Indra Airports

STUDY OF AIRPORT CAPACITY VS. EFFICIENCY SESAR CHALLENGES

Report

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> A perfection of means and confusion of aims
> seems to be our main problem
> *Albert Einstein*

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EXECUTIVE SUMMARY

Recent studies carried by Eurocontrol (Challenges to Growth 2004) predict that in the incoming years, traffic demand will increase at a highest rate than capacity of airports, leading to a considerable unbalance between supply and demand by 2020: air traffic is envisaged to almost double by 2020 (17.2 million IFR flights per year) in Europe, and despite the 60% of potential capacity expected increase of the airport network , 17.6% of demand (3.7 million flights per year) will not be able to take place. This will leave more than 60 airports in capacity shortage conditions and the top-20 airports will be saturated at least 8-10 hours per day.

Given such expectancies, an immediate solution is needed, not only to find new solutions for increasing capacity at airports and avoiding such bottlenecks, but also for increasing the efficiency of use of the available declared capacity by the introduction of new operational procedures and technologies.

These are some of the incentives that led to the *Single European Sky* concept, and the conception of the SESAR program.

The EU SES is the ATM modernization program to structure airspace and air navigation services at EU level (rather national one), to better manage air traffic, create additional capacity and increase overall efficiency of ATM system.

The *Single European Sky Air traffic management Research* program is the technological pillar of the SES policy. The aim of SESAR is to develop the new generation ATM system capable of ensuring the safety and fluidity of air transport over the next 30 years.
Specifically for airports, the airport capacity and efficiency action plan of SESAR consists of:

- Better use of existing capacities
- New technologies
- Intermodality
- Observatory for airport capacity
- Improved capacity planning
- Capacity inventory
- Increase predictability
- Reduce of delays

The objectives of SESAR are:

- Capacity: Enable up to 3-fold increase in air traffic movements whilst reducing delays
- Safety: Improve safety levels by a 10 factor
- Environment: Reduce by 10% the environmental impact per flight
- Cost-Effectiveness: Cut ATM costs per flight by 50%

The **objectives** of this study are to present a real case study for evaluating the impact of SESAR enhancements on the capacity and efficiency of the Barcelona – El Prat Airport by analyzing the impact of the future SESAR enablers on the capacity and efficiency indicators and by evaluating the effectiveness and the applicability of the SESAR concept on increasing its capacity and efficiency.

The first half of the study is dedicated to analyze the following aspects of T1:

- <u>Capacity:</u> current capacity of T1 was assessed, which in this case turns to be the capacity of the global Airport. Capacity is always given by the most restrictive subsystem, which in this case is the runway component.

- <u>Efficiency:</u> a good indicator for evaluating the airport's efficiency is an estimation of the delays. Given that runway component is the subsystem which limits the capacity of the airport, the delay introduced is a good KPI for efficiency.

The results obtained from selected methodologies used in the capacity and efficiency assessments, (mainly FAA methods for airside and IATA for landside) show that, on 19th July 2009, Barcelona's Airport capacity is **62 operations per hour** and its efficiency **18.4 minutes of delay per hour** on the runway component.

Such conditions will be not enough to absorb the future traffic, even if operating at best performance, and it is here were SESAR will play a key role for the survival of Barcelona's airport.

The second half of the study is devoted to evaluate the SESAR scenario. The objective is to assess by how much SESAR will improve the capacity and efficiency of the airport and how this improvement will evolve over time. To this effect, the list of SESAR KPIs that will help in the determination of such parameters is obtained.

The study concludes that both capacity and efficiency of Barcelona's Airport are going to increase in the incoming years thanks to the new systems and procedures of the SESAR Program.

- Thanks to new approach procedures (CDA), Barcelona's landing capacity will be incremented, but because of current airspace limitations this improvement could not be reached by means of runway capacity since the airport is "closed" in terms of noise in the takeoff phase.

- Thanks to SESAR CDM, delays will be reduced by a 3%, in means of improving Barcelona's efficiency, which in values means 17.8 min delay per hour.

Both factors will experience their biggest evolution rate from 2012 on until their entire completion on 2020 (63% for capacity and 67% for efficiency). This theoretical increase would mean, for example, that a capacity of 80 operations per hour could be reached by 2020.

In terms of environment, SESAR will increase the capacity and efficiency of the Airport of Barcelona while minimizing the environmental impact of aviation on the surroundings of the airport by implementing its new environmental tools and procedures, such as CDA operating techniques which will reduce aircraft's emissions and noise.

The implementation of SESAR will represent an investment for the airport, and to this effect, a business case is presented, containing the analysis of the costs derived from implementing the SESAR requirements in the airport and the balance with the benefits obtained.

CBA results show that Airport CDM is a solid investment given its technical applicability and economic viability, since benefits are 4 times bigger than implementation costs and the payback period is within only 2 years; all this at a nearly non-existent financial loss risk.

To sum up, SESAR is an extremely positive option for the Airport of Barcelona, since it brings the necessary increases in capacity and efficiency in order to cope with future scenarios, and gives substantial economic benefits.

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1 INTRODUCTION

Skies are getting more and more congested. Recent modeling studies reveal that flight demand and capacity (in airspace and airports) are not increasing at the same rate: for instance, a growing mismatch between supply and demand will be considerable by 2020. If no counter action is taken, the current air traffic management (ATM) structure will be a source of numerous bottlenecks, constraining flight demand by both airspace and airport capacity.

The challenge of satisfying traffic demand will increase over the next 10 years, being airports a key element of the required future air transport capacity, as ground nodes of the air transport chain that link consecutive flights. Since forecasts indicate that traffic may be more than double, many airports will need to operate close to their maximum capacity.

In 2004, EUROCONTROL carried out a study to analyze the situation of the European airport capacity, in order to assess the available capacity, the percentage of capacity usage and existing constraints. This study showed that only 70% of European airport capacity was used.

To cope with this significant growth of the traffic levels, the European Commission and EUROCONTROL launched the Single European Sky ATM Research (SESAR) Program, which represents a new paradigm for the future European Air Traffic Management.

The future European concept of operations, SESAR, aims at developing the new generation ATM system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years, and represents a key challenge and opportunity for enhancing airport capacity, specially emphasizing on new procedures and technologies.

2 AIM OF THE STUDY

2.1 The need of this study

Up to this date, the impact of SESAR in terms of capacity and efficiency at airports has not been deeply analyzed. Based on this, it is interesting, and somehow useful, to demonstrate and analyze if SESAR will really be successful or not and to discuss all the different implications or limitations or problems that might appear, based on a real case.

SESAR is a huge step that will bring certain complexity to the airports by the time of its implementation. This report is meant to be a seed for more complete, deep and complex documentation, to serve as a guideline to the SESAR mutation.

This report might be used as a quick reference book, which provides key information in a brief and concise way: describing what SESAR is, emphasizing the technological enhancements introduced by SESAR, which benefits means, which systems are needed, when it should be implemented, how much it would cost, ect.

On the other hand, SESAR finds its justification in the growth that air traffic will undergo over the next 15 years. As mentioned before, the European airspace is fragmented and will become more and more congested. Air navigation services and the system that supports them are not significantly integrated and are based on technologies which are already running at maximum.

It is clear that a program to improve the European ATM involving:

- civil and military,
- legislators,
- industry,
- operators,
- users,
- ground and airborne

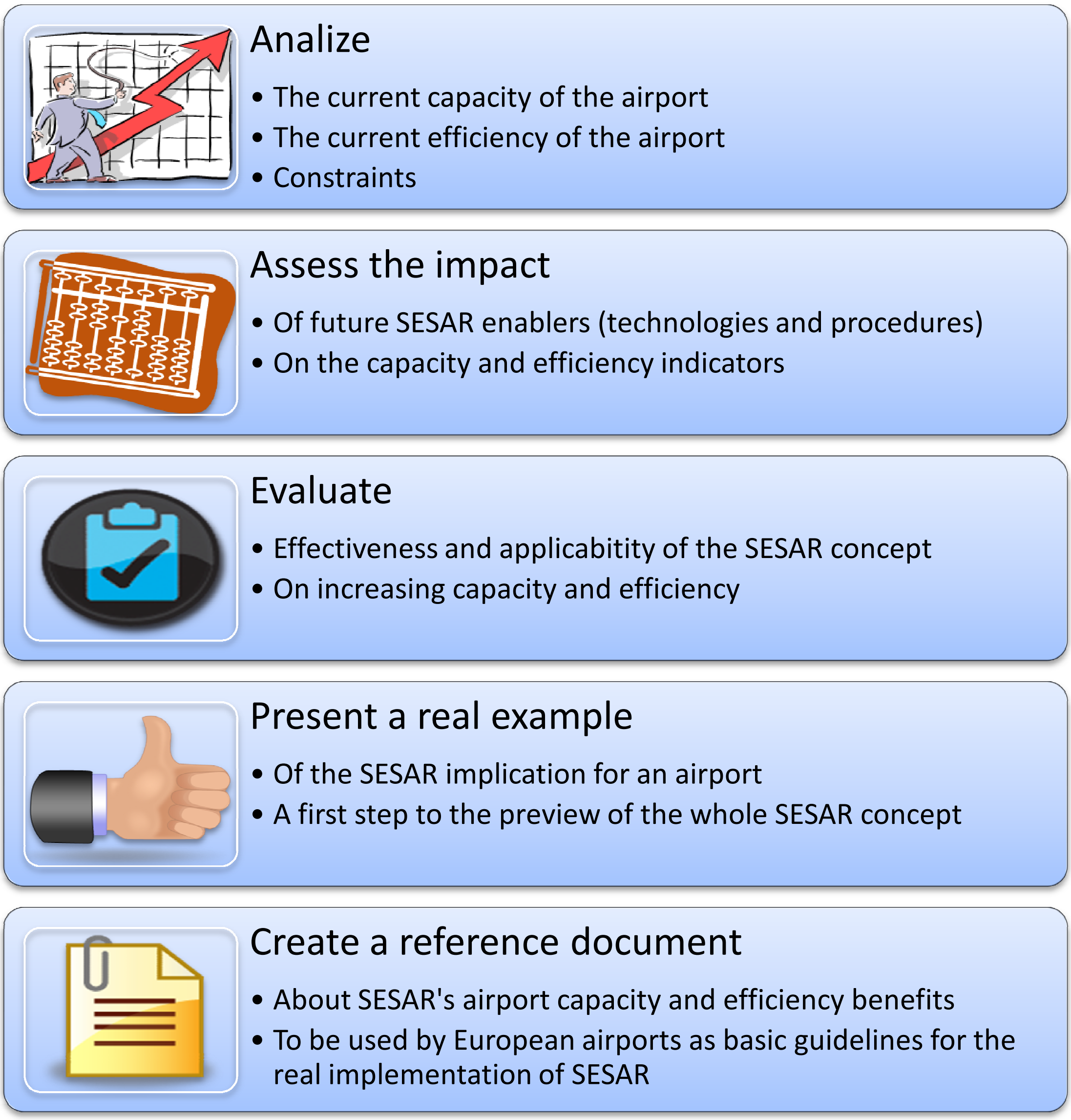
is needed for:

- defining, committing to and implementing a pan-European program,
- supporting the SES legislation

as well as a new concept of technologies and procedures for incrementing the capacity and the efficiency of the airports.

2.2 Objectives

The present study aims at developing a case study for a chosen European airport in order to:



Analize

- The current capacity of the airport
- The current efficiency of the airport
- Constraints

Assess the impact

- Of future SESAR enablers (technologies and procedures)
- On the capacity and efficiency indicators

Evaluate

- Effectiveness and applicabitity of the SESAR concept
- On increasing capacity and efficiency

Present a real example

- Of the SESAR implication for an airport
- A first step to the preview of the whole SESAR concept

Create a reference document

- About SESAR's airport capacity and efficiency benefits
- To be used by European airports as basic guidelines for the real implementation of SESAR

Figure 2.1. Case study's objectives

3 SCOPE

The scope of this study aims to evaluate the impact of SESAR enhancements on an airport's capacity and efficiency. To do this, a case study based on the detailed analysis of a real airport is developed. Both airside and landside will be considered, either at global level (declared capacity) and at single process level (landside: check-in, apron, etc; airside: runway, taxiway, ect.).

En-route and TMA approach and departure capacity are not under the scope of this study and will not be analyzed.

A short, middle, and long term analysis of all the enhancements introduced by SESAR will be undertaken. Moreover, its new procedures and tools will be used.

For capacity assessments, no numerical simulations will be made or simulation specific software will be used: capacity will be estimated from mathematic formulae provided by different references[1].

Moreover, a business case is presented, containing the analysis of the costs derived from implementing the SESAR requirements in the airport and the balance with the benefits obtained.

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[1] [B4], [B5], [B10], [B13], [B14], [B19], [B23], [B26], [B28], [B38], [B41]

4 THE METHODOLOGY

In general, the study is developed in four main steps:

4.1 Airport survey and sample selection

Among Eurocontrol's network of airports, this selection will be done based on a small characterization of some airports following the criteria of traffic congestion, available capacity, annual traffic, capacity assessment method that will be used, and available data. The analysis will be divided into different categories of airports: main, secondary, regional, etc.

4.2 Airport capacity survey

A radiography of the current situation of the available capacity at airports will be developed. For the selected group of airports a detailed analysis will be performed (either process by process or the total capacity): declared capacity; subsystems capacity (airport ATC, runways, taxiways, apron, baggage handling, passenger check-in …); identification of the bottleneck subsystem.

In order to do this, a recompilation of the different capacity assessment methods will be carried out in order to know about all the different possibilities to continue further in the analysis of this study, by doing an exhaustive research and by looking up official documentation sources (international rules, recommendations, recompilations, references to other similar studies…).

All the different methods will be submitted into an evaluation process of their viability and applicability, for determining the most suitable ones for this study (i.e. FAA assessments methods are valid for US airports, but for the European case they give overestimated values).

4.3 Airport capacity and efficiency assessment

A complete analysis of the selected airport will be made. Two different scenarios will be created: the current and the SESAR scenarios. First, an assessment of the current levels of capacity and efficiency indicators for the selected airport will be performed: capacity usage, delay indicators, etc. by identifying the most congested areas.

To do this, selected simple and direct formulae will be implemented, as well as graphs and figures found in different liable sources. No simulations will be performed.

Once it is decided which airport will be submitted into this study, direct measurements will be taken in place if needed for the assessments.

4.4 SESAR & future trends effect on airport capacity & efficiency

Airport demand-capacity balance solution for the SESAR 2020 scenario will be envisaged by assessing the new figures for the airport's capacity by taking into account SESAR's new procedures and technologies (wake vortex detection, time based separations, etc). Identification and quantification of the required solutions/strategies to accommodate the 2020 demand will be performed:

- declared capacity uplift due to new procedures & technology
- new infrastructures
- displacement of demand from main congested airports to secondary ones
- etc.

In this step, capacity will be assessed again for the new scenario and it will be possible to evaluate in a precise way whether SESAR introduces capacity improvements or not and to extract some interesting conclusions about its effectiveness.

Discussion and evaluation of efficiency will also be undertaken. To do this, several efficiency indicators will be defined, so that these variables (i.e. SESAR's KPIs[2]) quantify, in some way, the efficiency of the airport as well.

4.5 Environment and business case

Regarding environment, it will be discussed how SESAR influences the environment and which benefits / inconvenient brings. Concretely for budget, a short-scale business case will be evaluated, but since SESAR is at a very early stage, no numbers are available at all, so some hypotheses may be assumed, and bare numbers will be obtained, to at least have an idea of how much would cost implementing SESAR at the airport and how many years after its implementation the airport would start having a positive revenue.

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[2] Key Performance Indicator

5 PROJECT SCHEDULE

5.1 Study's task list

The procedure to successfully complete the present study will go through the following steps:

1. Documentation process to get in touch with the scope of the study: capacity at airports and the SESAR Program
2. Research of existing current methods for airport capacity assessments: in this task, a complete scan to determine the different existing methods used to calculate an airport's capacity by either process by process or total capacity will be undertaken. To do this, several sources such as official documents, internet…will be looked up
3. Airport processes identification and methodology to calculate their capacity
4. SESAR general impact on airports analysis
5. Airport capacity and efficiency indicators definition: in this task it will be determined which variables will indicate whether SESAR introduces capacity improvements or not and will quantify, in some way, the efficiency of the airport as well
6. Airport candidates evaluation and choice: decide which of the airport candidates is the most suitable for this study
7. Current scenario analysis for the selected airport
8. SESAR scenario creation: new technologies, new procedures, etc. to be implemented
9. SESAR scenario analysis for the selected airport
10. Comparison of indicators between both scenarios
11. Environmental impact key issues
12. Business case preliminary analysis
13. Conclusions
14. Document edition and formatting

5.2 Study's calendar

The calendar planning for the different tasks described before is included in the following Gantt chart detailing the duration of every specific task, its start and its end and how the tasks are inter-related.

The red line indicates the critical path, that is to say, the series of tasks that cannot be delayed so that the calculated start or finish date of the project is not modified. When the last task in the critical path is complete, the project is also complete.

6 LEARNING ABOUT SESAR

6.1 Current airport's infrastructure capacity in Europe

The current ATM and airport infrastructure cannot fully accommodate the increasing demand. The rhythm of growth of both flight demand and capacity is evolving at a different rate, leading to a considerable unbalance between supply and demand by 2020.

As traffic levels continue to increase, the ability of the air transport system to cope with demand is becoming an ever more critical factor. In 2007, about 10 million flights were recorded, whilst the most likely scenario according to [B7] is an average growth of 2.7% a year between now and 2030, which means that by 2015, around 20% of overall demand will be already unaccommodated and the air traffic will almost double by 2020 (17.2 million IFR flights per year) in Europe. At the same time, environmental awareness is rising, prompting the need for more efficient operations and better technology and introducing constraints in the ability to absorb traffic demand.

According to [B7], the airport network can absorb a growth of 60% in capacity in a long-term period, in part due to the fact that 25% of airports consider building new runways in the next 20 years, but only a small part of this extra capacity can be provided at the major airports and one third of it would in fact not be needed until 2025 due to insufficient demand at the concerned airports.

Almost 80% of the airports indicate that without adding extra runways, they will be unable to achieve the same capacity as the best performing airport with comparable runway configuration. The main reasons for this are physical site and infrastructure limits, followed by environmental issues, and physical constraints related to surrounding airspace and geography.

Today, most airports have some spare capacity. In the scenario with the highest traffic growth, even with maximum achievable capacity enhancements, this situation is expected to gradually deteriorate into capacity imbalance.

Already in 2010, more than 20 airports are expected to have a capacity shortage if demand evolution follows the high growth scenario. Despite this 60% of potential capacity increase of the airport network, only twice the volume of 2003 traffic will be accommodated, and 17.6% of demand (3.7 million flights per year) will not be able to take place. This is expected to have a significant impact on airport operations.

Ultimately, in 2025, with all new investments taken into account, more than 60 airports will be unable to handle the typical busy hour demand without generating delays or unaccommodated demand and the top-20 airports will be saturated at least 8-10 hours per day.

The progressive occurrence of unaccommodated flight demand will cause pressure to change the traffic distribution pattern: growth will be limited to parts of the airport network which are not yet congested, meaning that extra flights will only be possible at secondary airports, generally at less favorable times. There will also be a strong pressure to accelerate the switchover to larger aircraft, in order to accommodate more passengers while keeping the number of flights constant.

Therefore, to find new solutions for increasing capacity but also for increasing the efficiency of use of the available declared capacity by the introduction of new operational procedures and technologies.

6.2 Single European Sky initiative

Contrary to the United States, Europe does not have a single sky structure, one in which air navigation is managed at the European level. Furthermore, European airspace is among the busiest in the world with over 33,000 flights on busy days and airport density in Europe is very high. This makes air traffic control even more complex.

The EU Single European Sky (SES) is an ambitious initiative launched by the European Commission in 2004 to overcome this fragmentation and capacity crunch by structuring airspace and air navigation services at a pan-European level rather than at a national one, to better manage air traffic. It proposes a legislative approach to meet future capacity and safety needs. SES is the only way to provide a uniform and high level of safety and efficiency over Europe’s skies.

The key objectives are to:

- Restructure European airspace as a function of air traffic flows,
- Create additional capacity, and
- Increase the overall efficiency of the air traffic management system.

The major elements of this new institutional and organizational framework for Air Traffic Management in Europe consist in:

- Separating regulatory activities from service provision, and the possibility of cross-border Air Traffic Management services;
- Reorganizing European airspace that is no longer constrained by national borders.

6.3 SESAR Program

SESAR (*Single European Sky Air traffic management Research*) is the technological pillar of the SES policy. The aim of SESAR is to develop the new generation air traffic management system capable of ensuring the safety and fluidity of air transport over the next 30 years.

The SESAR program came to life with the acknowledgment that as traffic levels continue to increase, Europe's current air traffic control systems will soon be unable to cope with the growth in flight movements.

6.3.1 SESAR's objectives

As stated by the European Commission, the future European ATM system shall achieve the following key performance targets for 2020 and beyond (relative to today's performance):

Capacity

- Enable up to 3-fold increase in air traffic movements whilst reducing delays

Safety

- Improve safety levels by a 10 factor

Environment

- Reduce by 10% the environmental impact per flight

Cost-Effectiveness

- Cut ATM costs per flight by 50%

Figure 6.1. SESAR's objectives

The SESAR project will give Europe a high-performance air traffic control infrastructure which will enable the safe and environmentally friendly development of air transport. This, translated into key figures, means that:

- 945kg - 1575kg reduction of CO_2 emissions on average
- 300 - 500 kg of reduction in fuel per flight on average
- 8-14 min of gain per flight on average
- 20.4 million yearly flight movement by 2030 predicted by Eurocontrol = twice the current figure
- 2.1 billion Euros invested in R&D during the development phase

Some examples that will lead to improved safety:

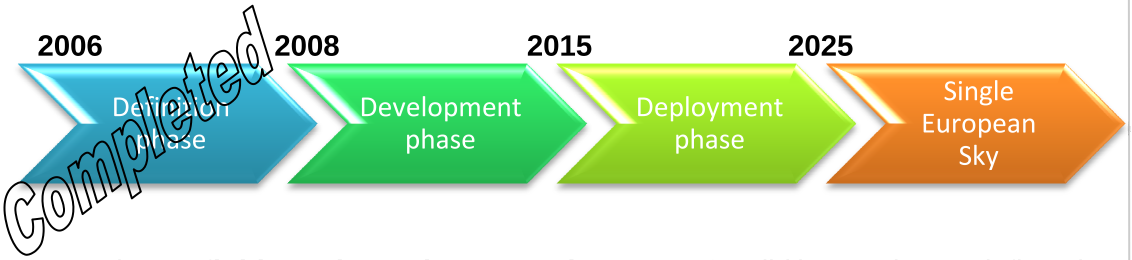
- More widespread provision of ATC services (e.g. implementation of remote towers, where none exist today);
- Improved surveillance on the airport surface, which will also be linked to safety nets that will help prevent runway incursions and conflicts on the taxiways;
- Improved visual aids, reducing the possibility of becoming lost and straying onto an active runway;
- Improved and more widespread precision approaches
- Better information (including weather, airspace restrictions, etc.)

Some more examples that will lead to improved efficiency:

- Better planning of airport surface operations and arrival / departure sequencing through AMAN / DMAN and SMAN[3] (e.g. less time wasted at the holding point because of difficulties with integration into the traffic sequence);
- Improved airspace design allowing a more efficient flight (e.g. better access to controlled airspace or improved and dynamic airspace dimensions

6.3.2 SESAR phasing and timeframe

SESAR is organized in three phases:



- The **Definition phase (2006-2008),** was a feasibility study to *define* the content, the different technological steps, program priorities, operational implementation plans, and the development and deployment activities of the next generation of ATM systems that will support the implementation of the SES policy. The delivery product of this phase is the European ATM Master Plan and a new set of Concept of Operations (ConOps).

- The **Development phase (2008-2015)**, is focused on the *development* of the required new generation of technological systems, components, equipments, standards and operational procedures as defined in the SESAR ATM Master Plan and Work Program and will demonstrate the feasibility of the ConOps.

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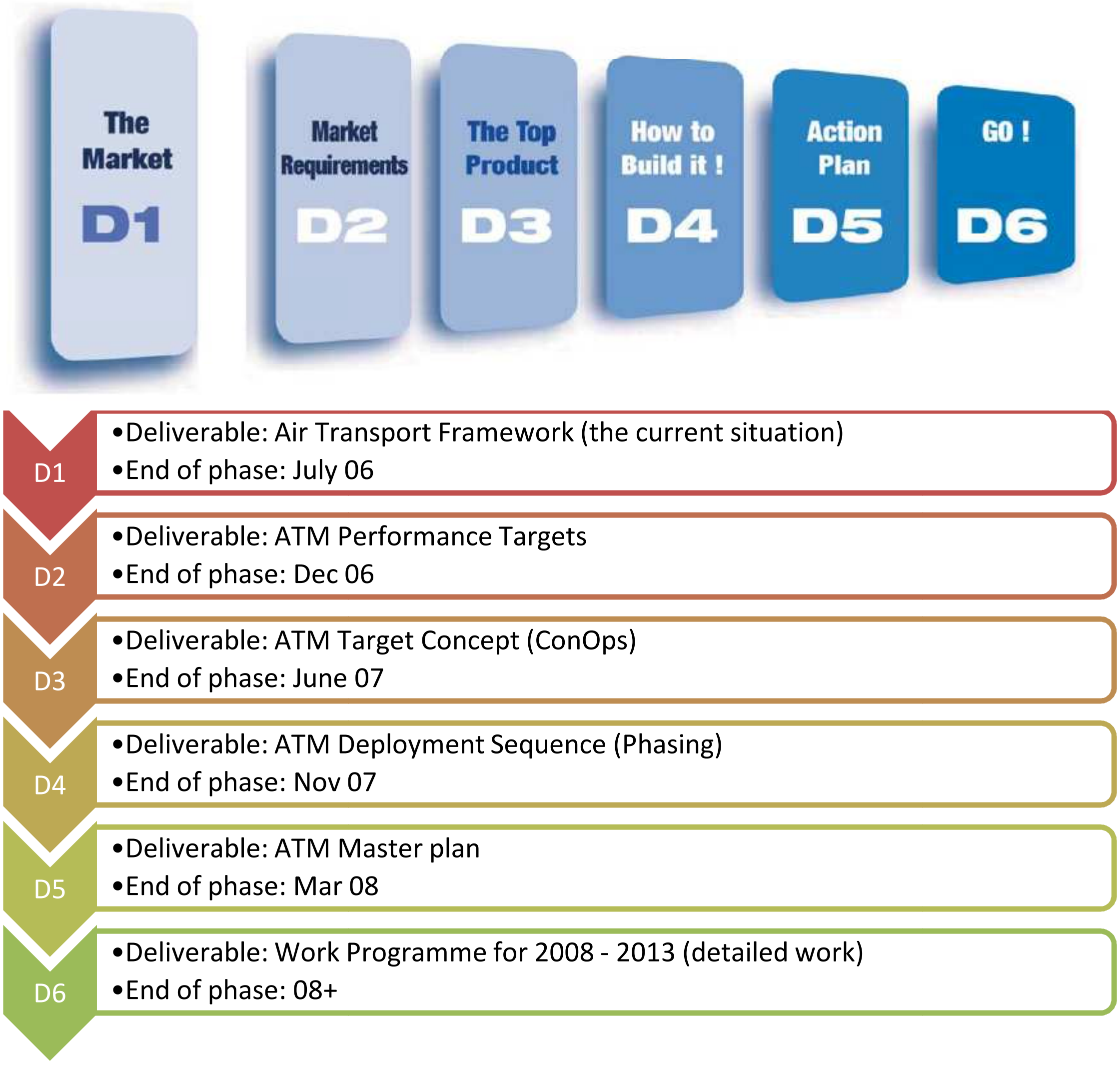
[3] SESAR system enablers

Managed by the SESAR Joint Undertaking (SJU)[4], a legal entity under European Community law.

