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1		1				1				1				1		
B	Introduction Date	2		1			1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
4	Weather conditions CAT I/ II/ III	1	1				1						1				1	
5	Weather conditions Visibility	1				1				1			1				1	
6	Weather conditions wind Crosswind	1		1				1					1				1	
7	Runway System	2	1				1				1				1			
8	Runway Use	3		1			1					1				1		
9	Cost value	1				1				1				1				1
10	Cost Payer	1		1				1				1				1		
Total	Yes (Y)		3				5				3				3			
1	No (N)			5				3				3				3		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					2				2				1				1
Total	Yes (Y)		4				9				5				5			
1	No (N)			8				3				5				5		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					2				2				1				1

Table 54: Matrix for CREDOS]

CANDIDATE 12: CREDOS			A.1				B.1				C.1				D.1			
Criterion	Designation	Weighting	A23D23				A05.D05				A15.D23				A05.D33			
			Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC	Yes	No	NI	NC
A	Maturity	1		1				1				1				1		
B	Introduction Date	2	1				1				1				1			
C	Weather conditions IMC/VMC	1	1				1				1				1			
D	Weather conditions CAT I/ II/ III	1	1				1						1				1	
E	Weather conditions Visibility	1				1				1			1				1	
F	Weather conditions wind Crosswind	1	1				1						1				1	
G	Runway System	2	1				1					1				1		
H	Runway Use	3		1				1				1				1		
I	Cost value	1				1				1				1				1
J	Cost Payer	1	1				1				1				1			
Total	Yes (Y)		6				6				3				3			
1	No (N)			2				2				3				3		
	Not Inquiry (NI)				0				0				3				3	
	Not Candidate (NC)					2				2				1				1
Total	Yes (Y)		8				8				4				4			
1	No (N)			4				4				6				6		
+	Not Inquiry (NI)				0				0				3				3	
weighting	Not Candidate (NC)					2				2				1				1