- The **Deployment phase (2015-2025)**, aims at deploying the new system through a large scale production and the implementation of the new ATM infrastructure.

6.3.2.1 Definition phase: Milestones

The definition phase is broken down into six phases, corresponding to six main expected deliverables:



D1
- Deliverable: Air Transport Framework (the current situation)
- End of phase: July 06

D2
- Deliverable: ATM Performance Targets
- End of phase: Dec 06

D3
- Deliverable: ATM Target Concept (ConOps)
- End of phase: June 07

D4
- Deliverable: ATM Deployment Sequence (Phasing)
- End of phase: Nov 07

D5
- Deliverable: ATM Master plan
- End of phase: Mar 08

D6
- Deliverable: Work Programme for 2008 - 2013 (detailed work)
- End of phase: 08+

Figure 6.2. SESAR's deliverables [B29]

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[4] Founded by the European Comission and Eurocontrol, SJU is a unique and ambicious public-private partnership provided by its Members and in particular by using their experience and expertise that aims at modernizing ATM infrastructure in Europe.

6.3.2.1.1 D3 - The Concept of Operations (ConOps)

The ATM ConOps for 2020 is an important SESAR concept which describes in detail how an operational concept is applied and how the next generation ATM system needs to work in the future so that SESAR's goals can be achieved. It identifies the functions and processes, and their corresponding interactions and information flows; concerned actors, their roles and responsibilities. ConOps represents a shift from an airspace-based environment to a trajectory-based environment It includes the so-known *7 pillars of SESAR:*

Figure 6.3. SESAR's ConOps [B25]

- **4D Trajectory Management**, introducing a new approach to airspace design and management;
- Collaborative Planning and **Collaborative Decision Making** (CDM), continuously reflected in the **Network Operation Plan** (NOP);
- **Integrated Airport operations**, contributing to capacity gains;
- **New separation modes**, allowing increased capacity;
- **System Wide Information Management (SWIM)**, integrating all ATM business real time related data;
- **Humans (automation support)**, who will be central in the future European ATM system as managers and decision makers.

In the ConOps, SWIM and CDM/NOP are necessary as a foundation for the other elements.

ConOps are described in Detailed Operational Description documents (DOD).

6.3.2.1.1.1 Collaborative Decision Making (CDM)

Nowadays, the allocation of resources related to aircraft is performed by the following agents: Eurocontrol, Airliners, Airports and Air Traffic Control (ATC). Each agent has a partial vision of what happens to the aircraft, causing a heterogeneous environment of information associated to the operations. This situation implies degradation in the quality of the information and therefore a loss of efficiency in the management of resources related to the operations.

CDM refers to a set of applications aimed at facilitating the optimal assignation of the resources associated to an aircraft in order to improve flight operations through the increased involvement of airspace users, ATM service providers, airport operators and other stakeholders in the process of air traffic management.

By enabling Airport CDM based on accurate information, shared in a timely manner, A-CDM increases the overall efficiency of the airport operations and improves predictability, notably in case of bad weather or other unforeseen events. Experience in the airport environment has shown that just by sharing relevant information between partners, common situational awareness and understanding of a situation increases the quality of decisions sufficiently to enable a better use of resources, allow partners to set priorities and improve the predictability of operations, not only in the airport itself, but system wide.

It is oriented to the operations management and applies to all layers of decisions, from longer-term planning activities through to real-time operations, and is based on the sharing of information about events, preferences and constraints.

Nowadays, the interoperation of stakeholders can be achieved by exchanging data in a peer-to-peer (P2P) protocol, which consists of the exchange of information between all the actors implied in the management of the operations.

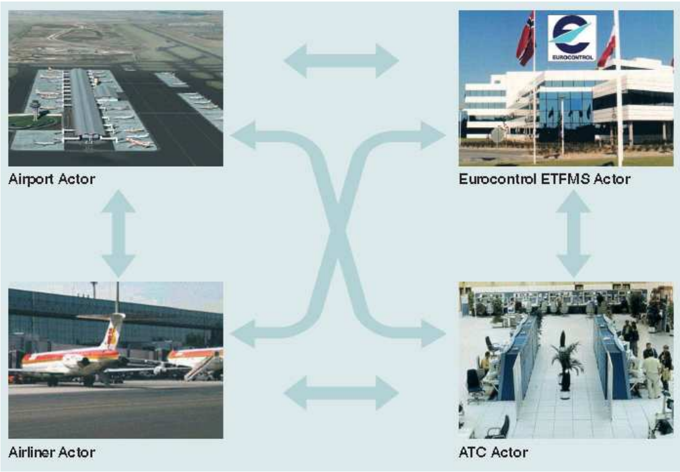

Figure 6.4. Current data exchange architecture [B18]

The main advantage of this configuration is that each actor obtains from the others the necessary data to fit his needs, whereas each actor must know the communication interface of the rest of actors, because of the absence of standards that regulate these communications.

In the other hand, the CDM information sharing environment is a common environment where the information is retrieved. In this case, each actor obtains the necessary data to fit his needs, through a common repository; and each actor only needs an interface to provide his prominent information. In addition, the environment can be regulated by standards that ensure communications between the actors. The main disadvantage of this configuration is that the environment does not make any oriented calculation to improve the adjustment of resources.

Figure 6.5. CDM data exchange architecture [B18]

As it can be seen, CDM is a concept to support the decision oriented to the management of operations based on the collaboration of the agents implied in the process. In this way, CDM system is not only a repository of unified information, but a mechanism that facilitates the cooperation between the actors involved in the management of resources.

CDM is already used at a number of European airports. In SESAR this method of decision making will not be confined only to airports but will be further developed and spread throughout the network. It needs to cover the sharing of information related to the progress of 4D trajectories (on the ground and in the air) and the actions taken on this information.

6.3.2.1.1.2 4D Trajectory Management

4D trajectories are defined by an aircraft’s 3D position (latitude, longitude, altitude) plus time. Consequently, the main change from the current way of ATM operation is the change from an airspace-based concept of operations to a trajectory-based system.

Instead of having several versions of the trajectory in the system, there is a unique accurate trajectory for each flight defined in all four dimensions that is used throughout the entire ATM network: it is called the Reference Business/Mission Trajectory (RBT).

6.3.2.1.1.2.1 The Business Trajectory

The Business Trajectory is the 4D trajectory which expresses the Business/Mission intention of the airspace user. It is fully owned by the airspace user and changes via CDM processes involving user but does not interfere with ATC/Pilot time-critical decision processes. When constraints are needed the solution is chosen by the user whenever possible. It is based on most timely and accurate data available and exists throughout all phases of the ATM process.

6.3.2.1.1.2.2 Business Development Trajectory (BDT)

It exists during Business Development processes and it is internal to the User (not all users have a Trajectory at this time)

6.3.2.1.1.2.3 Shared Business Trajectory (SBT)

The SBT is the published business/mission trajectory that is available for collaborative ATM planning purposes. It exists during the planning phase and it is “published” by the user and shared by all participants.

The refinement of the SBT (it may relate to changes such as time updates (schedule part), route optimization, allocation (by an airspace user) of a specific airframe to a specific (outbound) flight, linkage (by an airspace user) of a specific inbound flight to a specific outbound flight, etc...) will be an iterative process. The product of this iterating process is the RBT.

6.3.2.1.1.2.4 Reference Business Trajectory (RBT)

The RBT is the trajectory that an airspace user agrees to fly and the service provider agrees to facilitate.

The RBT is authorized in segments, either as a clearance by the Air Navigation Service Provider (ANSP) or as a function of aircraft crew/systems, depending on whether the ANSP or the flight crew is the designated separator (see Figure 6.7).

Non time-critical trajectory changes are made through CDM, with the airspace user adjusting the trajectory to comply in a way that best suits his operational business needs.

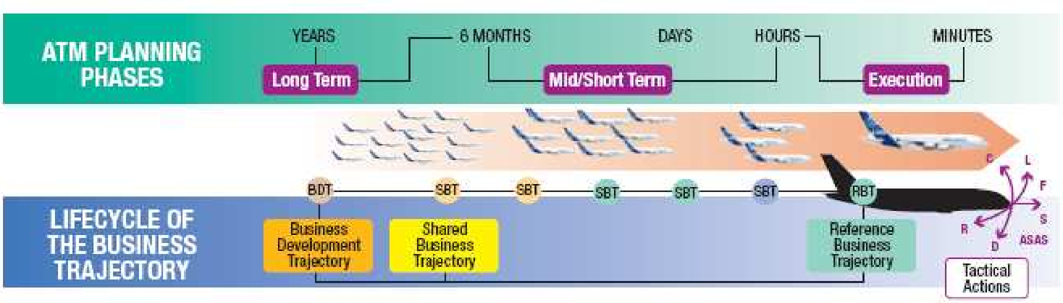

Figure 6.6. The Business Trajectory lifecycle [B31]

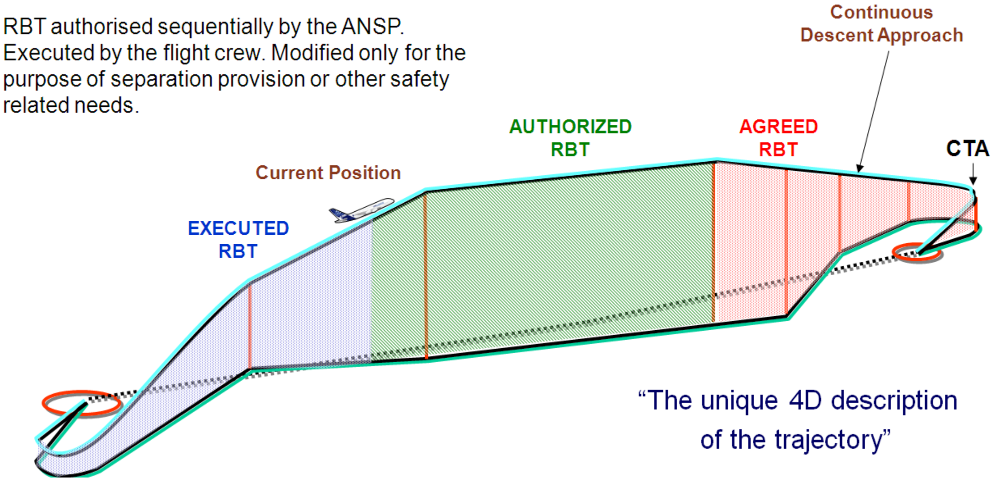

Figure 6.7. Reference Business Trajectory

6.3.2.1.1.3 Network Operations and NOP

The iterative planning process (in SBT) refines the trajectories and the available resources and expresses these as the Network Operations Plan (NOP). The NOP is a dynamic rolling plan for continuous operations rather than a series of discrete daily plans which draws on the latest available information being shared in the system giving a snapshot of the network at any time.

The NOP works with a set of collaborative applications providing access to traffic demand, airspace and airport capacity and constraints, scenarios to assist in managing diverse events and simulation tools for scenario modeling. The aim of the NOP is to facilitate the processes needed to reach agreements on demand and capacity.

The planning is overseen by a Network Management function which assures, at network and regional level, the stability, efficiency and contingency of the ATM network.

6.3.2.1.1.4 Automation support

The main constraint to airspace capacity today is human (controller/pilot) task load. Therefore in order to increase capacity there must be a substantial reduction of human (controller/pilot) task load per flight, while also meeting the SESAR safety, environmental and economic goals.

This will require an intense enhancement of integrated automation support while human operators are expected to remain at the core of the system.

Humans will need to remain in command as overall system managers, but using automated systems possessing the required degree of integrity and redundancy.

6.3.2.1.1.5 Integrated airport operations

Airports will become an integral part of the ATM network as nodes in the system due to the extension of trajectory management (this means that the airside and turn-around process will both be part of the trajectory: it will be an en-route to en-route concept; not a gate-to-gate anymore).

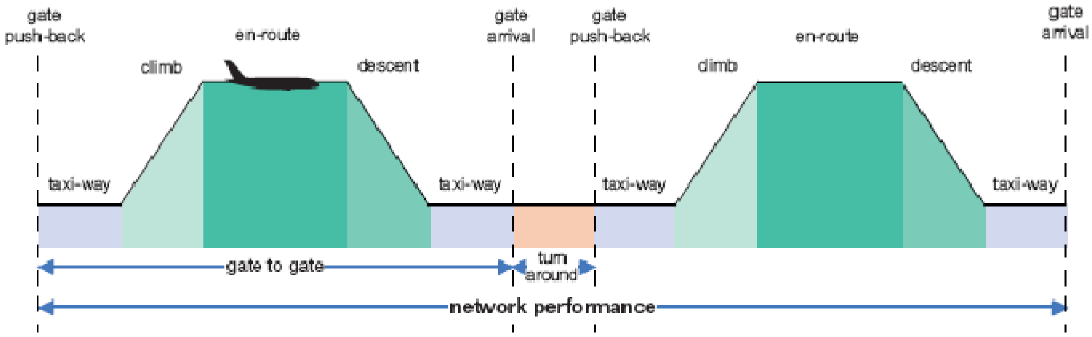

Figure 6.8. Integrated airport operations concept

The execution of an individual flight can be expressed in distinctive events from push back from the gate to the arrival at the gate, which includes taxiing, takeoff, climb, en-route, descent and taxiing to the gate.

The operational performance targets for an individual flight are currently expressed in gate-to-gate parameters. While this includes the runway, taxiway and gate assignment planning and operations, it does not include the turnaround ground handling process at the airport.

Increased throughput and reduced environmental impact (through e.g. turnaround management, reduction of the impact of low visibility conditions, etc.) is envisaged. With improved Airport Resource Planning processes there will be greater coordination between the stakeholders and thereby improved use of available capacity to meet the increased demand.

The performance of these processes is a result of the collaboration process between Airspace Users and airport operators involving more partners such as ground handlers, catering and fuel suppliers and needs to be coordinated with the ANSPs to ensure that the gate-to-gate performance can be met for connecting flights.

6.3.2.1.1.6 New separation modes

As a further means of reducing controller/pilot task load new separation modes are introduced within the SESAR concept.

Separation modes fall into three broad categories:

- Conventional Modes: those that are essentially unchanged by SESAR
- New ANSP Separation Modes: new modes that are applied purely by ATC that involve Precision Trajectory Clearances (PTC)
- New Airborne Separation Modes: new modes that involve the aircraft and in which the pilot is the separator either by delegation or as the standard case

6.3.2.1.1.7 System-wide Information Management (SWIM)

SWIM can be defined as the vehicle to promote the development and implementation of new separation modes at the legal, institutional, business, organizational, operational and technical levels.

SWIM is a *horizontal* support process whose aim it is to establish the concepts and mechanisms which combine the forces of all suppliers of shared ATM information so as to assemble the best possible integrated picture of the past, present and (planned) future state of the ATM situation, as a basis for improved decision making by all ATM stakeholders during their strategic, pre-tactical and tactical planning processes, including real-time operations and post-flight activities.

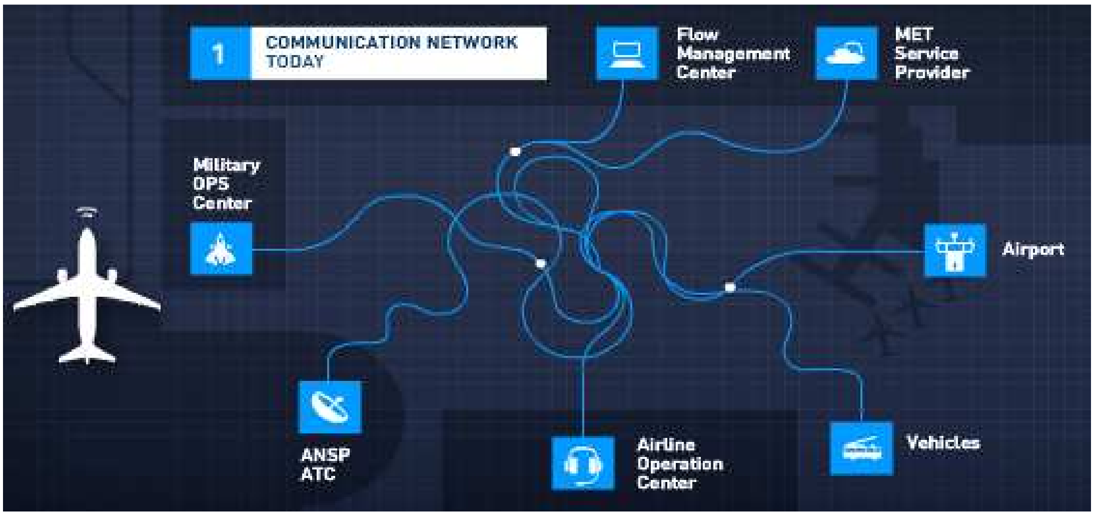

Figure 6.9. Communications network today [W1]

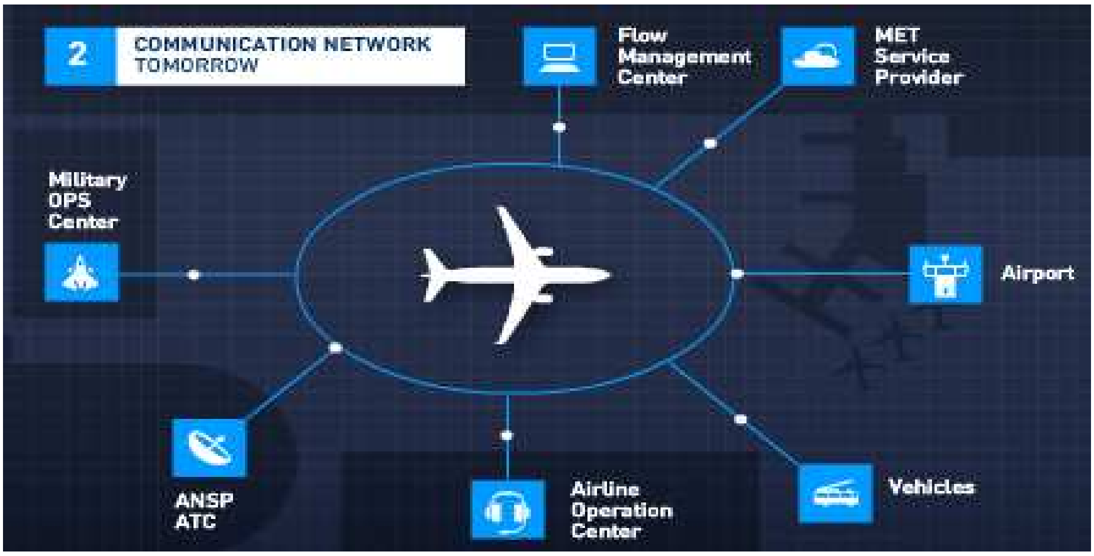

Figure 6.10. SWIM architecture [W1]

6.3.2.1.2 D4 - Deployment sequence

The SESAR Deployment Sequence is based on ATM Capability Levels (ACL), which is a set of functional evolutions for Aircraft, Terminal Control Area (TMA) centers, or Airports as enablers. The implementation of those ACLs will enable all the supply stakeholders to deliver the required ATM Service Levels (ASL) to the Airspace Users for a given operational improvement (OI).

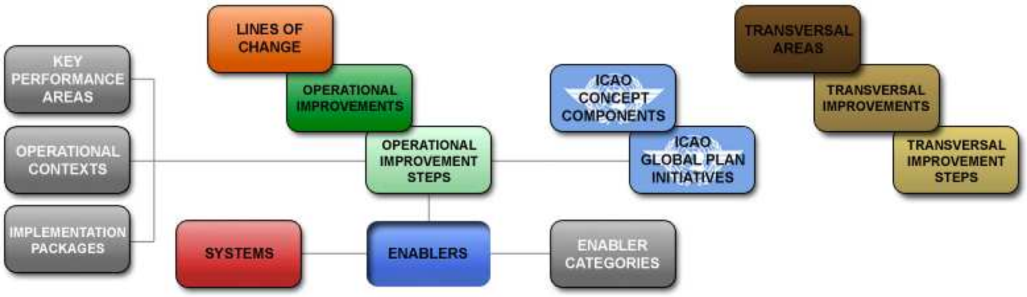

Figure 6.11. SESAR Deployment Sequence breakdown structure [W17]

In the following a further description of each agent affecting the deployment sequence will be given.

6.3.2.1.2.1 ATM Capability Levels (ACL) and ATM Service Levels (ASL)

The notions of ASL and ACL are used as the top-level system-wide basis to establish the performance characteristics with which all components (covering both those on-board aircraft and within the ground-based systems) of the future European ATM System will be linked.

SESAR has defined six levels, which will progressively be deployed as shown in the figure below.

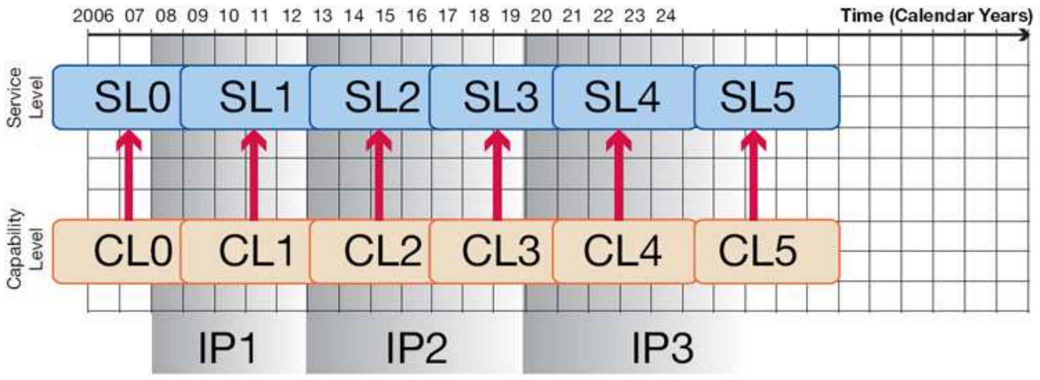

Figure 6.12. SESAR ACLs and ASLs over time [W17]

Capability levels are associated with stakeholder systems, procedures, human resources etc. Upgrading a stakeholder to a higher capability level means deployment of new enablers, and this requires investments (costs).

Service levels are associated with operational services offered by a service provider and consumed by a service user. Upgrading a service to a higher service level means deployment of operational improvement steps, and this leads to benefits (performance improvements).

Delivering a service at a given service level X requires that both the service provider and the service user have at least evolved to capability level X. Backward compatibility is also required: each system, which has a given capability level, should also be able to provide and receive services at a lower service level. This ensures interoperability between systems of different capability levels. For example: an aircraft at capability level 3 is flying into a capability level 2 airport. They will provide and use service level 2. The performance benefits are those associated with service level 2.

Utilizing a service requires that both the service provider and the service user possess the required capability, but not necessarily all the capabilities of a particular level.

In a mixed ATM environment it is clear that such capability mismatches will occur to some extent. However the general rule for deployment should be that air and ground deployment should be geographically synchronized as much as possible, to avoid 'wasting' capabilities.

The above relationships are illustrated in the figure below.

Figure 6.13. Relationship between ATM Service and Capability Levels [W17]

6.3.2.1.2.2 Implementation Packages (IP)

For the sake of situating the various ASLs and ACLs in time, the SESAR Implementation Phase has been subdivided into three time periods (called Implementation Packages in D4) which are linked to the Initial Operational Capability (IOC) dates of the ASLs as shown in Figure 6.12 and Figure 6.13:

- IP1: Creating the foundations: (short-term: IOC dates up to 2013). This is mainly the identification of initiatives which are already planned today in various places in Europe. Covers ATM Service Levels 0 and 1;

- IP2: Accelerating ATM to implement the 2020 Target Concept: (medium term: IOC dates in the period 2013-2020). It is the identification of improvements which are feasible during the timeframe 2013 to 2020 and which are expected to bring significant benefits in terms of performances. Covers ATM Service Levels 2 and 3;

- IP3: Achieving the SESAR goals in the long term: (long term: IOC dates from 2020 onwards). It will identify the remaining improvements to be achieved in order to cover the whole SESAR ConOps. Covers ATM Service Levels 4 and 5.

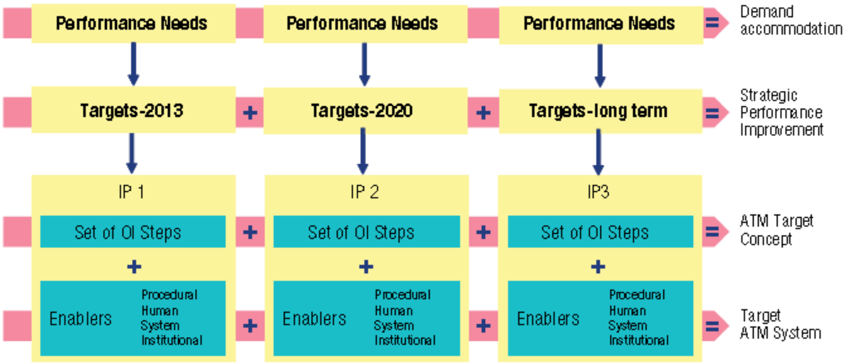

Figure 6.14. IP sequence approach [B32]

Each of the 3 IPs identified represents a timeline in the evolution of the ATM system from today to the ConOps end state. Each IP has to be in place before its successor can be implemented and they represent the main transition steps to the SESAR target goal.

Based on the D3 deliveries, D4 is currently refining the SESAR Operational Concept and its costs and benefits assessment. As said before, Milestone Deliverable D3 presented a ConOps able to meet future demand. To ensure that the evolution to this ConOps will meet the required performance over time, the IPs have been considered through the main operational areas that describe the evolution of the ATM environment (so called Line of Changes).

6.3.2.1.2.3 Line of Changes (LoC)

LoC are identifiable and well defined operational areas of the ATM environment, including all its aspects (procedures, practices, processes, systems, institutions, etc), that will need to undergo change in order to meet declared performance objectives and arrive at the SESAR ConOps end-state. Ten LoC are defined, namely:

SESAR’S LINES OF CHANGES	
L01	Information Management
L02	Moving from Airspace to Trajectory Based Operations
L03	Collaborative Planning using the Network Operations Planner
L04	Managing the Network
L05	Managing Business Trajectories in Real Time
L06	Co-operative Ground and Airborne Decision Making Tools
L07	Queue Management Tools
L08	New Separation Modes
L09	Improved Cooperative Ground and Airborne Safety Nets
L10	Airport Throughput, Safety and Environment
L01	Information Management

Table 6.1. SESAR’s Lines of Changes [W17]

6.3.2.1.2.4 Operational Improvements (OI)

An OI is any operational measure or action taken through time in order to improve the current provision of ATM operations. OI are not necessarily related exclusively to the effect of a change in technology, they can relate to procedures, working methods or routines and human factor aspects. An OI is always associated to an operational benefit and also to one or more “strategic objectives” and is part of one or more “directions of change”. An OI could also mean the “improvement of an existing capability” and/or the introduction of a new capability. There are 44 different OI:

SESAR’s OPERATIONAL IMPROVEMENTS	
L01-01	Improving Flight Data Consistency and Interoperability
L01-02	Improving Aeronautical and Weather Information Provision
L01-03	From AIS to AIM
L01-04	Implementing SWIM
L01-05	Airspace User Data to Improve Ground Tools Performance
L01-06	Weather Information for ATM Planning and Execution
L02-01	From Traditional Airspace Classes to Airspace Categories
L02-02	Optimizing Airspace Allocation and Usage
L02-03	From FUA to Advanced FUA
L02-04	Facilitating OAT Transit
L02-05	Increasing Flexibility of Route Network
L02-06	User Preferred Routing Environment
L02-07	Enhancing Terminal Airspace
L02-08	Optimizing Climb/Descent
L02-09	Increasing Flexibility of Airspace Management

L03-01	Collaborative Layered Planning Supported by Network Operations Plan
L03-02	User Driven Prioritization Process
L03-03	Planning the Shared Business Trajectory (SBT)
L04-01	Improving Network Capacity Management Processes
L04-02	Monitoring ATM Performance
L05-01	Management/Revision of Reference Business Trajectory (RBT)
L05-02	Managing Air Traffic Complexity
L05-03	Enlarging ATC Planning Horizon
L05-04	Moving to Coordination-free Environment
L06-01	Introducing Ground based Automated Assistance to Controller
L06-02	ATC Automation in the Context of En Route Operations
L06-03	ATC Automation in the Context of Terminal Area Operations
L07-01	Arrival Traffic Synchronization
L07-02	Departure Traffic Synchronization
L07-03	Managing Interactions between Departure and Arrival Traffic
L08-01	4D Contract
L08-02	Precision Trajectory Operations
L08-03	Airborne Situational Awareness
L08-04	ASAS Spacing and ASAS Cooperative Separation
L08-05	ASAS Self-separation
L09-01	Safety Nets Improvements (TMA, En Route)
L10-01	Improving Safety of Operations on the Airport Surface
L10-02	Improving Traffic Management on the Airport Surface
L10-03	Improving Airport Collaboration in the Pre-Departure Phase
L10-04	Using Runways Configuration to Full Potential
L10-05	Maximizing Runway Throughput
L10-06	Improving Operations under Adverse Conditions incl. Low Visibility
L10-07	Visual Conducted Approaches
L10-08	Implementing Environmentally Sustainable Operations

Table 6.2. SESAR's Operational Improvements [W17]

6.3.2.1.2.5 Operational Improvements Steps

Each IP is made up of a set of OI Steps. OI Steps describe a change to a specific area of the ConOps, which can be implemented in a given period of time, and results in a direct performance enhancement. Implementing an OI Step implies that a number of conditions are met and actions are performed. These are the enablers of the OI Steps. One or more enablers usually support an OI Step.

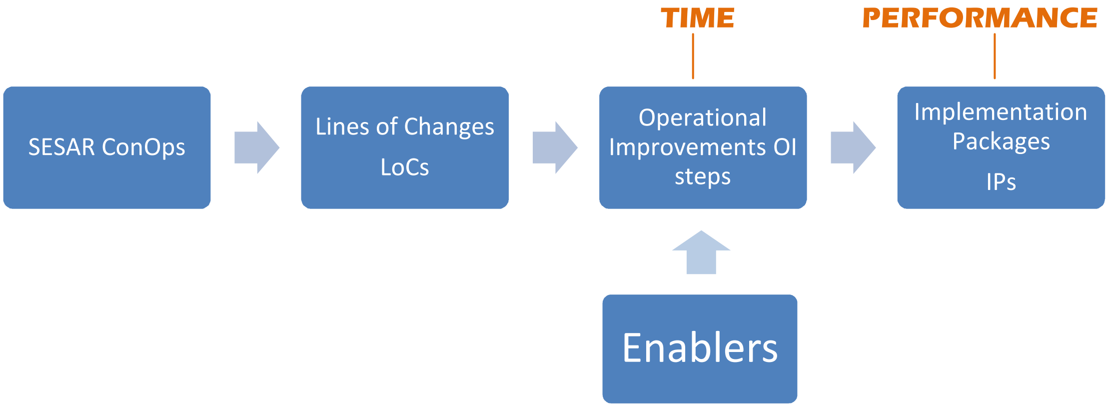

Figure 6.15. From the ConOps LoC to IPs

183 OI Steps exist, and they are divided into different groups:

SESAR'S OI Steps groups	
AO	Aerodrome Operations (ex. AO-0501)
AOM	Airspace Organization and Management (ex. AOM-0202)
AUO	Airspace User Operations (ex. AUO-0403)
CM	Conflict Management (ex. CM-0101)
DCB	Demand and Capacity Balancing (DCB-0303)
IS	Information Services (ex. IS-0704)
ATM SDM	ATM Service Delivery Management (ex. SDM-0203)
TS	Traffic Synchronization (ex. TS-0301)

Table 6.3. SESAR's OI Steps groups [W17]

6.3.2.1.2.6 SESAR enablers

Enablers are, in terms of systems, procedures, institutional and human aspects, changes to the supporting infrastructure, and they are needed in order to facilitate the desired OI Step, i.e. their implementation and deployment. They are not necessarily specific to a given OI Step, i.e. they may "enable" a range of OI Steps. SESAR enablers are grouped in four categories: system, human, institutional and procedural.

System enablers: changes to the architecture and supporting CNS[5] technologies

Procedural enablers: Include all operational procedures relevant to the ATM system and services

Institutional enablers: Includes global, regional, national and organization level institutional arrangements that impact on ATM and may relate to laws, treaties, agreements, regulation, standards, allocation of resources and other matters.

Human enablers: Include all aspects of the human as part of the ATM system.

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[5] Communications, Navigation and Surveillance

SYSTEM ENABLERS	PROCEDURAL ENABLERS	HUMAN ENABLERS	INSTITUTIONAL ENABLERS
Wake Vortex Detection AMAN DMAN SMAN	Time based separation UDDP APOC	Ergonomics Training Recruitment Selection Staffing	EU Legislation Bilateral/Multilateral Treaties Domestic Legislation

Table 6.4. Examples of SESAR enablers

The-in total 779 defined-enablers are grouped as well per domains:

SESAR’s ENABLER DOMAINS	
A/C	Aircraft systems
AAMS	Advanced Airspace Management System
ADETECT	Airborne Detection System
ADSB	Automatic Dependent Surveillance -Broadcast
AGDLS ATC AC	Air-Ground Data Link System
AGSWIM	Air-Ground SWIM systems
AIMS	Aeronautical Information Management System
AIRSP	Airspace
AIS/M	Aeronautical Information Services / Management
AOC ATM	Airline Operations Centre ATM systems
ARCH	Architecture
ASAS	Airborne Separation Assistance Systems
ASMGCS	Advanced Surface Movement Guidance Control System
BTNAV	Business Trajectory Navigation
CTE	Communications & Technology
ENV	Environment
ER APP ATC	En Route / Approach ATC systems
FCM	air traffic Flow and Capacity Management
GGSWIM	Ground- Ground SWIM systems
GSURV	Ground Surveillance systems
HUM	Human
LEG	Legislation
MIL	Military
NIMS	Network Information Management System
PRO	Procedures
PRO AC	Procedures Aircraft
PRO ENV	Procedures Environment

Table 6.5. SESAR enablers' domains [W17]

6.3.2.1.2.7 Operational/Operating Contexts

It is an additional classification which lists OI steps according to 5 distinct categories or operational contexts:

- Airport
- En-Route
- Information Management
- Network
- TMA

6.3.2.1.3 D5 – Master Plan

The SESAR Master Plan provides a plan for the successful implementation of all the aspects envisioned in the SESAR ConOps. It contains all the actions of every stakeholder to achieve the performance benefits and it can be regarded as the main outcome of the SESAR Definition Phase.

6.3.2.1.4 D6 – Work Program

It defines the way of structuring the different activities that are needed for the implementation of the Master Plan.

The main outcome is a set of DoWs[6] (system, operational and transversal threads) and an initial Work Breakdown Structure (WBS), as well as a preliminary description of methodologies (i.e. SE, Safety, etc.) and supporting tools (i.e. validation).

The Work Program defines all projects and activities to be undertaken in the 2008-2014 timeframe, and will be executed by SJU Members, under the supervision of the SJU.

It comprises 16 work packages split into 4 different threads: operational activities, system development activities, SWIM and transverse activities.

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[6] Description of Work

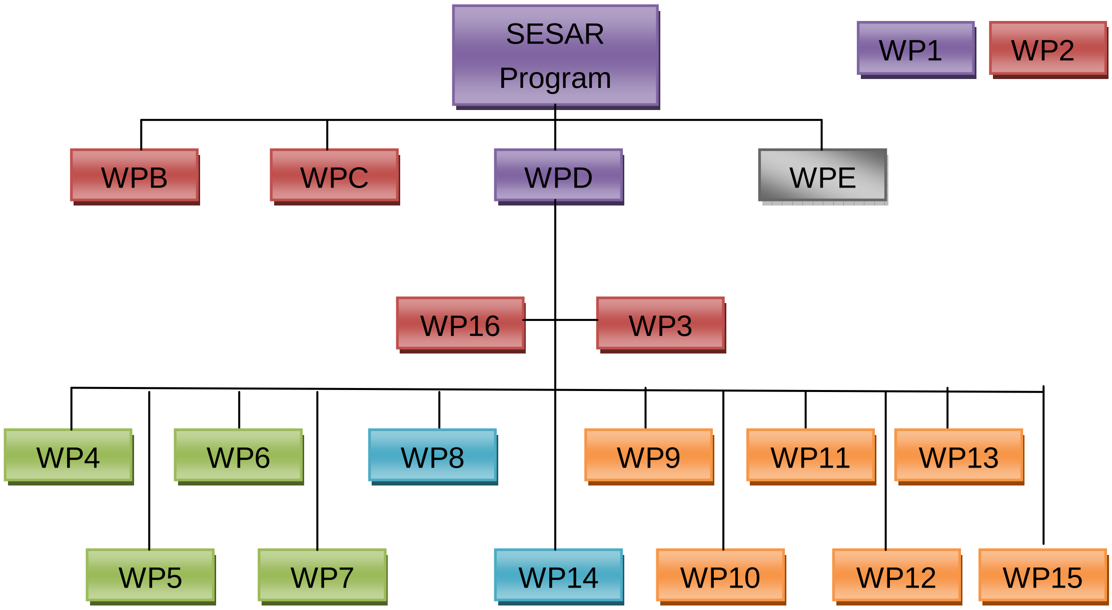

Figure 6.16. SESAR Work Breakdown Structure

Legend:

🟩 Operational thread
🟦 SWIM thread
🟧 Systems thread
🟥 Transversal thread

NOMENCLATURE			
WPB	(High Level) Target Concept and Architecture Maintenance	**WP7**	Network Operations
WPC	Master Plan Maintenance	**WP8**	Information Management
WPD	ATM Network R&D Program	**WP9**	Aircraft Systems
WPE	Long-term Innovative Research Program	**WP10**	En-Route & TMA ATC System (ER & APP ATC)
WP1	R&D Program Management Support	**WP11**	Flight Operation Centre (FOC) System (W/FOC)
WP2	R&D Overall Consistency	**WP12**	Airport Systems
WP3	Validation Infrastructure Adaptation and Integration	**WP13**	Network Information Management System (NIMS)
WP4	EN-ROUTE Operation	**WP14**	SWIM Technical Architecture
WP5	Terminal (TMA) Operations	**WP15**	Non-Avionic CNS System
WP6	Airport Operations	**WP16**	R&D Transversal Areas

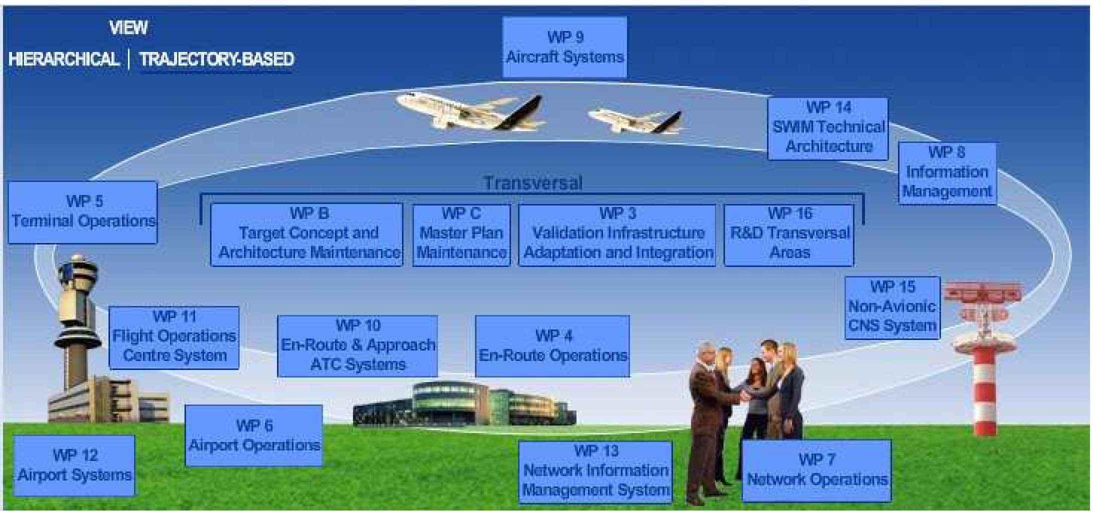

Figure 6.17. A Work Package for every step of the flight [W1]

6.3.3 SESAR Performance Framework

6.3.3.1 Key Performance Areas (KPA)

KPAs result from the top-level decomposition of ATM performance into areas corresponding to high-level expectations. In alphabetical order, the eleven KPAs are the following:

KPA 01	Access and Equity	**KPA 07**	Global Interoperability
KPA 02	Capacity	**KPA 08**	Participation by the ATM community
KPA 03	Cost Effectiveness	**KPA 09**	Predictability
KPA 04	Efficiency	**KPA 10**	Safety
KPA 05	Environment	**KPA 11**	Security
KPA 06	Flexibility		

It has been found useful to cluster KPAs into the three major groups “Societal Outcome”, “Operational Performance” and “Performance Enablers”. The decision criteria for grouping are based on the “highest” degree of visibility of the KPA outcome and impact, rather than on how the performance is achieved.

Basically, the three levels of visibility are:

- <u>Societal Outcome:</u> High visibility; effects are of a political nature and are even visible to those who are not users of the Air Transport System;
- <u>Operational Performance:</u> Medium visibility; visibility of the effects stops generally at the level of ANSPs, Airport Operators (AO), airspace users and airspace user customers (e.g. passengers);
- <u>Performance Enablers:</u> Low visibility; these are not of direct interest to airspace user customers and the KPAs play their role mostly at the business trajectory planning stage.

Figure 6.18 illustrates the grouping of KPAs into those three KPA Groups:

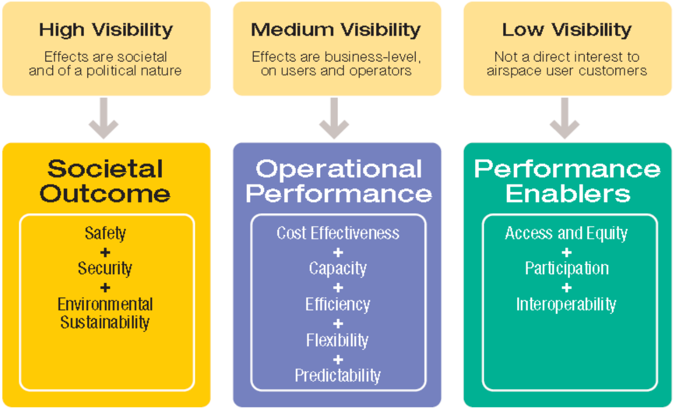

Figure 6.18. Grouping of KPAs [B30]

6.3.3.1.1 Societal Outcome KPAs

The desired societal outcome of the activities carried out by the airspace users and the rest of the air transport industry is creation of net positive 'value' for the societies served. Reduction of the net positive 'value' occurs to the extent that aviation does not meet expected levels of:

- Safety
- Security
- Environmental management and control

6.3.3.1.2 Operational Performance KPAs

The KPA Group "Operational Performance" comprises the areas that directly describe the operational performance and associated costs of airspace users, Airport Operators and ANSPs. The main areas in this group are:

- Cost Effectiveness (the financial outcome of operational performance)
- Capacity (the basic enabler for other operational performance aspects)
- The Quality of Service (QoS) dimensions within the "Operational Performance" group are covered by the following areas:
  - (Flight) Efficiency
  - Flexibility
  - Predictability

6.3.3.1.3 Performance Enabler KPAs

The KPA Group "Performance Enablers" comprises the performance of enabling activities and processes rather than that of operational outcomes. This group comprises the following areas:

- Access and Equity
- Participation by the ATM Community
- Interoperability

"Enabling" implies while things go well enablers tend to go unnoticed. However, if performance in these areas is unsatisfactory, performance in other KPA Groups will suffer. Unsatisfactory performance here may even act as a major inhibitor.

The KPAs in this group tend towards not having a mature performance measurement culture.

6.3.3.2 KPA Interdependencies

Interdependencies between performance objectives within a KPA, as well as between KPAs, need to be identified as they address the issue of trade-offs between the various performance objectives and targets. Preferably the target concept is to overcome the need for (some of the) trade-offs; alternatively if trade-offs are unavoidable, it points towards the need to take decisions on priorities between the KPA and Targets. Examples of these interdependencies are:

a) Financial Cost-effectiveness versus Efficiency, Flexibility and Predictability (also called QoS): the need to reduce the cost of providing ATM capacity may have to be balanced against the need to limit the cost of delay due to capacity shortages

b) Efficiency versus Environment: lateral efficiency affects fuel efficiency, which in turn affects indirect costs as well as gaseous emissions

c) Capacity versus Efficiency: the objective of providing flight trajectories closer to user Business Trajectories may have to be balanced against the objective of increasing capacity

d) Short-term Cost-effectiveness versus investment: reducing the cost of providing ATM services can have an impact on capital investment to deliver long-term performance

e) Access versus Capacity: the access of all aircraft, irrespective of their equipage or size, to a certain airspace or airport can have an impact on the capacity provided

f) Flexibility versus Capacity: airspace users' ability to modify flight trajectories or arrival and departure times may come at the expense of the capacity of the ATM System.

The magnitude of the trade-offs differs at regional and local levels.

6.3.3.3 Capacity and Efficiency KPAs and their Focus Areas

Regarding the present project, the two KPAs of major interest are *capacity* and *efficiency*:

Key Performance Area	
Capacity	This KPA addresses the ability of the ATM system to cope with air traffic demand (in number and distribution through time and space). It relates to the throughput of that volume per unit of time, for a given safety level
Focus Areas	
Airspace capacity	This Focus Area covers the capacity of any individual or aggregated airspace volume within the European airspace
Airport capacity	It focuses on the throughput of individual airports in terms of aircraft movements, taking into account the composite effect of air and landside constraints. So this Focus Area covers much more than just runway capacity.
Network capacity	Is concerned with overall network throughput, taking into account the network effect of the airspace and airport capacity in function of traffic demand patterns

Key Performance Area	
Efficiency	This KPA addresses the actually flown 4D trajectories of aircraft in relationship to their Shared Business Trajectory (SBT)
Focus Areas	
Temporal efficiency	This Focus Area covers the magnitude and causes of deviations from planned (on-time) departure time[7] and deviations from SBT durations (taxi time, airborne time)
Fuel efficiency	This Focus Area covers the magnitude and causes of deviations from optimum fuel consumption
Mission Effectiveness	Following military trajectory models focus is to reflect the economic impact of transit times associated with military training activities

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[7] On-time departure is defined as actual off-block departure less than 3 minutes before or after the departure time of the SBT; delayed departure is defined as actual departure more than 3 minutes after the departure time of the SBT

6.3.3.4 Key Performance Indicator (KPI)

Each KPA has a set of Key Performance Indicators (KPI) which “quantifies” the status level of their corresponding KPA. A KPA can be identified by several KPIs. For capacity and efficiency KPAs, the corresponding KPIs are those indicated in the diagram below:

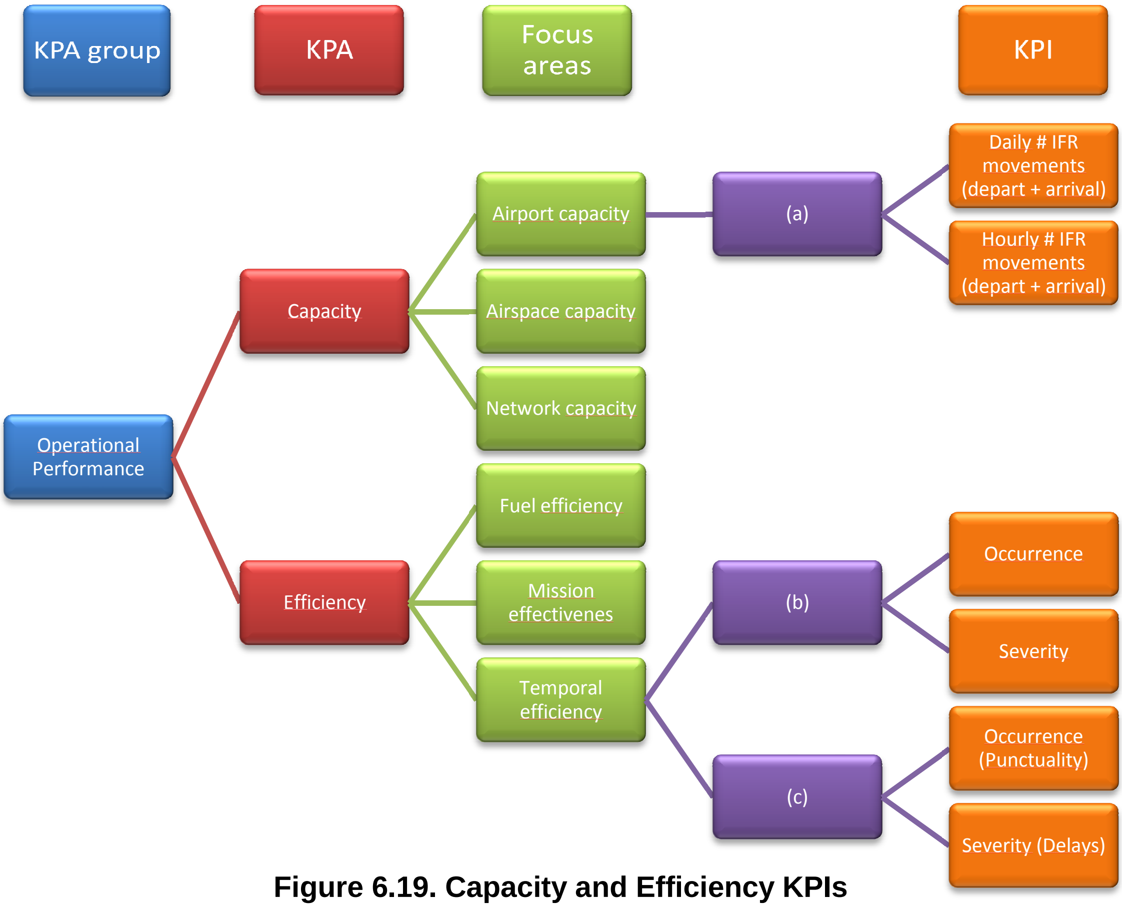

Figure 6.19. Capacity and Efficiency KPIs

Notes:

(a) Meet or exceed the growth of the busy-hour demand of individual airports
(b) Conform to the SBT Timing to the greatest extent
(c) Continually reduce the departure delay due to ATM

Occurrence: % of flights with normal flight duration[8]
Severity: the average flight duration extension of flights with extended flight duration
Occurrence (Punctuality): % of flights departing on-time
Severity (Delays): the average departure delay of delayed flights

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[8] Normal flight duration is defined as actual block-to-block time less than 3 minutes longer than the block-to-block time of the SBT; extended flight duration is defined as actual block-to-block time more than 3 minutes longer than the block-to-block time of the SBT

6.3.3.5 Target Operational Concept (TGT)

The Target operational concept is an ideal state in the future, to be reached progressively through a series of discrete change steps from the current situation. This means, TGTs contain the numeric targeted values by 2020 of each KPI. For capacity and efficiency KPIs, the corresponding TGTs are:

KPA	KPI	Baseline		2020 Target	
		Year	Value	Absolute	Relative
CAP	Annual IFR flights in Europe	2005	9.2 M	16 M	+72%
	Daily IFR flights in Europe	2005	29,000	50,000	+73%
	Best In Class (BIC) declared airport capacity in VMC (1 RWY[9]), mov/hr[10]	2008	50	60	+20%
	BIC declared airport capacity in VMC (2 parallel dependent RWYs), mov/hr	2008	90	90	+0%
	BIC declared airport capacity in VMC (2 parallel independent RWYs), mov/hr	2008	90	120	+25%
	BIC declared airport capacity in IMC (1 RWY), mov/hr	2008	25	48	+90%
	BIC declared airport capacity in IMC (2 parallel dependent RWYs), mov/hr	2008	45	72	+60%
	BIC declared airport capacity in IMC (2 parallel independent RWYs), mov/hr	2008	45	96	+110%
EFF	Scheduled flights departing on time (as planned)	-	-	>98%	-
	Avg. delay of the remaining scheduled flights	-	-	<10 min	-
	Flights with block-to-block time as planned	-	-	>95%	-
	Avg. block-to-block time extension of the remaining flights	-	-	<10 min	-
	Flights with fuel consumption as planned	-	-	>95%	-
	Avg. additional fuel consumption of the remaining flights	-	-	<5%	-

Table 6.6. Capacity and efficiency KPIs and TGTs [W17]

Notes about capacity:

In accordance with the political vision and goal, the ATM target concept should enable a 3-fold increase in capacity which will also reduce delays, both on the ground

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[9] Runway

[10] The selection of hourly capacity target implies that this hourly capacity is the average value available 365 days per year, all day long (from 0700 till 2200 hrs local time).

and in the air (en-route and airport network), so as to be able to handle well the traffic growth beyond 2020.

The initial indicative design target for capacity deployment is that the ATM System can accommodate by 2020 a 73% increase in traffic (annual IFR traffic growth in the European network from 2005 baseline) while meeting the targets for quality of service KPAs (Efficiency, Flexibility, Predictability): 5% in the period 2005-2010, 3.5-4% during 2010-2015, 2-3% during 2015-2020, and 2% p.a. beyond 2020. This corresponds to an optimistic demand forecast combined with an optimistic airport capacity growth scenario.

This deployment requirement means that the annual number of flights to be handled by the ATM System will increase from 9.1 to approximately 16 million flights p.a. within the 2005-2020 period. During the busiest months of the year, the system should be able to handle 50,000 flights / day around the year 2022.

These are the average European design targets (at network level). When transposing this to local targets, regional differences will exist. The ATM target concept should be able to support a tripling or more of traffic where required.

6.4 Airports in SESAR

The trajectory management focus of the ATM Target Concept extends to include the airports to address the airport capacity issue which is the key challenge in the 2020 timeframe.

Runway throughput must be optimized to achieve the airport capacity targets as defined in D2. This requires a spectrum of measures ranging from long-term infrastructure development, through realistic scheduling, demand and capacity balancing, queue management and runway throughput improvements.

The impact of adverse weather conditions shall be minimized to allow for airport throughput to remain close to “normal”. During turnaround, milestones will track the progress of the turnaround process and the impact of events on later parts of the trajectory can be established at an early stage.

Even with all these measures, the bulk of the required increase in airport capacity must come from greater use of secondary airports.

Airports will be fully integrated into the ATM network, with particular emphasis being placed on turnaround management, runway throughput and improved environmental performance.

As said before, the airport view of the ATM Target Concept is from the perspective of "en-route to en-route", managing the aircraft turnaround and flight operation as a single continuous event. The turnaround process links the flight and ground segments, and will include milestone monitoring, gate management and apron management. Sharing turnaround information in a collaborative process will improve estimated times of subsequent events such as off-blocks and take-off.

To do this, the SMAN tool within A-SMGCS will determine the optimal surface movement plans involving the calculation and sequencing of movement events and optimizing resource usage, while minimizing the environmental impact. SMAN will collaborate with AMAN/DMAN to establish the arrival and departure sequence.

The provision of separation between aircraft and hazards on the airport will continue to be achieved through visual means. However, better situational awareness for the controller, aircrew and vehicle drivers including conflict detection and warning systems will enhance airports' surface safety and will also create "room" for surface movement capacity expansion and improve throughput in low visibility conditions.

A-SMGCS will provide enhanced information and decision support to controllers (enhanced ground surveillance information, runway incursion alerts and ground route planning information) whilst CDTI[11] technology will provide aircrew and vehicle drivers with map, guidance and traffic information. Advanced, automated, systems may be considered such as “auto-brake” to make it impossible for an aircraft or vehicle to cross selected “stop bars”.

Various techniques and procedures will be in place to increase runway throughput and utilization such as:

- Reducing dependency on wake vortex separation by the re-classification of aircraft into a wider range of wake vortex categories, dynamic pair-wise separations considering prevailing wind conditions and stability of the air mass, improved prediction and detection of wake vortex;
- Re-sequencing of the traffic flow to group similar categories of aircraft;
- Minimizing runway occupancy time by runway and runway exit design improvements and improvement of the procedures to vacate at an agreed turn-off whether supported by systems or not;
- Accurate and more consistent final approach spacing achieved by time-based separation taking into consideration wake vortex by either controller tools or onboard tools like ASAS;

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[11] Cockpit Displays of Traffic Information

- Reducing departure spacing by better wake vortex management, runway design and improved terminal area capacity;
- Optimizing runway configuration / mode of operation in case of multiple runways;
- Interlaced take-off and landing procedures (mixed mode operations);
- Increased runway utilization during Low Visibility Conditions (LVC) by mitigating the ILS signal disturbance issues and by tools to enhance ground controller and pilots' situation awareness in low visibility conditions;
- Improved weather forecasting;
- Redesign of runways and taxiways to avoid runway crossing.

The remotely provided aerodrome control service concept will allow to offer enhanced ATC services to places not normally eligible for ATC (e.g. rural or smaller airports) where determined feasible (and in particular where the site and techniques are proven to meet all appropriate safety requirements) and where/when this is cost-effective.

In short, the airport capacity and efficiency action plan of SESAR consists of:
- Better use of existing capacities
- New technologies
- Intermodality
- Observatory for airport capacity
- Improved capacity planning
- Capacity inventory
- Increase predictability: planning and management in function of required time of arrival
- Reduce of delays

6.4.1 High/medium density airports context

All the subsystems depicted in the figure under are considered as mandatory in a high density and complexity context. The subsystems with a solid frame are delivering technical and communication services. The subsystems with a dotted frame are sub-systems that are not present at military aerodrome.

Most of the airport airside subsystems already exist today, but the target concept requires additional services to be provided as well as increased cooperation between the subsystems.

The main expected changes for the subsystems of both Aerodrome ATC and Airport Airside Operations systems mainly concern the provision and access to a commonly shared data available through SWIM. This will show positive effects through queue management improvements in relation to both inbound and outbound flows to constraint runways.

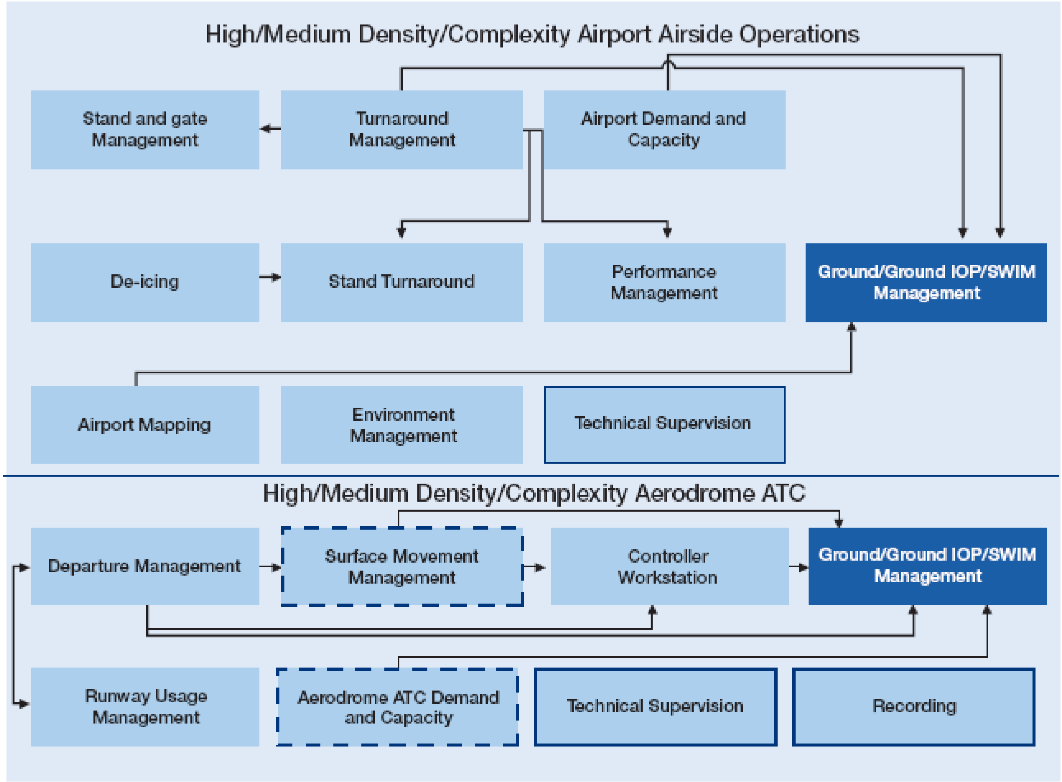


Figure 6.20. High/medium density Airport/Aerodrome ATC target architecture

For example, coordination with vehicle movements or Follow Me/marshallers can be performed by using Flight Data Processing (FDP) services or by setting time stamps for airside processes (e.g. Start-up, Push-back, Taxi-Given, etc.).

It is recommended that for high-density/complexity aerodrome ATC contexts, FDP services are made available. However, they could be delivered through the Surface Management subsystem (and therefore there is no need for a dedicated FDP subsystem).

The FDP services might not be necessary for other Aerodrome ATC contexts or could be delivered through a remote access via terminals, to the relevant Approach ATC centre.

Some important services for the airport operations such as Fire Services, Meteorological information management, Operational Supervision, Aeronautical Information Management are not depicted, as they are not considered to be significantly impacted by the ATM Target Concept. The potential impacts however shall be studied in later R&D and implementation phases.

6.4.2 Low-density airports context

In a low density context similar services than the one available in high/medium density airport may be provided. The expectations is that most of those services will be provide either manually or through a remote access via terminal to the relevant organization (either a larger airport or the relevant approach ATC centre) thus simplifying the local architecture.

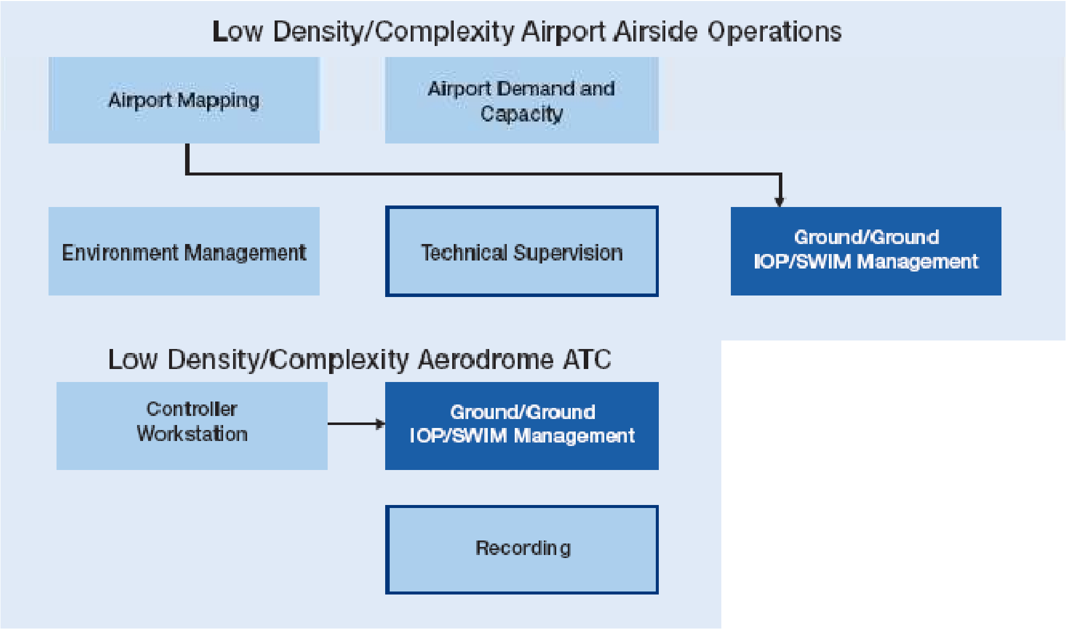


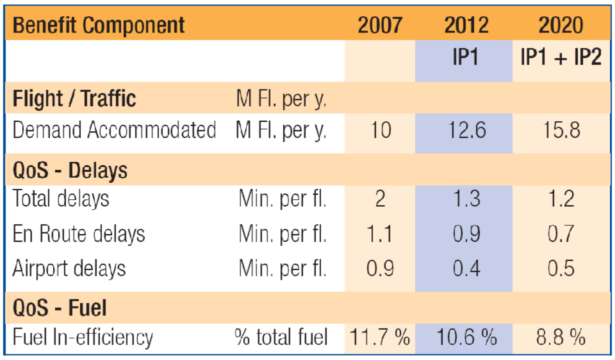
Figure 6.21. Low density Airport/Aerodrome ATC target architecture

In addition to airport operation aerodrome, conflict, queue and network management processes are involved.

6.4.3 Airport capacity D4 assessments

All benefits achieved with the implementation and deployment of Implementation Packages 1 and 2 will be further enhanced with Implementation Package 3 to meet SESAR long-term goals. Its main aspect is to introduce the most advanced features of the SESAR Concept of Operation (ConOps), aiming to achieve the long term performance goals.

Figure 6.22 provides a synthesis of the different performance assessments for each IP made in D4 to quantify the evolution of capacity over time at airports thanks to SESAR. An assessment trade-off was conducted between the accommodated traffic and the acceptable delay and the result is that in 2020, with IP1 and IP2 implemented, the ATM system will be able to accommodate 15.8 Million flights with an average delay of 1.2 minutes per flight and greater fuel efficiency (corresponding to a fuel saving of 2.9% compared to the 2007 baseline).



Benefit Component		2007	2012	2020
			IP1	IP1 + IP2
Flight / Traffic	M Fl. per y.			
Demand Accommodated	M Fl. per y.	10	12.6	15.8
QoS - Delays				
Total delays	Min. per fl.	2	1.3	1.2
En Route delays	Min. per fl.	1.1	0.9	0.7
Airport delays	Min. per fl.	0.9	0.4	0.5
QoS - Fuel				
Fuel In-efficiency	% total fuel	11.7 %	10.6 %	8.8 %

Figure 6.22. SESAR Performance assessment synthesis [B32]

6.4.3.1 Airport capacity assessment for IP1

With respect to airport initiatives, the Airport airside Capacity Enhancement (ACE) exercises (collection of best practices) already conducted at a number of medium/large airports shared the potential to improve runway utilization, thereby unlocking latent capacity, eventually increasing runway throughput (**up to +20%, depending upon infrastructure configuration once IP1 is completed**). Airports operating close to their "best-in-class" (BIC) capacities will not benefit of such capacity increases.

6.4.3.2 Airport capacity assessment for IP2

The purpose of this assessment was to assess the extent to which SESAR can raise airport capacities and the effect that this is likely to have across the network in accommodating traffic demand. The assessment was based on a “busy-hour” analysis of the extent to which the forecast unconstrained demand could be accommodated.

This forecast demand was assumed to grow by approximately a factor of 2.1 in 2020 vs. 2003 ([B7]) (varying from airport to airport) considering the set of runways (from 1 to many) that are operated together at a particular airport.

The capacity uplift ranges from 8% to 30% depending on the runway system category at the end of IP2.

It must be noted that all this assumed a widespread capacity declaration at 100% of BIC capacity. For example, in 2003, 4 Top 30 airports were declaring capacity at BIC. In 2020, this will have grown to 19 Airports, with the average utilization rising to 92%

from 71%. Across the Top 100 Airports, some 42% of movements would be operating at a very congested airport – compared to 13% in 2003.

7 AIRPORT SELECTION

7.1 Airport alternatives

It is essential for this report to select an airport in which SESAR can be applied to. For this purpose, three airports from Catalunya (Spain) have been selected and evaluated. These are:

- Barcelona – El Prat
- Girona – Costa Brava
- Lleida – Alguaire.

Figure 7.1. Location of selected airports in Catalunya [W6]

Those airports were considered specifically because of its local interest (for Catalunya) and because of their future development, such as:

- Girona is enlarging its infrastructures and there are projects put already on the table
- Barcelona T1 terminal has been recently inaugurated[12]
- Lleida's airport is under construction and it is foreseen to begin its economical activity soon[13]

Finally, the accessibility to confidential data and the possibility of obtaining real data from direct measurements (airport proximity to the author's premises) also played a positive role.

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[12] 16th June 2009
[13] November 2009

Deeper description and further information can be found in the Annexes. Here, just the essential information for the analysis is presented.

7.1.1 Barcelona – El Prat

Barcelona - El Prat airport is the main and largest airport serving Catalunya, located 10 km southwest from the city centre of Barcelona and is operated by AENA. The airport is Spain's 2nd largest behind Madrid Barajas Airport and a major European hub airport. It is made up of three terminals: T1 (recently inaugurated), T2 (comprising the previous A, B, C terminals into respective A, B, C modules) and a terminal for corporative aviation.

Figure 7.2. Barcelona–El Prat airport T1 Terminal [W8]

Figure 7.3. Barcelona–El Prat airport [W8]

T1 Copes with the desired expansion of the airport, by means of capacity, technology and modernity. It absorbs a part of international traffic (Schengen and non-

Schengen) arriving to the airport, grouping together the flights of the airlines Spanair, Lufthansa, TAP Portugal, Swiss International Airlines, Brussels Airlines, Adria Airways, Aegean Airlines, Air Baltic, Air Comet, Austrian Airlines, Blue1, Croatia Airlines, EgiptAir, Estonian Air, Lot Polish, SAS Scandinavian Airlines, Singapore Airlines, Turkish Airlines and US Airways.

T2A Gathers the majority of flights belonging to foreign airlines. It groups together the flights of the airlines Aer Lingus, Aeroflot, Aerolíneas Argentinas, Aeroméxico, Air Algerie, Air Cairo, Alitalia, American Airlines, Avianca, Bmibaby, Bulgaria Air, Czech Airlines, Delta Airlines, Finnair, Freebird Airlines, Germanwings, Jet2.com, KD Avia, Meridiana, Monarch Airlines, MyAir.com, Norwegian Air Shuttle, Royal Jordanian, SkyEurope Airlines, Tarom, Transaero Airlines, Transavia.com, Tunisair, Ukraine International Airlines, Vim Airlines and Wizz Air.

T2B Looks after the billing of national and foreign airlines integrated in the Oneworld and Star Alliance and those maintaining commercial agreements with them, such as Iberia, Air Europa, Spanair, British Airways or Lufthansa. It gathers Air Berlin, Air Europa, Air France, Amc Aviación, Arkia Airlines, Atlas Blue, Blue Air, British Airways, BA Cityflyer, Clickair, Continental Airlines, easyJet, easyJet Switzerland, El Al, FlyGlobespan, Iberia, Iberworld, KLM Royal Dutch Airlines, Luxair, Royal Air Maroc, Rossiya-Russian Airlines, TUIfly and Wind Jet operate from here.

T2C Houses the Iberia Air Shuttle, Vueling flights and Iberia Regional Flights.

T.A.CORP Is used for the general aviation companies.

7.1.2 Girona – Costa Brava

Girona-Costa Brava Airport is located 12 km south of the city of Girona, next to the small village of Vilobí d'Onyar, in the north-east of Catalonia, Spain. It is also run by AENA (like Barcelona – El Prat) and, at present, is the 9th Spanish airport regarding traffic of passengers. Many people use Girona Airport as an alternative airport for Barcelona, though the airport is 85 km north of Barcelona.

Figure 7.4. Girona–Costa Brava airport [W3]

Figure 7.5. Girona–Costa Brava airport [W6]

It is made up of only one main terminal and the majority of regular routes are international with destinations to EU, operated by Jetairfly, Ryanair, Thomas Cook Airlines, Thomson Airways and Transavia.

7.1.3 Lleida–Alguaire airport

Lleida-Alguaire is situated in Alguaire (a place close to Lleida), 150 km far away from Barcelona. It is an airport under construction which is expected to be completed during the second half of 2009, opening its services from November 2009 on. It will provide services mainly for the city of Lleida and the nearby regions.

Figure 7.6. Lleida–Alguaire airport Terminal [W11]

Figure 7.7. Lleida–Alguaire airport [W11]

Which airlines will operate this airport it is still unknown, but up to date some have already shown interest such as Ryanair, Air Berlin, Easyjet and Vueling.

7.1.4 Comparison between airports

	Barcelona	**Girona**	**Lleida**
TRAFFIC STATISTICS			
Passengers (in millions) 2008	30,196	5,511	-
Freight (in thousands) 2008	106,400	49,927	-
Aircraft Movements 2008	321,491	184,127	-
GENERAL			
IATA code	BCN	GRO	-
ICAO code	LEBL	LEGE	-
Coordinates	41°17' 49" N 2°04' 02" E	41°54′00″ N 2°46′00″ E	41°43′40″ N 0°32′09″ E
Elevation (amsl)	3.8 m	142 m	350 m
Airlines	78	6	-
LANDSIDE			
Terminals	3	1	1
Check-in counters	335	33	8
Auto check-in counters	59	0	-
Information desks	19	1	-
Security control zones	9	4	-
Security control counters	49	5	-
Passport control zones	12	1	-
Passport control counters	73	5	-
Customs areas	5	1	-
Boarding zones	13	2	-
Carousels	15+	3	2
Vehicle parking positions	24,000	3,800	240
Maximum capacity (million pax)	55	7	1
AIRSIDE			
Runways	3	1	1
Aircraft parking positions	168	50	6
Gates	159	9	-
Fingers	70	0	-
Declared capacity (ops/h)	90	23	14

Table 7.1. Airport comparison[14]

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[14] All values are referred to 2009 except when specified. Sources: [W8], [B2], [B16]

7.2 Airport selection results

For evaluating the alternatives, Press' selection of alternatives method is implemented to decide which airport is the most suitable for this study. It is a method used to select the best alternative to accomplish a certain purpose, function or scope given a list of criteria. It is not designed to find the alternative with the best average, but the one that has the highest punctuation in the majority of criteria. It is a relatively more complex method (when applied by hand) but is also very robust and is not overly influenced by the criteria of greater weight.

To proceed to the airport selection, these criteria are considered:

- Importance of the airport (mainly talking about passengers flow)
- SESAR applicability on airport's systems
- SESAR necessity (if it makes sense to talk about the implementation of SESAR in that airport; if it is worth or not)
- If the airport exists or not and if historical data is available

In this method weights must be assigned to the different criteria used. Punctuations are given in the range of 1 – 4 (4 being the most important) as it follows:

4 → Airport importance
3 → SESAR applicability and necessity
2 → Historical data availability
1 → Airport in operation?

Moreover, each alternative must be punctuated according to each criterion. In this case, punctuations are also given in the range of 1 – 4 (4 corresponding to the best):

Airport selection					
Criteria	**Airport importance**	**SESAR applicability**	**SESAR need**	**Historical data availability**	**Airport operative**
Weight	4	3	3	2	1
Relative	0,308	0,231	0,231	0,154	0,077
Alternatives					
Barcelona	4	4	4	3	4
Girona	3	2	2	4	4
Lleida	1	1	1	0	0
Pmax	4	4	4	4	4

Table 7.2. Press punctuation matrix

After that, a validation matrix is assessed, following the expression:

$$\mathrm{Prel}_i = \frac{\mathrm{P}_i}{\sum_i \mathrm{P}_i}$$

$$Q_{ij} = \left[\frac{\mathrm{P}_{ij}}{P\max_j}\right] * \mathrm{Prel}_j$$

Where

P(j) is the punctuation for the *j* criterion of the *i* alternative

Pmax(j) is the maximum punctuation given to the alternatives for the *j* criterion

Prel(j) is the relative punctuation with respect to the rest of criteria

Valuation Matrix					
Alternatives/ Criteria	**Airport importance**	**SESAR applicability**	**SESAR need**	**Historical data availability**	**Airport operative**
Barcelona	0,000	0,231	0,231	0,115	0,077
Girona	0,231	0,115	0,115	0,154	0,077
Lleida	0,077	0,058	0,058	0,000	0,000

Table 7.3. Press validation matrix

Next, a domination matrix is assessed:

$$T_{ij} = \begin{cases} \sum_{k=1}^{N_{criteria}} \left(Q_{ik} - Q_{jk}\right) & \text{if } Q_{ik} > Q_{jk} \\ 0 & \text{if } Q_{ik} \le Q_{jk} \end{cases}$$

	Domination Matrix			D
	0,000	0,308	0,769	1,077
	0,038	0,000	0,500	0,538
	0,000	0,000	0,000	0,000
d	0,038	0,308	1,269	

Table 7.4. Press domination matrix

Finally, importance indexes are assessed:

$$D_j = \sum_i^{Nrows} D_{ij}$$

$$d_i = \sum_j^{Ncolumns} d_{ij}$$

$$I_i = \frac{D_i}{d_i}$$

The alternative with the highest importance index (I) is the one corresponding to the best option.

	Barcelona	Girona	Lleida
i index	**28,000**	1,750	0,000

Table 7.5. Press importance indexes

To this effect, and according to Press' method, **Barcelona – El Prat airport is the best option for evaluating the SESAR impact**, because of its importance, applicability and necessity to deal with the anticipated traffic that was already announced in chapter 6.1.

Furthermore, it is important to mention that **T1 terminal** will be the only one considered in the assessments, concerning several reasons:

- Capacity analysis for T2 has been already permuted in ALG[15] whereas T1 is a new infrastructure and its current landside capacity is unknown

- Considering all the three terminals in Barcelona's airport, the one that is more preferable to implement SESAR's new technologies and procedures is T1, since it will process 90% of the airport's traffic, the three alliances: One World, Sky Team and Star Alliance

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[15] Advanced Logistics Group, the author's working company

8 METHODOLOGIES FOR ASSESSING AIRPORT CAPACITY AND EFFICIENCY

The capacity of an airport can be limited by the constraints on either air traffic movements or terminal passenger numbers. At different times of the day the limiting constraint may change from one to the other aspect of the airport.

Congested airports need to limit the number of available slots to balance the most restrictive constraint. The maximum aircraft movement rate can be determined by many factors, including airfield layout (runways, taxiways and stands), air traffic control procedures, scheduled aircraft mix, ground handling operations, meteorological conditions and environmental considerations. These factors, together with the policy of individual airports on delays, will determine the capacity.

The terminal capacity can be limited by the staffing or support infrastructure of any aspect of passenger processing. Some of these factors can be accurately assessed, while others are difficult to quantify and are subject to rapid change. An individual airport capacity will make specific assumptions in the process of its capacity declaration.

It is important to recognize that comparisons between airports are inevitably affected by the lack of standardization in these practices: for example, one airport may accept an average delay of three minutes while another may accept five minutes for setting the number of available airport slots.

Capacity in the air in the immediate vicinity of an airport and the ability of the airport air traffic control system and its runway approach facilities to manage traffic to and from the runways may also have a bearing on general airport capacity, though in this present study it is not considered.

Capacity on the ground must match the capacity in the air and vice versa: only a coherent approach addressing all the elements of capacity will result in an overall improvement in airport capacity.

Airside: it is not the runway system and more generally the movement area alone that produces figures for hourly output: safety, security, operational and even non-operational restrictions have a direct impact on the time between an aircraft landing and it leaving the airport, as do airline scheduling and handling procedures.

Landside: adequate access to the airport, facilitation and resources are required to meet demand. At a number of airports, this challenge should not be underestimated, as certain terminal management conditions can lead to congestion, slow processing of passengers and consequent delays.

Both passport and security controls need adequate resources to cope with the demand, and need to be fully coordinated with the airport operator in order to create an efficient facilitation environment while maintaining the highest level of security.

Capacity measurements vary from one subsystem to another. The term *capacity* has many definitions, but it generally makes reference to a limit, when reached or exceeded, which affects an airport's operations and level of service. Refer to Annex 3 for further information.

8.1 Airport systems and capacity

An airport is an emplacement that handles flows of many different natures and origins, such as pedestrians, vehicles, aircraft, baggage, cargo and mail. These must pass through inter-related systems to be queued, processed and circulated on various links such as taxiways, corridors, escalators, etc.

Balancing capacity is primarily required to avoid displacing bottlenecks form one critical facility to another. Seven major system studies are considered when balancing capacity and determining the reliable throughput of the airport:

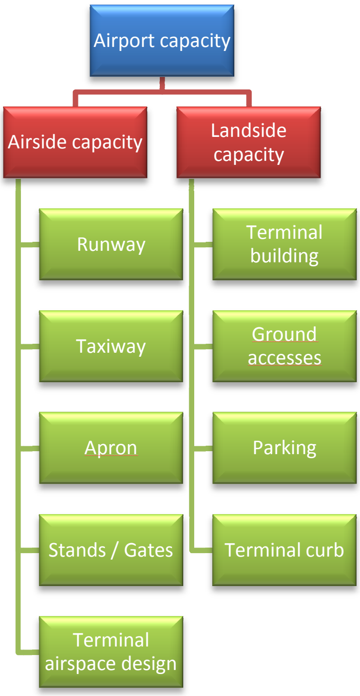

Figure 8.1. Subsystems affecting airport capacity

Runway: Runway system is a critical component to the overall system, and usually determines a given airport's maximum capacity.

Taxiway: When crossing with runways, taxiways then process a limited output capacity which must be considered.

Apron: Apron's capacity is often simulated to make sure it does not act as a bottleneck.

Gates: The number of stands and aircraft parking positions for different types/sizes of aircraft usually determines the ultimate runway capacity.

Terminal building: Capacity of passenger terminal is essentially given by passengers and visitor flows. When enplaning or deplaning passengers, they must pass through some or all of a series of subsystems which independently characterize different aspects of the capacity of the passenger terminal. Additionally transfer passengers must be considered since they utilize some of those subsystems. In the case of hub airports, the volume of transfer passengers may be very significant. Passenger terminals also process baggage flows, and this must also be accounted.

Ground access: Ground access is usually done by car. An airport road system connected to a regional road network system to give access to the various airport terminal facilities may be another crucial factor.

8.2 Capacity diagrams

All the previously mentioned airport systems break down into a series of subsystems as represented in the following diagrams:

8.2.1 Airside components

8.2.1.1 Runway

The fundamental capacity constraint of any airport usually lies in the runway system. Because runway capacity strongly limits the expansion capabilities of any airport, it is important to identify and eliminate the factors affecting its maximum throughput.

It is essential that the rest of critical systems, such as gates and terminals, are balanced with the maximum runway throughput, because in case of imbalance this turns into delays that reduce airport's sustainable capacity.

Delays and throughput are the main runway performance indicators. Delay is a primary indicator of level of service, and demonstrates that capacity is being reached or exceeded.

Runway capacity is defined as the hourly rate of aircraft operations (departures, arrivals or both), to be accommodated by a runway or combination of runways, under specified local conditions.

Runway capacity = [operations (flights) / hour]

Runway capacity largely depends upon:

1. Airplane's speed
2. Runway occupancy time
3. Runway layout: longitude, orientation and number of runways
4. Approach and departure spacing between successive aircraft
5. Availability of SIDs & STARs
6. Design of the airspace
7. Mode of operation[16] (segregated, mixed, dependent, independent…)
8. ATC facilities and procedures
9. Taxiway system: number, location, and characteristics of exit taxiways
10. Number and characteristics of taxiways and runway waiting areas
11. Aircraft mix
12. Ratio arrivals/departures
13. Apron area, gates
14. Weather conditions: wind, rain, fog…
15. Runway surface conditions
16. VFR systems and their conditions
17. Approach procedures (possible noise abatement procedures)

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[16] See Annex 3.4

Maximum capacity is based on operating conditions and rules, but is also largely dependent upon the particular demand profiles created by the mix of flights and flight sector for a typical busy day.

8.2.1.1.1 Considerations and parameters for runway capacity calculations

Maximum runway capacity should be determined assuming the best and favorable case: best practices, proper facilities and equipment, good weather conditions (IFR VMC[17]) in typical busy day. Runway capacity calculations require careful observation of the actual traffic schedule at an airport, particularly during typical peak periods.

8.2.1.1.1.1 Wake turbulence

Wake turbulence is turbulence that forms behind an aircraft as it passes through the air. This turbulence includes various components, being the most important wingtip vortices and jet wash.

<u>Jet wash:</u> refers simply to the rapidly moving gases expelled from a jet engine; it is extremely turbulent, but of short duration.

<u>Wingtip vortices:</u> are much more stable and can remain in the air for up to three minutes after the passage of an aircraft. Wingtip vortices make up the primary and most dangerous component of wake turbulence.

Wake turbulence is especially hazardous during the landing and take-off phases of flight, for three reasons:

1. During take-off and landing, aircraft operate at low speeds and high angle of attack. This flight attitude maximizes the formation of dangerous wingtip vortices.
2. Takeoff and landing are the times when a plane is operating closest to its stall speed and to the ground - meaning there is little margin for recovery in the event of encountering another aircraft's wake turbulence.
3. These phases of flight put aircraft closest together and along the same flight path, maximizing the chance of encountering the phenomenon.

Heavier aircraft generate more wake turbulence and are less affected than smaller aircraft. It is difficult to control an aircraft too close to a leading aircraft, which is why a separation minima criterion is recommended and it becomes a critical factor in determining runway capacity. IATA’s wake turbulence separation minima are based on ICAO’s aircraft category classification, as indicated in Table 8.1.

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[17] Instrumental Flight Rules, Visual Meteorological Conditions

Aircraft Class	Certified MTOW (kg)	Number of engines	Wake turbulence classification
A	7 000 or less	Single	Small (S)
B		Multi	
C	7 000 - 136 000	Multi	Large / Medium (L)
D	136 000 or more	Multi	Heavy (H)

Table 8.1. ICAO's mass classification for wake turbulence separation

According to [B19], the minimal separation between aircraft in take-off and landing operations should be:

Preceding Aircraft	Succeeding Aircraft	Separation Minima
Heavy	Heavy	4 NM
	Medium	5 NM
	Small	6 NM
Medium	Heavy	3 NM
	Medium	3 NM[18]
	Small	5 NM
Small	Heavy	3 NM
	Medium	3 NM
	Small	3 NM

Table 8.2. Basic wake turbulence separation minima for arrivals

It should be noted that the performance of radar equipment and ATC limitations in the surrounding area of the airport sometimes may impose greater separations than the minima shown in Table 8.2.

8.2.1.1.1.2 Runway occupancy time and taxiways

It is established that an aircraft cannot touch down until the preceding aircraft clears the runway. In this, the proper position of the exit taxiways is a key factor to minimize the time that an aircraft physically spends on a runway. Busy airports typically construct high-speed or rapid-exit taxiways in order to allow aircraft to leave the runway at higher speeds, permitting another to land in a shorter space of time.

The maximum time spent on a runway should be about **50 – 55 seconds.**

By not achieving this threshold, separation between successive aircraft will increase and thus runway capacity will be decreased.

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[18] 2.5 NM minimum radar separation on final approach is taking place at several European airports and should be investigated before considering constructing new runways

8.2.1.1.1.3 Mix of aircraft

The mixed sequence of aircrafts of different categories arriving in an airport will have an impact on the overall separation and thus a significant reduction on the runway capacity.

8.2.1.1.1.4 Mix of arrivals and departures

In an airport, aircraft will either land or take-off, resulting into a mixture in the use of the runway. The distribution of arrivals and departures has definitely an impact on runway capacity, because ATC not only needs to consider separation between successive arrivals and successive departures, but also the combination of both.

8.2.1.1.1.5 Mixed or segregated mode

Airports with two or more runways sometimes dedicate some runways to departures and others to arrivals. However, the arrival and departure peaks rarely coincide, and the separation between successive arrivals and successive departures is different. This results in gaps on one runway when another is at capacity; in these situations mixing arrivals and departures as if operating with a single runway can increase capacity.

8.2.1.1.1.6 Runway configuration

Runway capacity is directly affected by how runways are distributed. Parallel runways with adequate spacing can process independent arrivals and this does not decrease the capacity of both combined runways[19]. However, when the distance between runways does not meet the minimum or runways intersect, then the interaction between runways turns into a constraint that limits capacity.

8.2.1.2 Taxiway

The main purpose of the taxiway is to optimize runway throughput, minimize taxiing distance and delays and improve aircraft flow and operations. By implementing rapid exit taxiways, parallel taxiways and departing multiple queuing taxiways the system’s capacity is improved.

8.2.1.3 Apron and aircraft stands

Some airport professionals believe that apron configuration is one of the principal characteristics influencing airport landside capacity.

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[19] See Annex 3

If the apron area is not large enough to allow safe maneuvering of aircraft under established FAA, airline, and airport standards, capacity may be constrained.

The capacity of the runway, taxiway and apron systems is dynamic, as it relates to the ability to process flows, whereas the capacity of the aircraft stand system is related to the ability to accumulate aircraft, which is a static capacity. The aircraft stand system, if planned in the wrong way, might become a limiting factor of runways.

Stand capacity = [Number of stands and aircraft parking positions for different types / sizes of aircraft]

If a parking position is not available at the terminal building, the aircraft may be accommodated at a hardstand[20]. During periods of very high demand, commercial service aircraft may have to be parked and serviced at remote parking positions.

Some schedules, particularly long-haul flights, require that aircraft remains for several hours. Home-based aircraft are likely to remain at their stands overnight, however the majority of flights seek a rapid turnaround.

Flight type[21]	Typical aircraft[22]	Turnaround time[23] (min)
Long range, particularly international	Jumbo jet (B-747, DC-10, L-1011)	60-150
Medium to long range	Long-range jet (B-767, DC-9)	45-90
Short to medium range	Short-range, high-payload jet, turboprop (A-300, B-727, DASH 7)	25-60
Short-range, commuter	Smaller prop, turboprop jet (Shorts 330-200, F-27, Gulfstream II)	20-45

Table 8.3. Typical gate turnaround times for commercial service aircraft[24]

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[20] Refer to Annex 3.2.7

[21] Refer to Annex 3.5

[22] Refer to Annex 8

[23] Includes gate occupancy and recycle time. Times for continuing flights on medium to long-haul routes may be shorter

[24] [B24], [B28]

In case of ATC delay, at some airports, aircraft actually vacate their stands at their scheduled departure time and absorb the delay on specially designed remote stands near the runway; so, in theory, delays will not affect capacity due to aircraft stands.

The key aspects of stand availability are:

1. Number of stands provided for different types / sizes of aircraft
2. Availability of stands influenced by occupancy times
3. Availability of multiple aircraft ramp stands
4. Which terminal(s) are served by the stands
5. Whether the stands are terminal gate or remote

The flexible use of operational stands (e.g. two small aircraft on one large aircraft stand) affects directly to the maximum capability of a layout. The parking configuration adopted may not affect stand capacity but could have a significant impact upon the apron capacity.

8.2.1.4 Gates

Gate (contact) stands avoid the need of buses and enable better turnaround times[25]. Capacity of the gates can be indicated in a first approximation by the number of gates or other aircraft parking positions in the complex during a daily 1 or 2 hour peak period.

Gate capacity = [operations / hour]

As gate utilization increases, the risk of delay due to problems with operations increases. Frequent occurrence of such delays may indicate that the capacity of the gate system is being approached.

Gate supply is calculated to match the runway throughput, and ultimately the runway saturation schedule, plus the overnight parking requirements. Gate design gives an idea of the various characteristics and volume of traffic to be handled.

While there is a physical limit on the number of aircraft which can be simultaneously accommodated at the airport, operational factors such as gate assignment policy, exclusive/preferential use, sectorization and operational parameters affect the practical capacity of the system.

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[25] See Table 8.4 and Table 8.5

However, 100 percent gate utilization may not be achievable because of incompatibility between parking and ramp configuration or gate equipment and types of aircraft seeking access. Over the course of a full operating day, the patterns of arrivals and departures as well as airline ground operations, community factors, and weather determine the average number of operations per gate that can be served over the course of a year and whether a group of gates can accommodate additional flights.

The inputs required to conduct a gate assignment study include:

1. Busy day flight schedule
2. An apron plan indicating all contact gates and remote stands
3. List of all contact gates and stands by range of aircraft accommodated and sector accepted / preferred
4. Policy regarding exclusive and/or preferential use
5. Operational parameters, such as the buffer time between flights using the same gate (either on a gate by gate basis or globally), minimum tow-on and tow-off time by aircraft, and minimum ground time before an aircraft is considered a candidate for towing

Gate occupancy time is an important factor in establishing gate capacity. For gate assessments, the processing and servicing time shown in Table 8.4 and Table 8.5 should be considered.

Aircraft type	Pax load	Loading pax	Unloading pax	Aircraft Servicing	Through Flight	Turnaround Flight
B	40	10	5	10	-	25
C	130	20	10	15	25	45
D	250	30	15	30	45	75
E						
1 DOOR	350	40	25	45	45	110
2 DOORS	350	25	15	45	45	85
F						
1 DOOR	470	55	30	80	60	165
2 DOORS[26]	470	30	20	80	60	130

Table 8.4. Typical aircraft processing and servicing time (in minutes) at gate

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[26] A third door reduces the turnaround time by only 10-15 minutes to a total of approximately 115 minutes. The boarding and de-boarding processing times are no longer in the critical path. On the contrary, the catering process is on the critical path because of the high number of trolleys to be loaded and off-loaded

Aircraft	Terminal flight	Domestic traffic	International traffic
B-747	90	60	120-180
A-300	45 - 60	60	120
DC-10	45 - 60	60	120
MD-11	45 - 60	60	120
B-757	45	50	60
B-737	25	45	60
B-777	25	45	60
F-28	25	45	60

Table 8.5. Examples of mean gate occupation times

Because of typical gate service or turnaround time, capacity over the short term, normally a period of **0.5 to 2 hours,** is typically one aircraft per parking position and gate.

Demand and operating factors influencing service level and capacity of aircraft parking positions and gates are:

1. Number of parking positions and physical layout (controls the total number of aircraft at gate at one time, should include hardstands and apron parking)
2. Utilization (ratio of time that gate is effectively occupied (service, layover and recovery))
3. Hours of operation (specially noise restrictions) (limits the number of operations that can be handled per gate in a given day)
4. Flight schedule and aircraft mix (determines whether gates are likely to be available when needed, taking into account uncertainty in actual operation times compared with schedule; gates must be physically compatible with type of aircraft scheduled (see Utilization))
5. Airline leases and operating practices, airport management practice (gate use strategy controls gate availability and utilization)

8.2.2 Landside components

8.2.2.1 Ground access

Ground access is provided by an assortment of private and public transport modes. Except in those few cases where a rail transit system serves the airport, these ground access modes all use the metropolitan highway and street network and share the same roadways for circulation at the airport. Typically only those off-airport elements of ground access that serve significant volumes of airport traffic are considered in planning and analysis.

Ground access capacity = [m^2/person]

Those accompanying or meeting passengers influence the demand on ground access systems. Such individuals overwhelmingly travel by private automobile, as do airport employees. Additional vehicle trips result from the delivery of cargo, priority packages, mail and terminal building and concession supplies and the numerous service and maintenance requirements of an airport.

Demand and operating factors influencing service level and capacity of airport ground access are:

1. Available modes and prices (connections from various parts of the metropolitan area served, considering prices, comfort and convenience, particularly with respect to baggage and required vehicle changes)
2. Access times (total, including wait for vehicles or access and travel from representative locations)
3. Passenger characteristics (fraction choosing each mode, vehicle occupancy, number of people accompanying passenger, other visitors, baggage loads, origination / destination share)
4. Vehicle operator behavior (fraction going directly to curb or to parking, waving, curb dwell time, knowledge of traffic patterns)
5. Flight schedule and load (basic determinant of number of people using ground facilities)
6. Facilities and background traffic conditions (highway and transit routes, interchanges; levels of traffic on facility for other than airport purposes; availability of remote check-in facilities)

Although it is often necessary to view many of these factors on a metropolitan scale, the focus of capacity assessment is on the service provided between the terminal curb or parking area and the interchange linking the airport with the regional transportation system.

Access Mode	No. of Passengers per vehicle
Private automobile	1.9
Rental car	1.2
Taxi	2.5
Limousine	5.6

Table 8.6. Typical average vehicle occupancy rates for airport ground access

It is important to note that cost of parking can have a particularly significant impact on access mode choice at large airports. Moreover, driver familiarity with the roadway system and the complexity of the system significantly influence ground access operations. The management of taxi, limousine, and courtesy bus operations may also influence ground access operations. Control of cargo vehicles and employee access are also important at some airports.

8.2.2.2 Parking area (vehicles)

Parking areas consist of surface slots or multilevel garages used to store the vehicles of air passengers and visitors. Although parking and storage areas are also needed for employee vehicles, rental cars, taxis, and buses, these requirements have relatively little influence on the capacity or service level of the airport as viewed by a passenger.

For planning purposes, parking is divided into two or three general categories: short-term, long-term, and remote (which is usually long-term parking).

1. Short-term parking is usually located close to terminal buildings and serves motorists dropping off or picking up travelers.
2. Long-term parking serves passengers who leave their vehicles at the airport while they travel.
3. Remote parking consists of long term parking slots located away from the airport terminal buildings.

8.2.2.3 Terminal curb

A variety of pedestrians, private automobiles, taxis, buses, commercial delivery trucks, and hotel and rental car courtesy vans use the terminal curb area. Most passengers, their baggage, and sometimes accompanying visitors are dropped off or picked up at the terminal building curb frontage. In this area passengers leave ground transportation and become pedestrians on their way to or from the aircraft gate.

Terminal curb = [vehicles / hour]

Demand and operating factors influencing service level and capacity of terminal curb [B38] are:

1. Available frontage (length of curb frontage modified by presence of obstructions and assigned uses (e.g., airport limousines only, taxi only), separation of departures and arrivals)
2. Frontage roads and pedestrian paths (number of traffic lanes feeding to and from frontage area; pedestrians crossing vehicle traffic lanes)

3. Management policy (stopping and dwell regulations, enforcement practices, commercial access control, public transport dispatching)
4. Passenger characteristics and motor vehicle fleet mix (passenger choice of ground transport mode, average occupancy of vehicles, dwell times at curb, passenger patterns of arrival before scheduled departure, baggage loads)
5. Flight schedule (basic determinant of number of people arriving and departing at given time in given area)

The primary determinant for curb frontage space required at a terminal is the length of time that vehicles stop for loading and unloading, referred to as the *dwell time*.

Vehicle dwell time varies with type of vehicle, number of passengers in the vehicle, and baggage loads. Dwell times for originating (enplaning) passengers**¡Error! No se encuentra el origen de la referencia.** are typically shorter than those for terminating (deplaning) ones.

Type of vehicle	Average dwell time (min)	
	Enplaning	Deplaning
Automobile	1 – 3	2 – 4
Taxi	1 – 2	1 – 3
Limousine	2 – 4	2 – 5
Bus	2 – 5	5 – 10

Table 8.7. Observed curb dwell times at selected airports

Enforcement of regulations limiting vehicle dwell times in curb frontage areas influences traffic congestion, curb service levels, and capacity.

It is important to note that the capacity of the terminal curb lane is distinct from the capacity of the travel lanes adjacent to it. These travel lanes are part of the ground access component.

8.2.2.4 Terminal building

8.2.2.4.1 Terminal level of service

The level of service is a range of values that qualify the ability of supply to meet demand, and it is a parameter used to calculate passenger terminal capacity. According to IATA, it is divided into the following categories:

A	Excellent level of service. Conditions of free flow, no delays and excellent levels of comfort
B	High level of service. Conditions of stable flow, very few delays and high levels of comfort
C	Good level of service. Conditions of stable flow, acceptable delays and good levels of comfort
D	Adequate level of service. Conditions of unstable flow, acceptable delays for short periods of time and adequate levels of comfort
E	Inadequate level of service. Conditions of unstable flow, unacceptable delays and inadequate levels of comfort
F	Unacceptable level of service. Conditions of cross-flows, system breakdowns and unacceptable delays; an unacceptable level of comfort

Table 8.8. Level of Service Framework

The minimum level of service recommended by IATA is **C**, as it denotes good service at a reasonable cost.

8.2.2.4.2 Maximum Queuing Time

The occupancy patterns in various subsystems change rapidly and thereby affect the space available to occupants. The occupancy time results in a level of comfort. For this reason, time is a significant factor in determining the quality of service and must be considered as a primary variable in level of service measures. Table 8.9 shows maximum queuing time guidelines:

	Short to acceptable	Acceptable to long
Check-in economy	0 – 12	12 – 30
Check-in business Class	0 – 3	3 – 5
Passport control inbound	0 – 7	7 – 15
Passport control outbound	0 – 5	5 – 10
Baggage claim	0 – 12	12 – 18
Security	0 – 3	3 – 7

Table 8.9. Maximum Queuing Time guidelines

8.2.2.4.3 Passenger processes

According to the flight segment (economic, business, etc.), characteristics and needs are different. Design attributes such as how much more queuing space might be required for passengers who use luggage carts and tend to carry a certain amount of luggage, varies depending on their passenger segment. Demand always exceeds capacity at some point, and providing space for the formation of a queue is part of terminal design.

Space standards for a short-haul flight with passengers with carry-on luggage only (e.g. business class flyers) should be different than for a flight mostly with passengers on a two-week trip checking in two or three pieces of luggage piled on a cart.

Passenger queuing is very uncertain (especially at check-in), because of fluctuation not only in demand but also in capacity. The arrival pattern of passengers in departures may change from flight to flight and from day to day.

8.2.2.4.3.1 Check-in

Passengers might arrive at the terminal from several minutes to several hours before departure time, and the first subsystem they might visit is the check-in counters or the auto check-in servers. Length of arrival time before a scheduled departure may be expected to vary by type of service offered and by size of airport. Check-in counters are key facilities with significant impact on level of service, terminal development costs and operations.

Check-in capacity = [m^2/occupant], [min/person]

Operation of the ticket counter and baggage check component begins when the passenger enters a queue to obtain a ticket and check his baggage and ends when that passenger leaves the ticket counter area. Curbside baggage check is a part of this component.

Demand and operating factors influencing service level and capacity of ticket counter and baggage check [B38] are:

1. Number and type of position (processing rates are function of position type (baggage check only, ticket purchase, frequent or first class traveler, etc.))
2. Airline procedures and staffing (number of positions manned and processing times)
3. Passenger characteristics (number preticketed or with boarding pass amount of luggage, and distribution of arrival before scheduled departure influence demand loads, fraction of passengers by-passing check-in)
4. Space and configuration (available waiting area for queues approaching agent positions; banked or separate queues; conflict with circulation patterns)
5. Flight type, schedule, and load (basic determinant of number of people arriving at ticket area)

6. Airline lease agreement and airport management practices (counter use policy, as formalized in lease agreements, similar to gate issues and options)

In some airports a single queue may feed a bank of check-in positions, and so long queues might form, but this does not necessarily indicate that the component has a capacity problem.

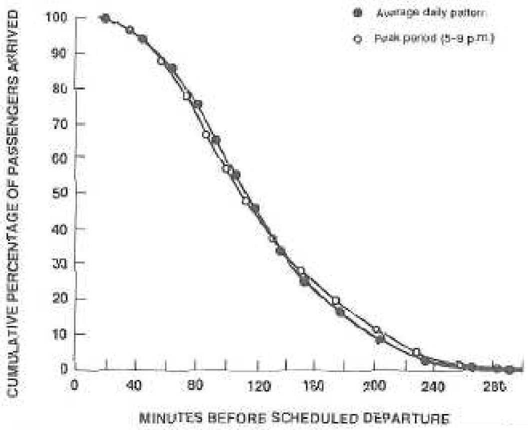

Figure 8.2. Observed departing passenger arrival times at John F. Kennedy International [B38]

Increased use of advanced ticketing and seat assignment has raised the fraction of passengers bypassing the ticket counter and baggage check component.

Data from several U.S. large hub airports show that average processing or contact time per passenger at ticket counters varies widely. Processing times at any particular airport will depend on airline staff experience, flight market, and passenger characteristics, as well as on airline operating policies. Surveys are typically required to determine these times, and for this reason “in-situ” measurements will be done.

Airport	Typical Service Time (min/person)
Miami [B39]	
Full service	1.9 – 5.6
Express	2.3
Manual ticketing [B37]	
With baggage	3.0 – 4.0
Without baggage	1.7 – 3.3
Baggage only [B37]	0.5 – 0.8
Automated ticketing [B37]	
With baggage	2.7 – 3.7
Without baggage	1.5 – 3.0

Table 8.10. Typical processing times observed at ticket counter and baggage check [B23], [B39]

Regarding space of check-in room, frequently applied architectural and planning space standards are summarized in Table 8.11. A guideline of **8 ft^2** per person, for example, allows approximately a **3 ft** separation between passengers in a queue. Typical airport design standards call for a queuing space **15 ft** deep in front of ticket counters [B27] and specify different spacing between service positions to allow for different functions.

Source	Space Standard (ft^2/person)
IATA level of service [B16]	
Level A (excellent)	> 17.2
Level E (inadequate)	< 10.8 for > 15 min
System breakdown	< 8.6 for > 15 min
FAA implied guidelines [B27]	
Multipurpose check-in	15 – 23
Baggage check only	12 – 18
Ticketing only	43 – 7.6

Table 8.11. Space standards for terminal check-in areas [B17], [B27]

8.2.2.4.3.2 Passenger security screening

All originating passengers must pass through a security screening. In addition, interline transfer passengers at some airport may be required to clear a security screening on their way to a connecting flight. These areas are often points of queuing and delay for passengers, especially when passengers arrive at rates exceeding the service rate of the security screening area, queues form. Persistence of such queues during a peak hour is often evidence of a capacity shortage at the security screening area.

Passenger security screening capacity = [min / passenger]

Passenger security screening occurs in concourse corridors at entrances to terminal gate areas or at the entry to gate lounges. Equipment configuration and staffing are the primary factors influencing capacity.

Demand and operating factors influencing service level and capacity of passenger security screening areas ([B38]) are:

1. Number of channels, space, and personnel (influences number of passengers processed per unit time (magnetometer and x-ray considered separately))
2. Type, equipment sensitivity, and airport/airline/agent policy and practice (determines average service time per passenger and likelihood of close inspection)

3. Passenger characteristics (amount of hand luggage, mobility and patterns of arrival influence average service time as well as number of passengers)
4. Building layout and passenger circulation patterns (interference among pedestrian flows can influence flow rates and create congestion)
5. Flight schedule and load (basic determinant of number and direction of people on concourse)

Processing rates at the security screening area are affected by the number and size of pieces of hand luggage carried on. Holiday travelers, tourists, and business travelers seeking to avoid checking baggage may have a larger number of parcels to be inspected. High percentages of passengers in wheel-chairs or children in strollers may also lead to slower processing.

The sensitivity of magnetometer can be varied to pick up smaller amounts of metal on the passenger's person. Less sensitive settings will tend to decrease average service time by reducing the frequency of intensive inspections.

Airport	Average processing time (min/pax)
Miami [B40]	0.47 – 0.51
Denver [B40]	0.18 – 0.56
La Guardia [B40]	0.15 – 0.77
Hand-checked baggage [B24]	0.50 – 1.00
Automated check [B24]	0.50 – 0.67

Table 8.12. Typical processing times for security screening

8.2.2.4.3.3 Waiting area

After check-in, passengers have to be redirected to their assigned gate. The amount of time spent by a passenger to move from the entrance of the airport to the gate will depend on the time spent in waiting areas and in service facilities, and the time taken to move from one facility to the other.

Passenger waiting area capacity = [m^2 / person]

The number of passengers waiting for flight departures and arrivals depends primarily on:

1. Number of aircraft served by the waiting area
2. Flight schedules
3. Aircraft seating capacity
4. Aircraft passenger load factors

5. Degree to which passengers are accompanied by family or friends
6. Passenger arrival time at the airport
7. Passenger behavior, including the length of time it takes for passengers to pass though the other components of the landside
8. Length of time between commencement of boarding of a flight and its departure.

Waiting areas such as gate lounges serve originating and transfer passengers, whereas terminal lobbies accommodate primarily originating passengers and their non-traveling companions. The number of waiting passengers in an area generally is greater when passengers arrive at the airport early for their flights and decreases when more time is required for check-in or transfer.

Variations in aircraft departure times may increase the number of passengers waiting.

Airlines normally seek to avoid crowding in their exclusive-use areas. However, during the 15 to 20 min before departure when about 70 to 90 percent of the passengers are near the gate, crowding is sometimes unavoidable. Design of a common waiting area for several gates is used at some airports to void severe crowding.

Demand and operating factors influencing service level and capacity of passenger waiting areas are:

1. Waiting and circulation area (lounge and accessible corridor) (space available for people to move around and wait for departing flights; depends on terminal configuration, for example, waiting areas may be shared by passengers on several departing flights or restricted to single gate)
2. Seating and waiting-area geometry (seated people may occupy more space but are accommodated at higher service levels)
3. Flight schedule, aircraft type, passenger load, and gate utilization (larger aircraft typically mean higher passenger loads; areas used jointly to serve simultaneous departures)
4. Boarding method (availability and type of jet ways, stairs, and doors from terminal to aircraft affect rates at which passengers board as well as airline passenger handling procedures)
5. Passenger behavioral characteristics and airline service characteristics (how soon before scheduled departure people arrive at gate areas, amount of carry-on baggage, knowledge of system, and percentage of special needs passengers (families with small children, elderly, handicapped, first class and business travelers); airline passenger service policy, seat assignment and boarding pass practices)

Some of the most frequently used design space standards for gate lounges and other terminal waiting areas are given in:

Design situation	Space standard (ft^2/person)
IATA design standard for departure lounges [B3]	8,5 per aircraft seat
IATA suggested breakdown level of service in waiting and circulation areas [B19]	> 10,8 for more than 15 min
Unofficial FAA minimum-space guidelines for departure lounge design [B28]	6,7 – 10 per aircraft seat; 15 per seated waiting passenger
Architectural reference standard for adequate waiting and circulation space with baggage [B27]	13

Table 8.13. Typical space standards used in planning and design

8.2.2.4.3.4 Connecting passenger transfer

An airport's ability to accommodate the quick and efficient transfer of connecting passengers and their baggage from an arriving aircraft to a subsequently scheduled aircraft departure is important to passenger safety, comfort, and convenience, as well as to airline operating efficiency. Airport serving significant numbers of connecting passengers increasingly play a key role in the nation's air transportation system.

Transfer passengers must travel with their carry-on baggage from one gate to another by walking or with the aid of buses or other mechanical devices, sometimes moving between separate terminal buildings, possibly leaving and reentering secure areas, and sometimes using check-in and other facilities along the way. Arriving international passengers must pass through customs and immigration, claim and recheck their luggage.

When an on-line connection is made (between two flights operated by the same airline), the airline will typically try to ensure that the passenger is assisted with the transfer. Airline hub-and-spoke operations depend on the ability of passengers to make the transfer quickly and easily. Transfer passengers arriving and departing on flights operated by different airlines must make an interline transfer. Typical problems encountered by transfer passengers making transfers at some airports include long distances to be traversed, obstacles such as changes in elevation and unprotected areas separating terminals, and poor information on where the next flight's gate is located.

Demand and operating factors influencing service level and capacity of passenger transfer are (extracted from [B38]):

1. Terminal configuration (distance between gates, information for connecting passengers, intervening security screening)
2. Ground transport (connecting passenger assistance systems, baggage transfer systems)
3. Passenger characteristics (fraction needing assistance for ground transport, integrate travel speeds, baggage loads)
4. Flight schedule and load factors (basic determinant of number of people making peak-period connections)

These factors influence how long it may take for passengers to make the transfer, which is the primary basis for judging service level and estimating capacity.

The physical design of the airport's terminal facilities is the principal variable influencing service provided to transfer passengers. However, effective signing and other assistance to aid the transfer passenger may influence their ability and perceptions of service offered and mitigate some difficult aspects of making a transfer.

In many airports, interline transfer passengers have no choice but to walk from one airline's area to another's. But in some large airport, systems are available to aid the passenger in this movement, such as moving walkways, people movers, and inter-terminal buses. Buses, however, are subject to congestion on airport roadways and at the terminal curb. Collection of fares for buses and people movers makes these facilities less effective and desirable from the passenger's point of view.

8.2.2.4.3.5 Customs and immigration

Passengers arriving on international flights must generally undergo customs and immigration formalities at the airport of their final landing, including passport inspection, inspection of baggage and collection of duties on certain imported items, and sometimes inspection for agricultural materials, illegal drugs, or other restricted items.

Customs and immigration = [passengers / hour /agent]

On arrival at one of the several inspection booths, foreign passengers present their passports and other documents and parallel queues form. The simultaneous arrival of several fully loaded wide-body aircraft can bring a surge of demand that causes service levels to drop dramatically in the international arrivals area.

Variations in airline arrival schedules, government operating standards, and budget constraints may sometimes cause staffing shortages or excessive demand loads.

Demand and operating factors influencing service level and capacity of customs and immigration ([B38]) are:

1. Number of channels, space and personnel (inspector channels, U.S. citizen pass-though positions in immigration, “red-green” channel use in customs)
2. Inspector (average processing time per passenger, efficiency rate of selection for close inspection policy)
3. Passenger characteristics (fraction U.S. citizens, flight origin, citizenship of foreign nationals, baggage loads)
4. Space and configuration (available queue space, access to and configuration of baggage display devices, use of carts)
5. Flight schedule load (basic determinant of number of people arriving at FIS areas)

Customs and immigration capacity is generally determined over the short run – typically a peak period of 1 to 2 hours during which several flights may arrive.

8.2.2.4.3.6 Baggage unit

Terminating passengers with checked luggage frequently judge their deplaning experience largely in terms of the service provided at the baggage claim. Delays at this area have encouraged many business travelers to carry their entire luggage on board, a practice that affects operations and capacity of other airport components such as security screening and passenger waiting areas

Baggage unit capacity = [m^2/occupant].

Baggage claim areas are typically located adjacent to the direct route of deplaning passenger circulation to provide an area suitable for an activity that involves waiting and heavy circulation.

Demand and operating factors influencing service level and capacity of baggage claim [B38] are:

1. Equipment configuration and claim area (type, layout, feed mechanism, and rate of baggage display; space available for waiting passengers; relation of wait area to display frontage; access to and amount of feed belt available)
2. Staffing practices (availability of porters (sometimes called “sky caps”) and inspection of baggage at exit from claim area influence rates of exit; rate of baggage loading/unloading from cart to feed belt)
3. Baggage load (numbers of bags per passenger, fraction of passengers with baggage, time of baggage arrival from aircraft)
4. Passenger characteristics (rate of arrival from gate, ability to handle luggage, use of carts, number of visitors)

Capacity over the short run – typically a period of 20 min to 45 min – is determined primarily by how many passengers can wait in the same area and the speed with which their luggage arrives and is displayed. Baggage claim devices may serve two or more flights on one or more airlines.

Regarding flow distribution, passengers typically form layers (very wide queues) around the baggage claim device, which tend to be deepest around the upstream end of the device and near the primary access point to the claim area. A row of passengers one to two deep has direct access to the claim device and will be able to see and reach their bags. Other passengers wait to gain access to this queue.

8.2.2.4.3.7 Terminal circulation

The terminal circulation component is used by all air passengers. Generally speaking, the total time it takes for a passenger to move though the airport's landside is the sum of the time waiting for service and being served at each of the functional components used along the way, such as check-in or baggage claim, plus the time required to travel between components.

Terminal circulation capacity = [m/s]

If only the travel time is added, the sum represents an estimate of the time it takes to travel through the landside without stopping. A business traveler with all tickets and boarding passes in hand and with no luggage to check or retrieve might allow just this much time plus time for brief delays at the security screening at the gate awaiting departure, and at ground transportation for the terminal portion of his trip.

Demand and operating factors influencing service level and capacity of terminal circulation ([B38]) are:

1. Terminal configuration (space available for people to move freely without conflict of flows; availability of alternative paths; placement of seating, commercial activity, stairs, escalators)
2. Passenger characteristics (amount of hand luggage, mobility, and rate of arrival before scheduled departure influence demand loads and service time)
3. Flight schedule and load (basic determinant of number and direction of people on concourse)

Passenger demand within this component is determined primarily by patterns of passenger arrival at the airport before scheduled flight departures; by the paths passengers take going between gates and the terminal curb, and by speeds at which both arriving and departing passengers make this trip. The rate at which passengers move through the landside depends on such characteristics as age, purpose for the travel, and time available before the flight or following the arrival; on the degree of crowding encountered along the way; and on the geometry of the path travelled.

Escalators and elevators may become bottlenecks but generally improve service levels. Passengers normally do not take the shortest route through the terminal. Concessions, rest rooms, and pay telephones located along corridors typically create some congestion and slow general travel speeds as well as increases the path lengths of the passengers who use these facilities.

8.3 Methodology for capacity and efficiency assessment

Mathematically, not all the components affecting the airport's capacity can be easily computed without recurring to simulations. In this report, a first level capacity analysis is undertaken, so not all the agents described in the previous diagrams will be considered.

8.3.1 Capacity assessment alternatives

After an exhaustive survey on all the different existing methods for capacity (described in Annexes 4 and 5), the possibilities applicable to this study are listed below:

AIRSIDE			
System	**Assessment method**	**Ref**	**Variable assessed**
APRON CAPACITY	Parsons estimate	[B13]	m^2 required
	Aggregate efficiency	[B38]	m^2 required
	Apron and stands	[B38]	-
GATE / STANDS CAPACITY	Direct calculation	[B4]	ops/h
	FAA method	[B10]	ops/h
	Parsons gate-enplanement curve	[B28]	ops/h
	Average-to-peak utilization correction	[B5]	Correction factor
	Graphic analysis	[B11]	ops/h
	Ramp chart hourly utilization analysis	[B23]	ops/h
RUNWAY CAPACITY	FAA method	[B10]	ops/h
	Ministerio Obras públicas, Transporte y Medio Ambiente	[W16]	ops/h
	Separation analysis method		Movement area
TAXIWAY CAPACITY	FAA method	[B10]	ops/h
TERMINAL AIRSPACE	No method found		-

Table 8.14. Airside capacity assessment methods

LANDSIDE			
System	**Assessment method**	**Ref**	**Variable assessed**
GROUND ACCESS CAPACITY	Estimation method	[B22]	m^2 required
	Access capacity-to-demand index	[B41]	PDI, PCI indexes
PASSENGER TERMINAL CAPACITY			
Arrival hall	IATA method	[B19]	m^2 required
Baggage claim units area	Surface method	[B19]	m^2 required
	Baggage claim units	[B19]	Number of baggage claim units required
Centralized security check	IATA method	[B19]	Number of security servers
Check-in	Check-in queue	[B19]	m^2 required
	Number of check-in counters	[B19]	Number of check-in counters
Passenger transfer	Estimation method	[B38]	Average time required
Customs and immigration	Estimation method	[B38]	Passengers/(hour*agent)
Gate hold room	Surface method	[B19]	m^2 required
Passport control	Surface method	[B19]	m^2 required
	Passport control arrivals capacity	[B19]	Number of passport desks
	Passport control departures capacity	[B19]	Number of passport desks
Terminal circulation	Estimation method	[B39]	Speed (m/s)
Waiting area	Surface method	[B38]	m^2 required
PARKING	Parking requirement planning curve	[B25]	Number of parking spaces required
TERMINAL CURB	No method found	[B38]	-

Table 8.15. Landside capacity assessment methods

8.3.2 Capacity and efficiency assessment methods used in this study

After having recompiled a list of capacity assessment methods, and considering the liability of the methods, the data needed to implement them, the results obtained from each and the complexity they introduce when it comes to proceed, the following methods will be the ones used in the capacity assessment:

System	Assessment method
AIRSIDE	
APRON CAPACITY	Apron and stands
GATE CAPACITY	FAA method
RUNWAY CAPACITY	FAA method
TAXIWAY CAPACITY	FAA method
TERMINAL AIRSPACE	No methodology found

LANDSIDE	
GROUND ACCESS CAPACITY	Access capacity-to-demand index
PAX TERMINAL CAPACITY	
Arrival hall	IATA method
Baggage claim units area	Baggage claim units
Security check	IATA method
Check-in	Number of check-in counters
Passenger transfer	Estimation method
Customs and immigration	Estimation method
Gate hold room	Surface method
Passport control	Passport control arrivals / departures capacity
Terminal circulation	Estimation method
Waiting area	Surface method
PARKING	Parking requirement planning curve
TERMINAL CURB	No methodology found

Table 8.16. List of selected capacity assessment methods

Following those, capacity assessment of T1 terminal of Barcelona airport is executed in the following chapters.

Regarding efficiency, a good indicator for evaluating the airport's efficiency is an estimation of the delays. FAA proposes a method to determine delays on the runway component (hourly and daily), and in this report such method will be used as well.

9 T1 BARCELONA AIRPORT CURRENT CAPACITY AND EFFICIENCY ASSESSMENT

9.1.1 T1 Barcelona airport characterization

9.1.1.1 Terminal sections

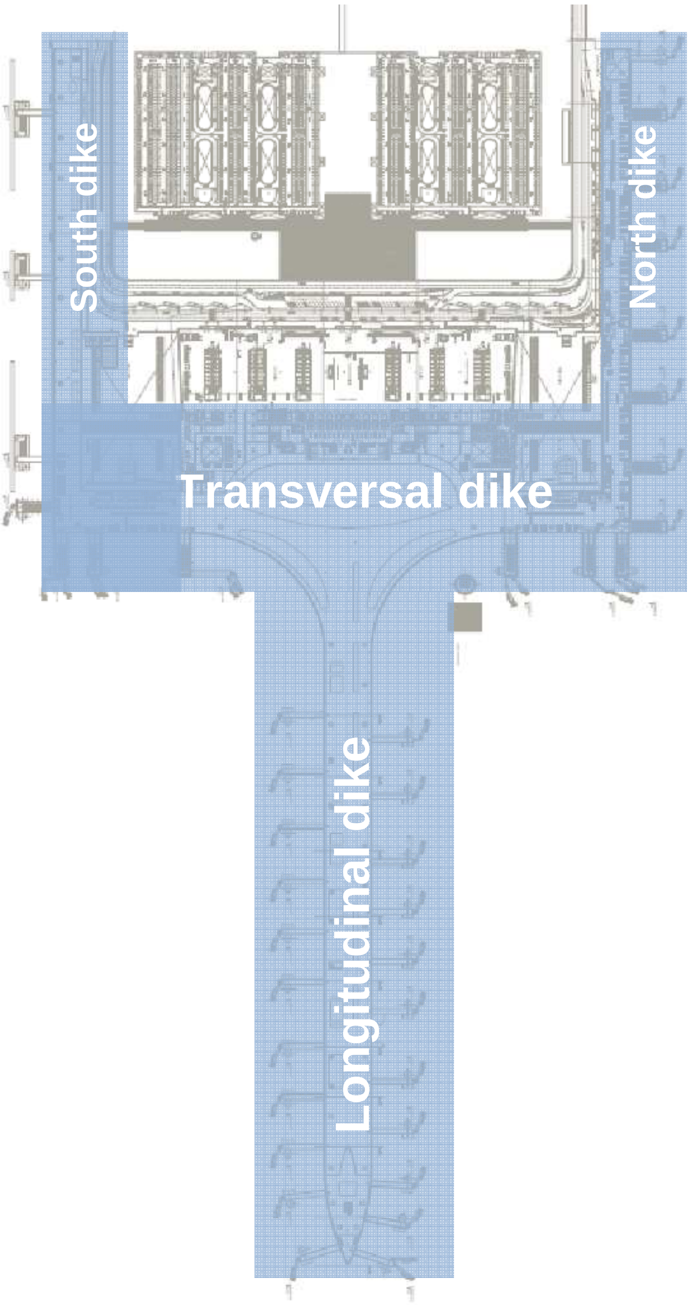

Figure 9.1. Barcelona T1 main sections

9.1.1.2 Terminal floors and plan levels

In the following sections, many references to plans and floors of the airport are done, and it is important to have it clear since the beginning:

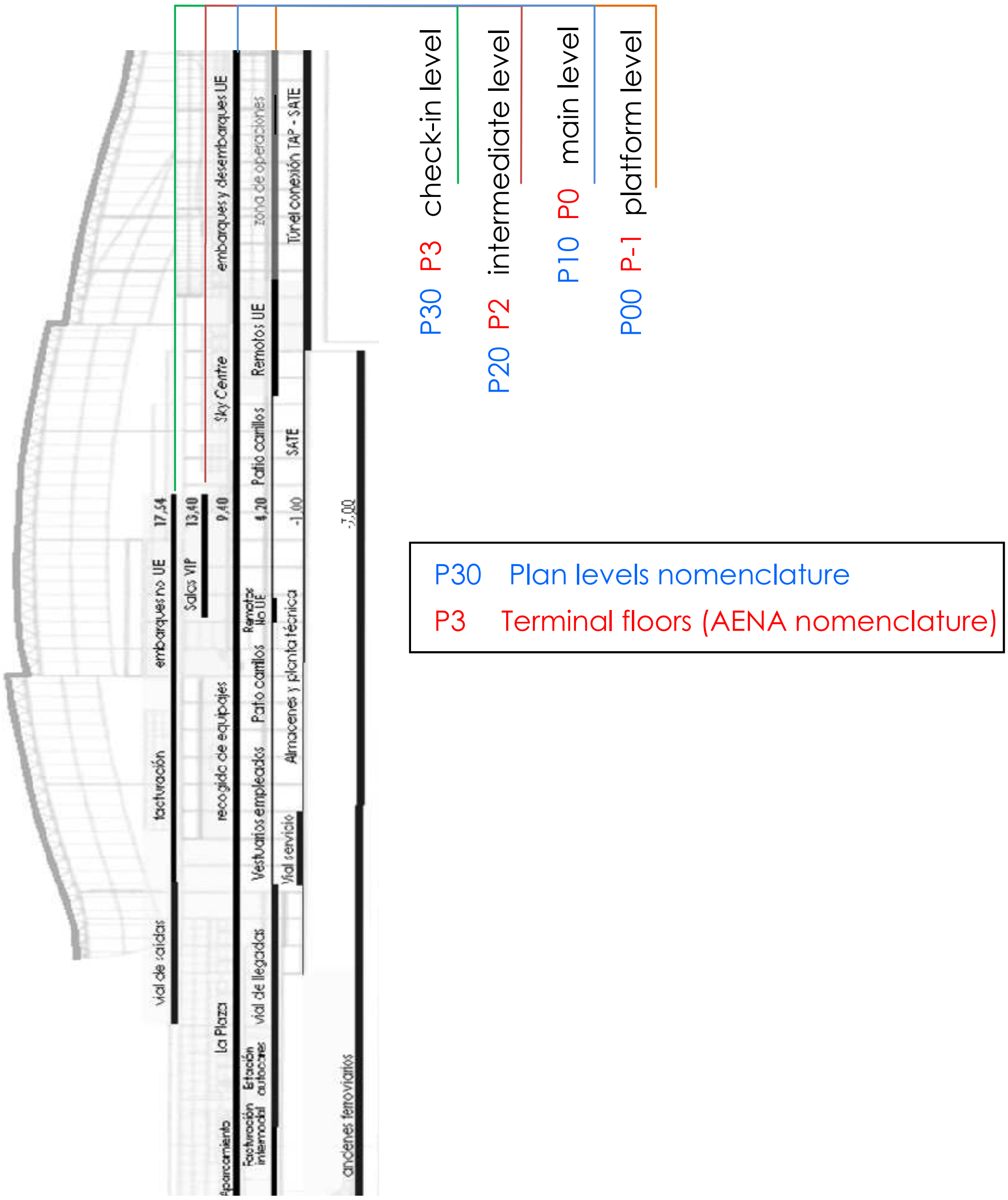

Figure 9.2. Nomenclatures used[27]

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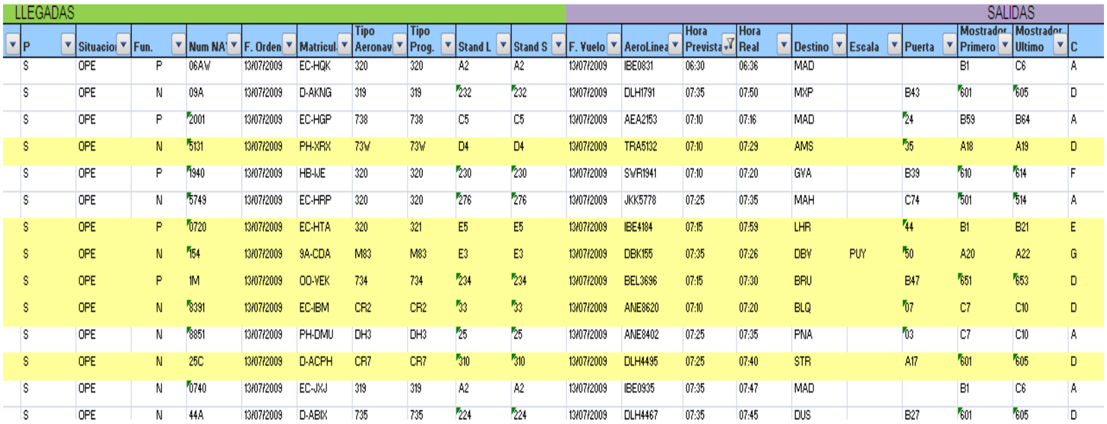
[27] Recall Annex 6 for better details

9.1.1.3 Arrival / departure operations register

The operations register is a database containing all flights (both in arrivals and departures) operating at an airport. Each airport has its own arrival / departure operations register, and from multiple traffic analysis, capacity, demand, etc can be made.

In an operations register the following information is detailed:

- Flight date
- Airline + Flight number
- Programmed arrival/departure time
- Real arrival/departure time
- Airport of origin/destination
- Stopover
- Baggage carousel
- Check-in desk
- Traffic (C): A (national), D (UE), E, F (freight), G, H (no UE)
- Passenger (M): C, D, J (regular), P (positional), S (pont aeri)
- Scheduling (P): A (authorized 48h), S (slot)
- Situation: OPE (operated), CAN (cancelled)
- Functionality: N (non programmed), P (programmed)
- Num NAV: flight plan code
- Aircraft registration code
- Aircraft type
- Stands used
- MinR: Delay minutes (if negative it means in advance)



LLEGADAS											SALIDAS									
	P	Situacio	Fun.	Num NA	F. Orden	Matricul	Tipo Aeronav	Tipo Prog.	Stand L	Stand S	F. Vuelo	AeroLinea	Hora Prevista	Hora Real	Destino	Escala	Puerta	Mostrador Primero	Mostrador Ultimo	C
	S	OPE	P	06AW	13/07/2009	EC-HQK	320	320	A2	A2	13/07/2009	IBE0831	06:30	06:36	MAD			B1	C6	A
	S	OPE	N	09A	13/07/2009	D-AKNG	319	319	232	232	13/07/2009	DLH1791	07:35	07:50	MXP		B43	601	605	D
	S	OPE	P	2001	13/07/2009	EC-HGP	738	738	C5	C5	13/07/2009	AEA2153	07:10	07:16	MAD		24	B59	B64	A
	S	OPE	N	5131	13/07/2009	PH-XRX	73W	73W	D4	D4	13/07/2009	TRA5132	07:10	07:29	AMS		35	A18	A19	D
	S	OPE	P	1940	13/07/2009	HB-IJE	320	320	230	230	13/07/2009	SWR1941	07:10	07:20	GVA		B39	610	614	F
	S	OPE	N	5749	13/07/2009	EC-HRP	320	320	276	276	13/07/2009	JKK5778	07:25	07:35	MAH		C74	501	514	A
	S	OPE	P	0720	13/07/2009	EC-HTA	320	321	E5	E5	13/07/2009	IBE4184	07:15	07:59	LHR		44	B1	B21	E
	S	OPE	N	154	13/07/2009	9A-CDA	M83	M83	E3	E3	13/07/2009	DBK155	07:35	07:26	DBV	PUY	50	A20	A22	G
	S	OPE	P	1M	13/07/2009	OO-VEK	734	734	234	234	13/07/2009	BEL3696	07:15	07:30	BRU		B47	651	653	D
	S	OPE	N	8391	13/07/2009	EC-IBM	CR2	CR2	33	33	13/07/2009	ANE8620	07:10	07:20	BLQ		07	C7	C10	D
	S	OPE	N	8851	13/07/2009	PH-DMU	DH3	DH3	25	25	13/07/2009	ANE8402	07:25	07:35	PNA		03	C7	C10	A
	S	OPE	N	25C	13/07/2009	D-ACPH	CR7	CR7	310	310	13/07/2009	DLH4495	07:25	07:40	STR		A17	601	605	D
	S	OPE	N	0740	13/07/2009	EC-JXJ	319	319	A2	A2	13/07/2009	IBE0935	07:35	07:47	MAD			B1	C6	A
	S	OPE	N	44A	13/07/2009	D-ABIX	735	735	224	224	13/07/2009	DLH4467	07:35	07:45	DUS		B27	601	605	D

Figure 9.3. BCN airport quadrant of operations extract

9.1.2 Airside capacity assessment

9.1.2.1 Runway capacity

As listed in Annex 4 in section 4.1, several assumptions are considered. In order to be able to justify that FAA method is applicable to the Barcelona airport case, those assumptions are compared to the real case and checked:

	Can it be considered?
Arrivals equal departures	✓
A full-length parallel taxiway	✓
Ample runway entrance/exit taxiways	✓
No taxiway crossing problems	✓
No space limitation	✓
At least one runway equipped with an ILS	✓
Weather conditions occur roughly 10 percent of the time	✓
80% of the time the airport is operated with the runway-use configuration which produces the greatest hourly capacity	✓
PVC conditions not involved	✓
No absence of radar coverage or ILS	✓
No runways are limited to be used by small aircraft	✓

Table 9.1. IATA’s methodology feasibility for BCN’s airport

9.1.2.1.1 Operational capacity assessment

Following the methodology described in Annex 4.3.1, the capacity of the runway is calculated.

1. *Select the runway-use configuration which best represents the use of the airport during the hour of interest.*

The current configuration of Barcelona’s airport was designed to increase runway capacity and also to reduce its environmental impact.

<u>Runway operations configuration</u>

The original idea of building a 3rd runway was that the airport would absorb its traffic in an independent regime of operation, which means that both 07R/25L and 07L/25R parallel runways would allow simultaneous takeoffs and landings, significantly increasing the capacity offered.

Original configuration			
Independent mode			
Daytime	**Southern Terminal**	3rd runway	TO[28] / LD[29] small A/C
		1st runway	TO for heavy A/C
	Northern Terminal	1st runway	TO / LD all A/C
Nighttime	**Both Terminals**	2nd runway	TO
		1st runway	LD

Table 9.2. Original runway configuration of operation of BCN's airport

As it can be seen, the main idea was to distribute the traffic in order of its originating Terminal and in a second term, the MTOW of the aircraft, so that the airport was virtually divided between *Mundo Norte* and *Mundo Sur* during the day.

Although the third runway respected La Ricarda and El Remolar marshes, unfortunately it increased considerably the environmental noise (especially in the take-off phase; in landing phase is lower mainly because it comes from the aerodynamic drag) over Gavà Mar and Castelldefels neighborhoods:

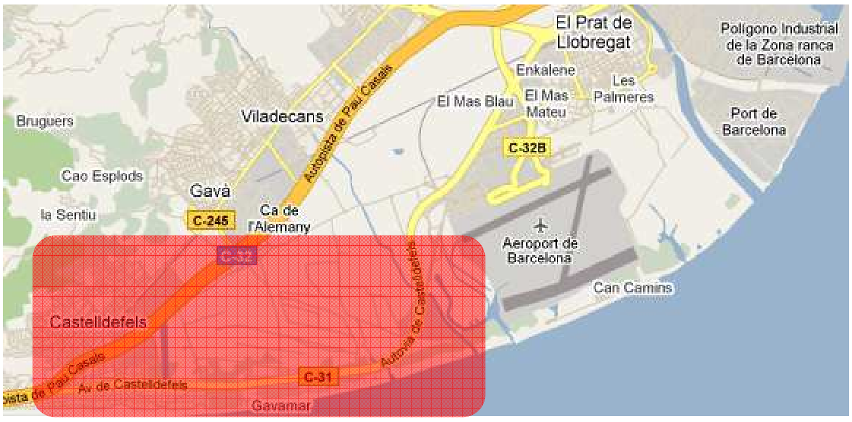


Figure 9.4. Gavà Mar and Castelldefels affected areas

As a result of this, it was decided to change the mode of operation to a segregated regime, which, depending on the direction where the wind blows, operates one way or another:

---

[28] TO = Take off

[29] LD = Landing

Current configuration			
Segregated mode			
Daytime	**East configuration**	TO	3^{rd} runway + immediate turn towards Mediterranean Sea Heading to: Polígon industrial Zona Franca
		LD	1^{st} runway Arriving from: Gavà / Castelldefels
	West configuration	TO	3^{rd} runway + immediate turn towards Mediterranean Sea Heading to: Gavà / Castelldefels
		LD	1^{st} runway Arriving from: Polígon industrial Zona Franca
Nighttime		TO	2^{nd} runway
		LD	1^{st} runway

Table 9.3. Current runway configuration of operation of BCN's airport

So, as it can be seen, takeoffs are operated through the 3^{rd} runway and immediately turning towards the sea in 2nd segment, excluding transatlantic flights which the 3^{rd} runway does not have enough length to allow their take-off; while landings are operated on the 1^{st} runway. Obviously, the default configuration is the Eastern Configuration because it is less annoying for the neighborhood of Gavà Mar. The percentage of usage is approximately 80% with respect to a 20% in Western Configuration.

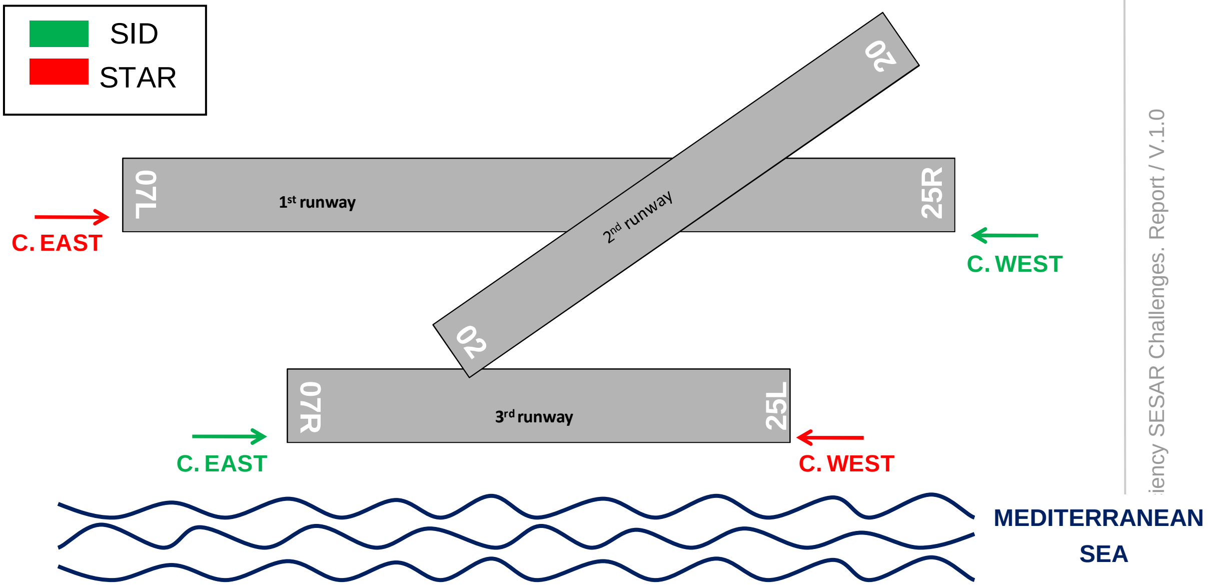


Figure 9.5. Runway operation configuration in BCN airport

So, according to all this, it will only be considered the operation of parallel runways as it is the most significant case. The runway-use configuration which best represents the use of the airport during the hour of interest is **Diagram n. 2.**

2. *Select the figure number for capacity*

DIAGRAMA DE PISTAS	DIAG. Nº	SEPARACIÓN ENTRE PISTAS EN PIES	FIGURA Nº			
			PARA CAPACIDAD		PARA DEMORA	
			VFR	IFR	VFR	IFR
S	2	700 ó más	3-4	3-44	3-72	3-91

3. *Determine the percentage of Class C and D aircraft operating on the runway component and calculate the mix index*

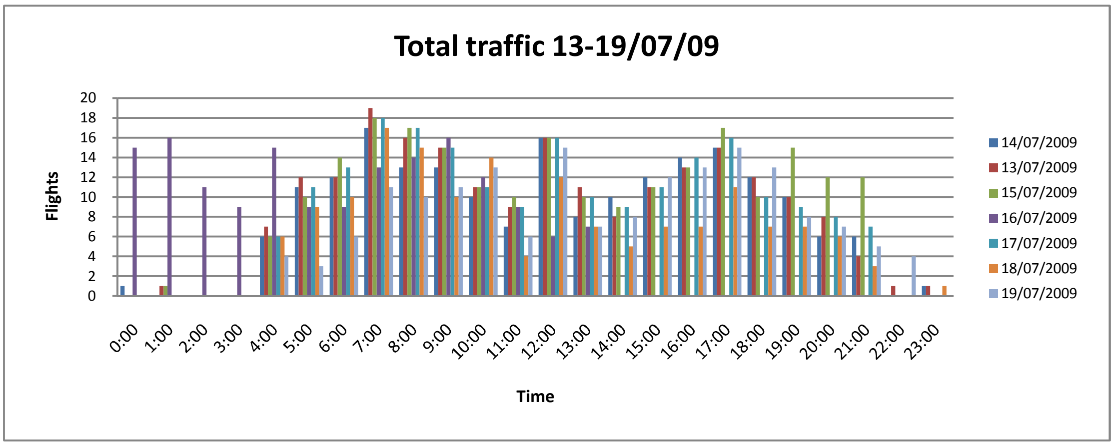
Based on *the arrivals / departures register* for the week of 13th to 19th of July 2009, specially released for ALG by the airport of Barcelona, flights are classified by different categories of aircraft (A, B, C or D according to IATA's MTOW classification (see Table 4.1 in Annexes), and the following results were obtained:

MIX INDEX		
Number of A/B aircraft	11	S
Number of C aircraft	4665	M
	55	L
Number of D aircraft	214	H
Number of N/A	2057	
Number of unknown	0	
Total aircraft	7002	
%C aircraft	95,45	
%D aircraft	4,33	
Mix index 2009	108,43	

Table 9.4. Mix index

4. *Determine percent arrivals (PA)*

First, scheduled departures are taken into account and then, for each day and hour, the departures and arrivals are added:



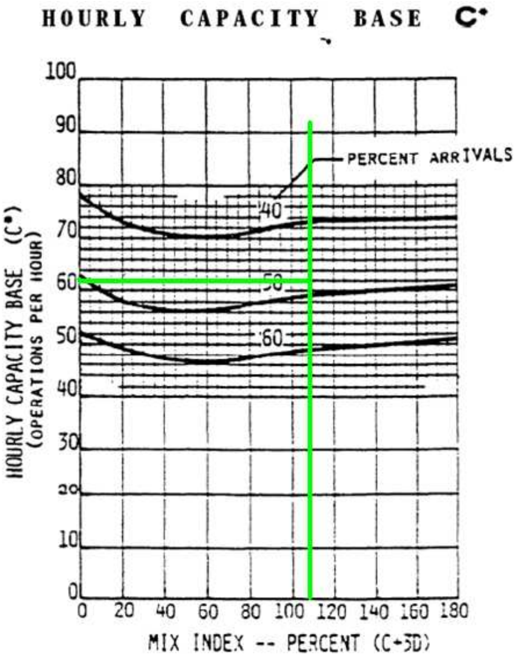
Then in each time zone PA formula is applied (considering T&G=0) and the mean value is chosen:

$$PA = \frac{A + \frac{1}{2}T\&G}{A + DA + T\&G} \cdot 100$$

MEAN %PA	46,67

Where A stands for arrivals, DA for departures and T&G for touch and go.

5. *Determine hourly capacity base from graph (C*)*



Hourly capacity base (C*)
IFR conditions
62

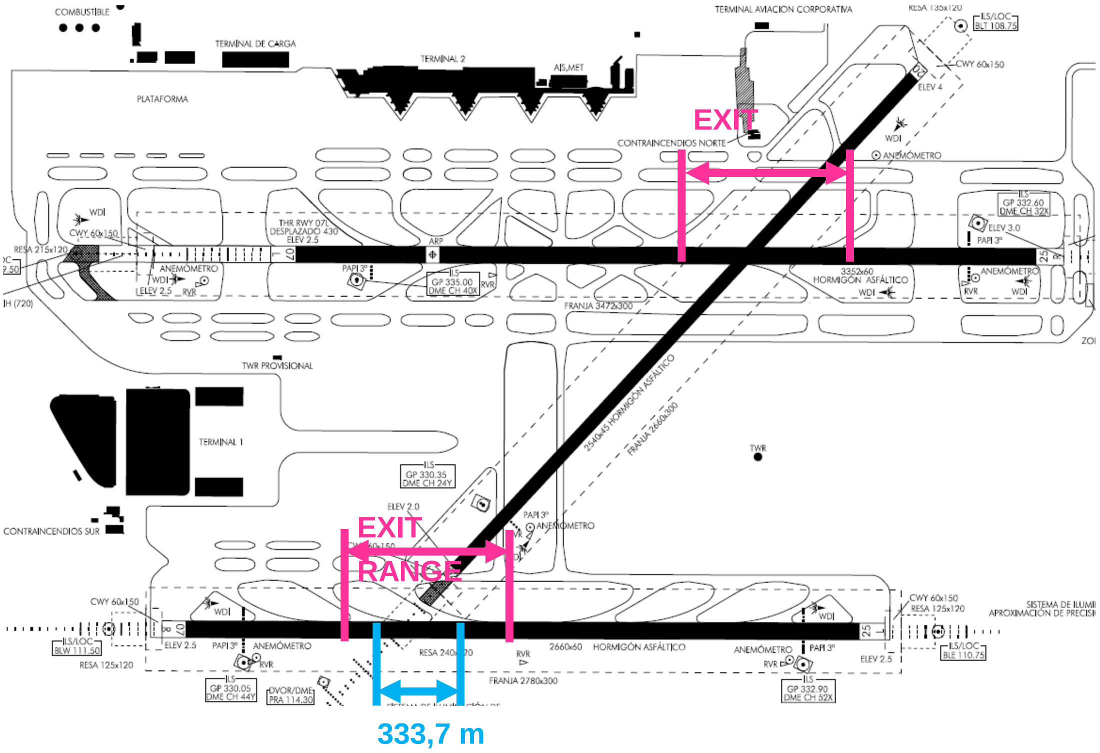
6. *Determine the touch and go factor (T)*

Touch and go factor (T)
IFR conditions
1

7. *Determine the location of exit taxiways and determine the exit factor (E)*

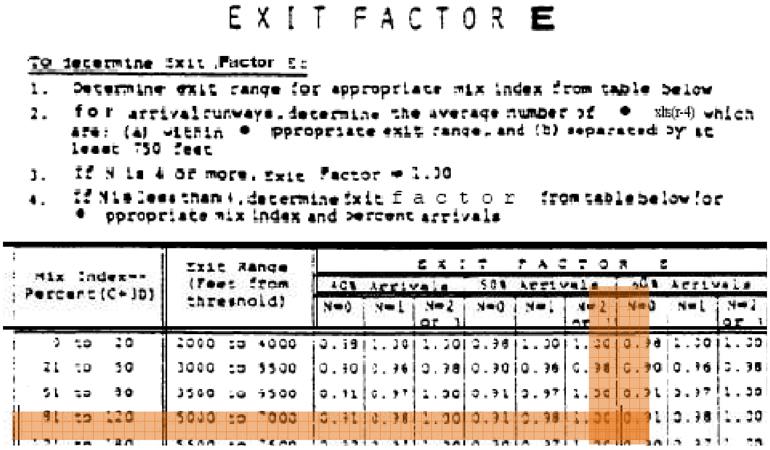
In order to find this factor, for arrival runways, the average number of exits (N) - which are (a) within appropriate exit range and (b) separated by at least 750 ft (228,6 m) - has to be determined.

To do this, refer to the aerodrome plan of BCN (downloaded from [W8]). According to the mix index, the appropriate exit range (measured from threshold) is 5000 – 7000 ft (1524 – 2133,6 m).



Note: although there are no defined procedures, nor officially published, as a consequence of having moved the threshold of runway 07L so much, the first two exits on the left are hardly ever used and then what pilots do is use the last rapid exit and eventually the end of runway 02.

N	
07L/25R	07R/25L
2	



EXIT FACTOR E

To determine Exit Factor E:

1. Determine exit range for appropriate mix index from table below
2. for arrival runways, determine the average number of exits (N) which are: (a) within appropriate exit range, and (b) separated by at least 750 feet
3. If N is 4 or more, Exit Factor = 1.00
4. If N is less than 4, determine Exit factor from table below for appropriate mix index and percent arrivals

Mix Index--Percent (C+3D)	Exit Range (Feet from threshold)	EXIT FACTOR E								
		40% Arrivals			50% Arrivals			60% Arrivals		
		N=0	N=1	N=2 or 3	N=0	N=1	N=2 or 3	N=0	N=1	N=2 or 3
0 to 20	2000 to 4000	0.79	1.00	1.00	0.98	1.00	1.00	0.98	1.00	1.00
21 to 50	3000 to 5500	0.90	0.96	0.98	0.90	0.96	0.98	0.90	0.96	0.98
51 to 80	3500 to 6500	0.91	0.97	1.00	0.91	0.97	1.00	0.91	0.97	1.00
81 to 120	5000 to 7000	0.91	0.98	1.00	0.91	0.98	1.00	0.91	0.98	1.00
121 to 180	5500 to 7500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Exit factor (E)	
IFR conditions	
07L/25R	07R/25L
1.00	

8. *Calculate the hourly capacity of the runway component with* $C = C^* \cdot T \cdot E$

Runway current capacity [ops/hour]	
IFR conditions	
07L/25R	07R/25L
62	

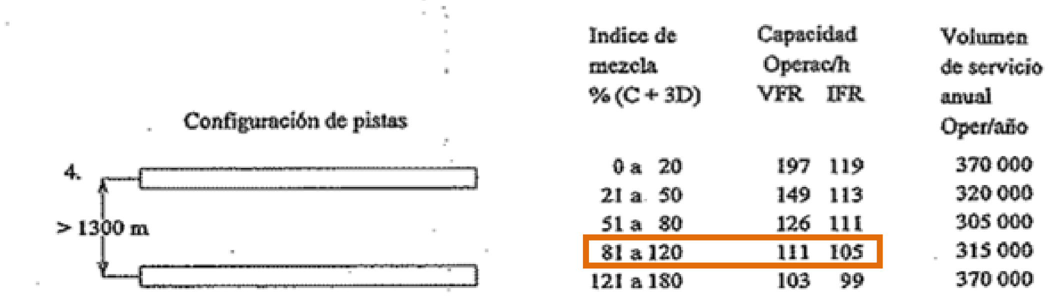
Table 9.5. Runway current capacity

9.1.2.1.2 Maximum capacity assessment

For this calculation tables in Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4 from the Annexes are used. In this method the following parameters are needed:

- Mix index (obtained in the previous section): 108,43
- Separation between runways: 1350 m

According to this, the configuration which best represents BCN airport is:



Indice de mezcla % (C + 3D)	Capacidad Operac/h VFR	IFR	Volumen de servicio anual Oper/año
0 a 20	197	119	370 000
21 a 50	149	113	320 000
51 a 80	126	111	305 000
81 a 120	111	105	315 000
121 a 180	103	99	370 000

According to FAA, the theoretical maximum capacity of BCN's airport is:

Maximum runway capacity [ops/hour]
IFR conditions
105

Table 9.6. Maximum runway capacity

It is important to remark that this value corresponds to the US operating standards. For the European case it is a bit lower (in the US, separation between aircraft in the landing sequence is shorter than in Europe, for example).

Conclusions

From the previous results it can be seen that runway 07L/25R is the most limiting one in terms of IFR conditions (and moreover, is the used one for landings in the Eastern configuration), so when it comes to runway capacity, this is the one to set its value.

It is important to make some remarks though. Let's remember the following definitions:

Operational capacity: capacity depending on current operations. According to FAA's method is:

→ Segregated mode: 62 ops/h

Declared capacity: capacity that an airport declares to be able to absorb. It is the maximum operational capacity that the airport can accept, and it is binding. It does not usually correspond to the theoretical maximum and depends on the different configurations of operation.

It is important to keep this definition in mind because declared capacity is the usual value that one can find published in articles and it is usually the value which “defines” the airport. According to AENA’s website:

→ Declared capacity of BCN airport: 90 op/h [AENA]

From AENA: “*En cuanto a las operaciones de vuelo (aterrizajes + despegues), si en 2003 la capacidad era de 52 ops/hora, desde el 28 de septiembre de 2004, con la puesta en servicio de la 3ª pista, la capacidad ha ido aumentando hasta las 64 ops/hora*[30]*, e irá aumentando gradualmente según las necesidades hasta poder alcanzar las 90 ops/hora*.”

Maximum capacity: capacity during maximum efficiency of operation conditions. It is a theoretical maximum which depends on runway infrastructure.

→ Maximum capacity of BCN airport: 105 ops/h

So, it is important to remark that this 62 ops/h is the capacity due to the current traffic, but that this value will increment over the next years because of the increasing traffic demand forecasted.

9.1.2.2 Taxiway capacity

Not assessed. There is no problem of congestion and capacity limitation of the taxiway component because the crossed runway (which is the one which might introduce problems) is only used at night, and in that slot the number of flights is so small that there is no possibility that taxiway capacity turns to be affected.

9.1.2.3 Gate capacity

---

[30] This difference between our result (62 ops/h) and 64 ops/h it is because we analyzed only one week (but contemplating the effect of T1) and AENA uses the data over one year (probably 2008)

9.1.2.3.1 Gate groups distribution

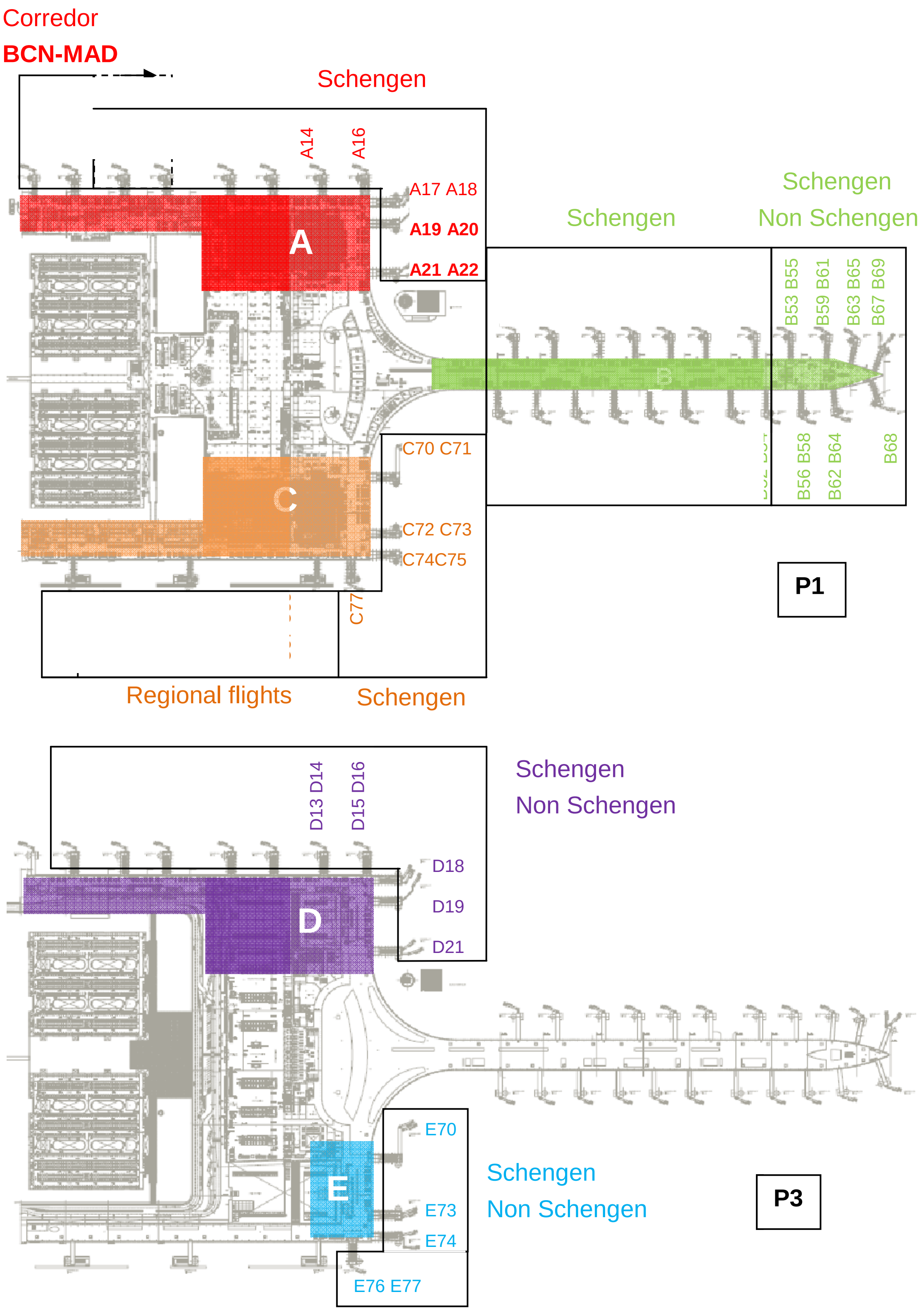


Figure 9.6. Barcelona T1 gate groups

Note: this configuration corresponds to a “standard” configuration, but it is flexible to be changed (except for Non Schengen gates)

9.1.2.3.2 Boarding bridges, contact and remote positions

Each boarding bridge usually contains one finger + one remote position. The configuration of the boarding bridges allows simultaneous UE boardings + Non UE deboardings. Thick metallic nets separate international arrivals from Schengen departures.

In transversal dike there are boarding bridge modules with 2 fingers, and always 2 UE gates + 1 Non UE gate are served (see Figure 9.11).

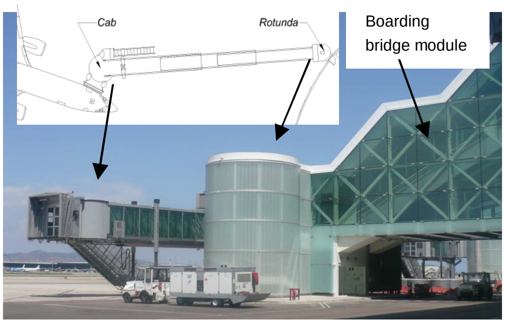


Figure 9.7. Boarding bridge parts

Figure 9.8. A380 feeding

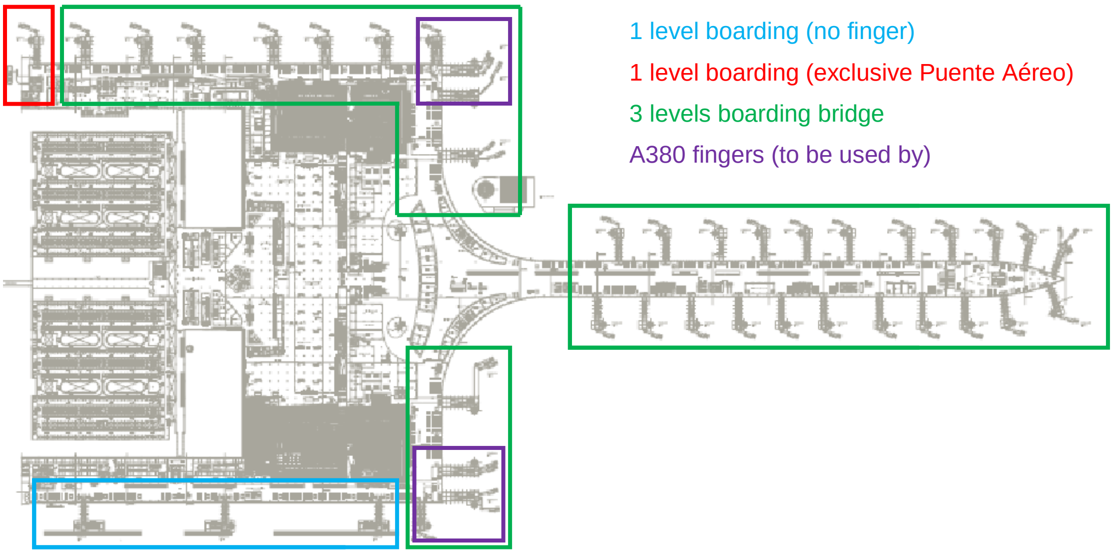


Figure 9.9. Barcelona T1 contact positions

A, B Aircraft Types	1 contact position without finger
C Aircraft Type	1 contact position is able to feed 2 C type aircrafts at the same time (1 per finger)
E Aircraft Type	1 contact position fed by 2 fingers
A380	3 contact positions fed by 3 fingers

Table 9.7. Contact position feeding per aircraft type

When boarding in C module or in D module is not the same path. In Figure 9.10 and Figure 9.11 a simple scheme is given.

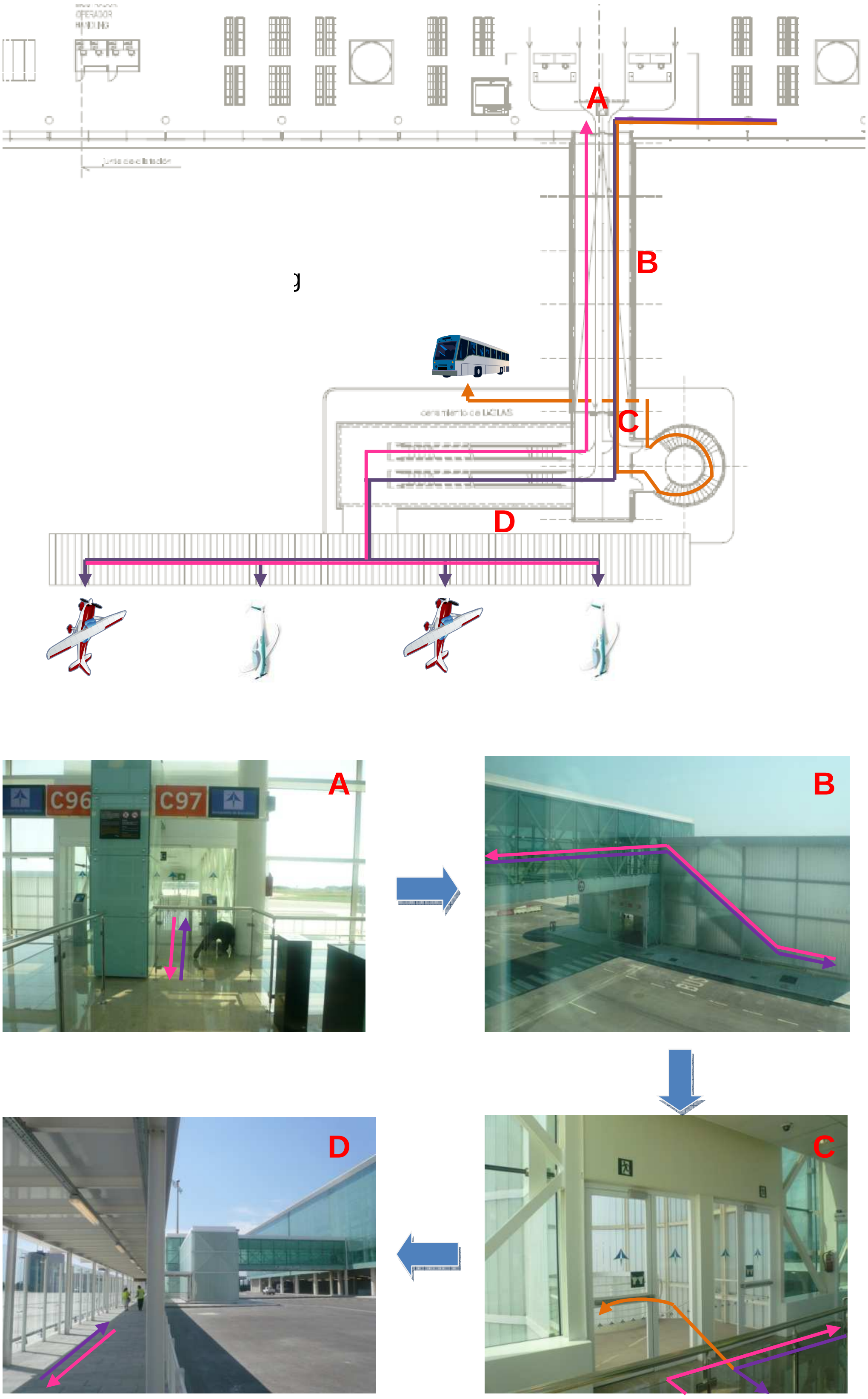


Figure 9.10. 1 level boarding process path (simultaneous board/deboard)

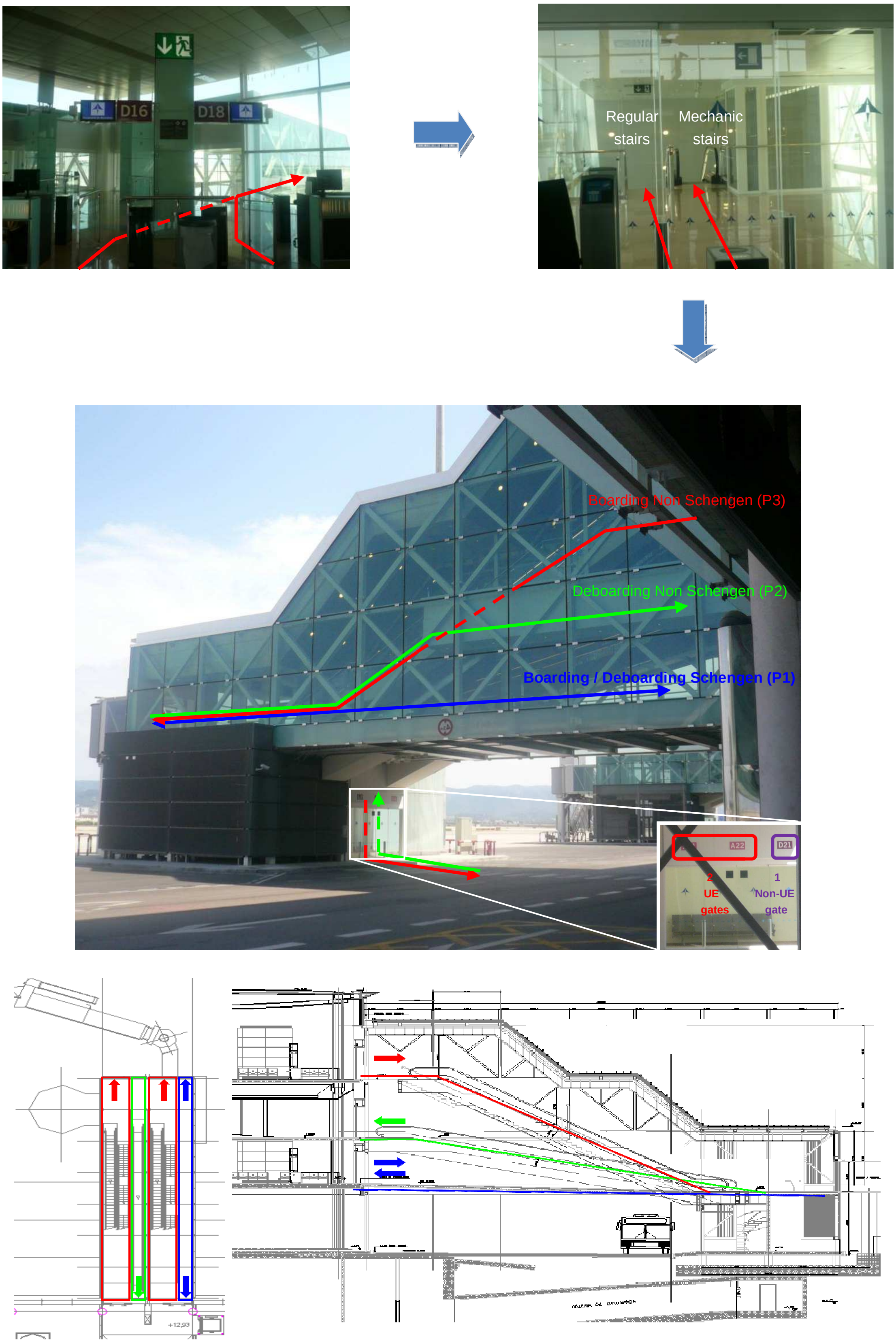


Figure 9.11. 3 levels boarding process path

9.1.2.3.3 Capacity assessment

Following the methodology described in Annex 4.5.1, the capacity of the gate is calculated.

1. *Determine the number of gate groups and the number of gates in each gate group*

T1 terminal of BCN's airport is divided into **5 gate groups,** named as A, B, C, D, E.

Number of gates per gate group				
A	**B**	**C**	**D**	**E**
16	43	19	16	5

2. *Determine the gate mix*

To calculate the gate mix, the number of narrow-body (NB) aircraft that operates in each of the gate groups is counted. To this purpose, it has been listed, from an entire list of aircraft types, whether they fit within NB or wide-body (WB) categories in terms of carried number of passengers:

Wide body	200-600 pax
Narrow body	< 200 pax
Regional	<100 pax

Finally, the total number of aircraft operating in each gate group is counted and gate mix index is calculated:

GATE MIX					
Gate group	A	B	C	D	E
Number of NB	48	354	140	20	9
Total A/C in gate	48	356	141	34	9
Gate mix	100,0%	99,4%	100,0%	58,8%	100,0%

Table 9.8. Gate mix

3. *Determine the percentage of gates in each gate group that can accommodate wide-bodied aircraft*

In T1 plans it is indicated, for each stand, the maximum size of aircraft that can accommodate, and in turn are classified by type of gate, depending on the type of gateway:

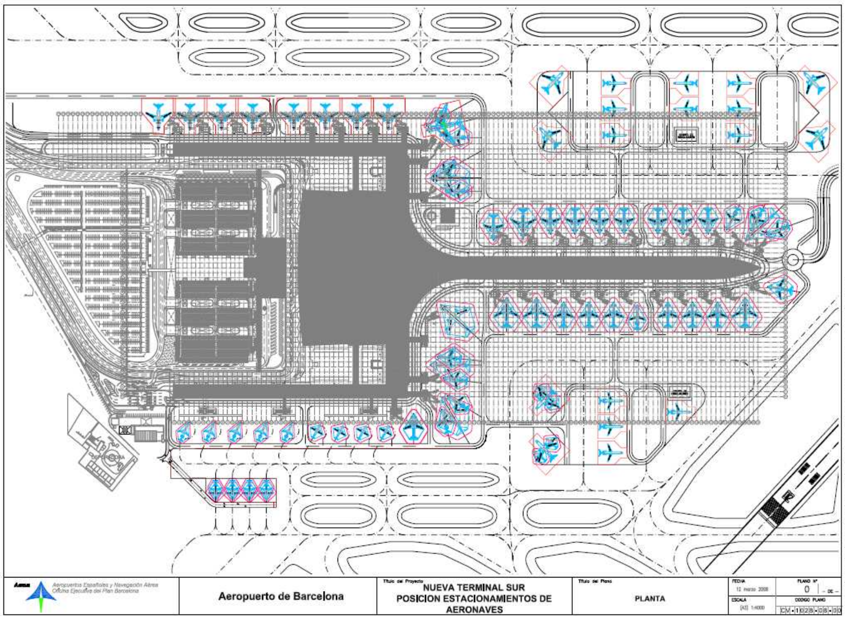


Figure 9.12. AENA's parking positions plan

Number of gates per gate type		
Gate type	**Number**	**Aircraft**
1	2	B767
5	21	B767, B757
5C	3	B767
6	18	MD88, A340, A380
7	9	MD88, A340
2	40	B757, B767, MD88
2B	1	B757
3	2	MD88, A340
4	8	ATR72
4B	4	< ATR72

Wide body	Narrow body
B767-200	B757-200
A380	MD88
A340-600	ATR74

So then, taking into consideration the previous and counting how many gates per gate group can accommodate WB, the following results are obtained:

% of gates in each gate group that can accommodate WB		
Gate	**Number gates that can accommodate WB**	**Percentage**
A	16	100%
B	39	90,7%
C	7	36,84%
D	16	100%
E	5	100%

4. *Determine for each gate group the average gate occupancy time for wide-bodied and non wide-bodied aircraft*

For this calculation the following values of IATA (in minutes) are taken as reference:

Aircraft type	Pax load	Loading pax	Unloading pax	Aircraft Servicing	Through Flight	Turnaround Flight
B	40	10	5	10	0	25
C	130	20	10	15	25	45
D	250	30	15	30	45	75
E						
1 DOOR	350	40	25	45	45	110
2 DOORS	350	25	15	45	45	85
F						
1 DOOR	470	55	30	80	60	165
2 DOORS	470	30	20	80	60	130

Table 9.9. IATA's aircraft gate occupancy times

Through flight: single flight from origin to destination with one or more intermediate stops

Turnaround flight: terminal flight

Then, for each gate group the number of flights in turnaround and through flight is accounted for each aircraft type and then the average occupation time is assessed, taking into account the times of the previous Table 9.9:

AVERAGE GATE OCCUPANCY TIME [in minutes]											
Gate group		A		B		C		D		E	
Type aircraft		NB	WB	NB	WB	NB	WB	NB	WB	NB	WB
# Turnaround	B	9	0	28	0	0	0	0	0	0	0
	C	39	0	326	0	140	0	19	0	9	0
	D	0	0	0	2	0	0	0	7	0	0
	E	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0
# Through	B	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	1	0	0	0
	D	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	7	0	0
	F	0	0	0	0	0	0	0	0	0	0
SUM		48	0	354	2	140	0	20	14	9	0
SUM gate		48		356		140		34		9	
Avg occupancy time [min]		41,3	0	43,4	75	45	0	44	60	45	0

Table 9.10. Average gate occupancy times

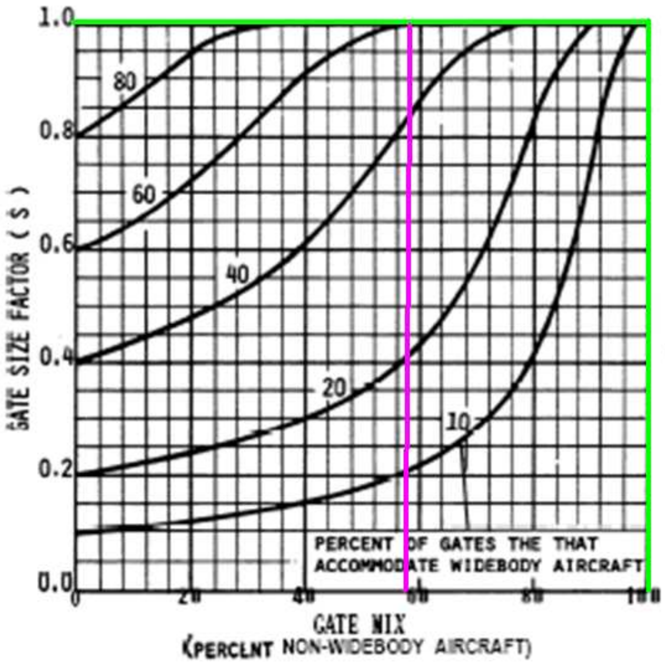
5. *Calculate the gate occupancy ratio (R)*

$$R = \frac{\text{Average gate occupancy time for widebody aircraft}}{\text{Average gate occupancy time for non – widebody aircraft}}$$

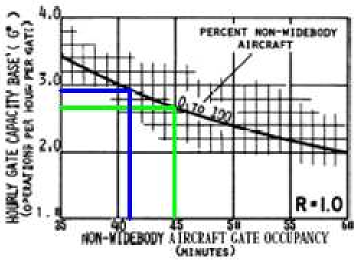
* If operations do not include wide body aircraft → R = 1.0

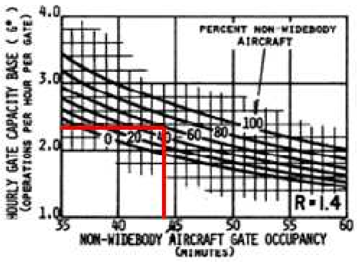
R				
A	**B**	**C**	**D**	**E**
1	1.7	1	1.4	1

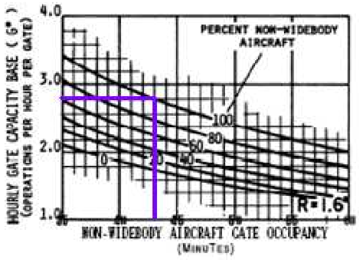
6. *Calculate the hourly capacity of each gate group by using the formula above*



S					
	A	**B**	**C**	**D**	**E**
Gate mix	100,0%	99,4%	100,0%	58,8%	100,0%
% gates accommodate WB	100,0%	90,7%	36,84%	100,0%	100,0%
S	1	1	1	1	1







G*					
	A	**B**	**C**	**D**	**E**
R	1	1,7	1	1,4	1
NB gate occupancy	41.3	43.4	45	44	45
% NB	100%	99%	100%	59%	100%
G*	2,95	2,8	2,6	2,4	2,6

Gate capacity					
	A	**B**	**C**	**D**	**E**
[ops*/hour]	**47**	**120**	**49**	**38**	**13**
# aircraft /hour	24	60	25	19	7
Total aircraft	134				

Table 9.11. Gate current capacity

*Notes: By operations should be understood turnaround process for arrival + departure.

Conclusions

From the previous results it can be seen that group of gates B is the one which allows more simultaneous operations, whereas group E is the lowest, and so, it is the most limiting gate group in terms of gate capacity. Regarding the number of operations, it can be seen that in Barcelona's T1 terminal it is possible to operate up to 267 ops/h, which means to serve up to 134 aircraft at the same time.

9.1.2.4 Terminal airspace capacity

Not assessed. It is not possible to execute a simple assessment for terminal airspace capacity; simulations using specific programs are required. And, as said already before, this is not the main purpose of this document. Moreover, although terminal airspace is physically within the airport, it is more an en-route and ATC issue than airport.

9.1.3 Landside capacity assessment

9.1.3.1 Ground access capacity

Not assessed. It is not possible to execute a simple assessment for ground access capacity; simulations using specific programs are required. And, as said already before, this is not the main purpose of this document. Moreover, although terminal airspace is physically within the airport, it is more a road network issue than airport.

9.1.3.2 Terminal building capacity

9.1.3.2.1 Check-in capacity

9.1.3.2.1.1 Check-in counters distribution

Main level

On the main level there are 6 rows of check-in counters, numbered as it follows:

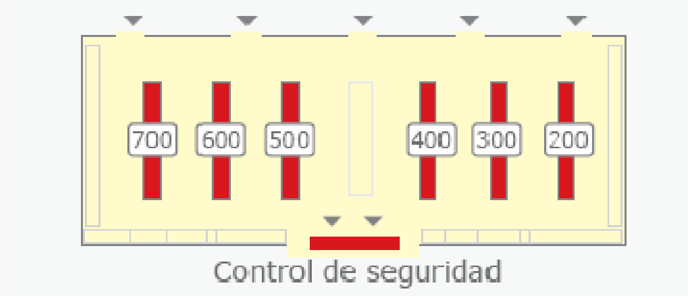
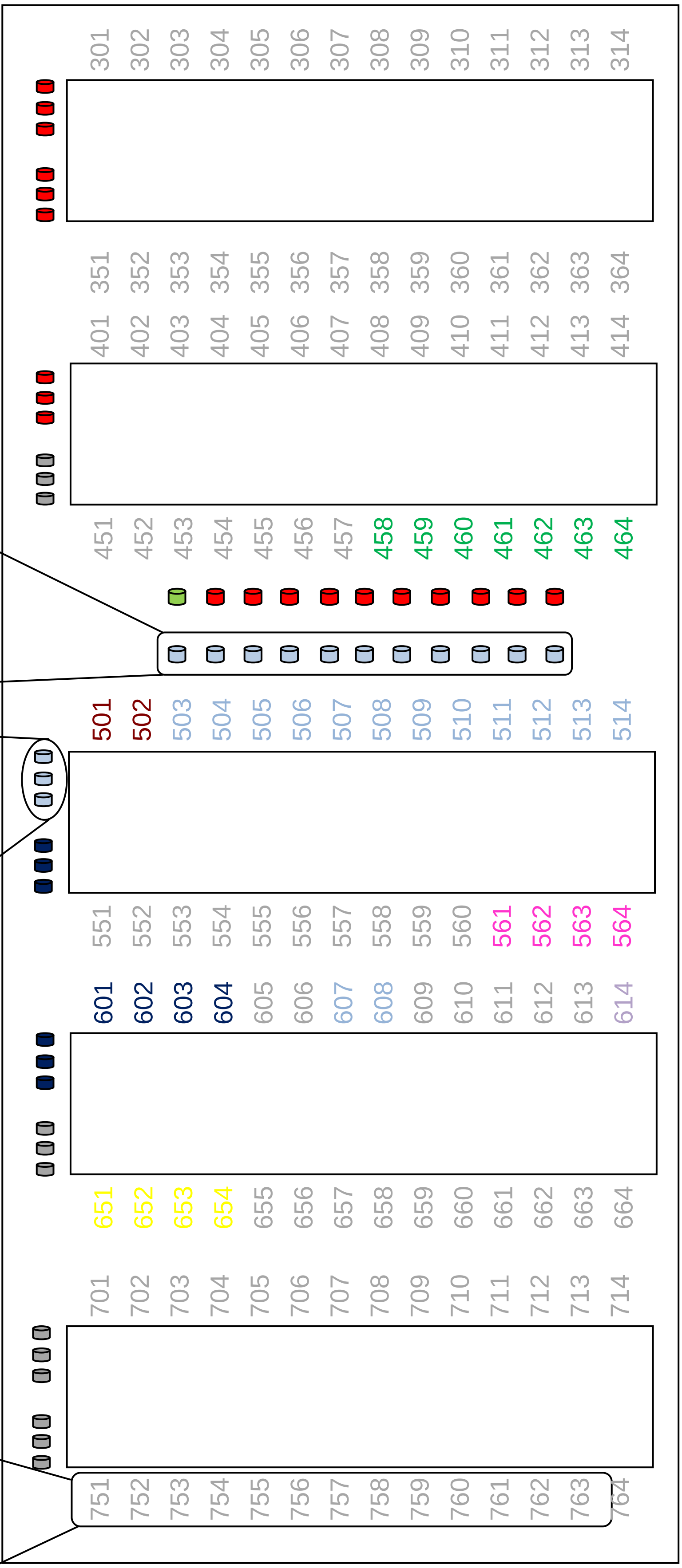


Figure 9.13. Check-in counters numbering [W8]

NOTES:

- 200's row is currently under construction (26/08/09).
- In principle, there are universal counters everywhere, but there are some which are already assigned though (26/08/09).
- It is not possible to check-in in Module C as it is not connected to the SATE network (it is compulsory to check-in through the main level and then walk all the way to C gates).

- ⛁ Auto check-in servers
- 🟥 Iberia
- ⬜ Universal
- 🟨 Brussels Airlines
- 🟪 Swiss Airlines
- 🟩 British Airways
- 🟦 Lufthansa
- 🟦 Spanair
- 🟩 Turkish Airlines
- 🟪 TAP
- 🟫 Austrian Airlines
- 🟧 Special luggage



Airline	ECO	BUS
Iberia		
Brussels Airlines	4	-
Swiss Airlines		
British Airways		
Lufthansa	3	1
Turkish Airlines	6	1
Spanair	13	1
TAP	3	1
Austrian Airlines	2	-

Picture taken on the: 26th August 2009 16:30h

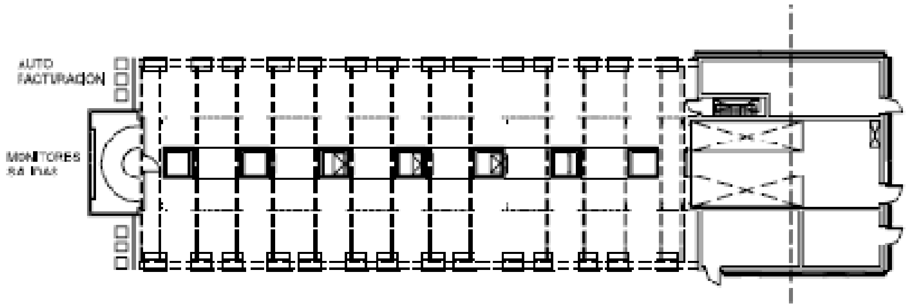


Figure 9.14. 200’s and 700’s check-in counters (P30 level)

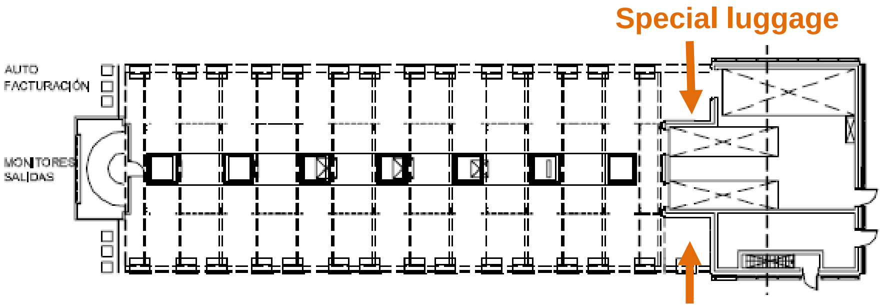


Figure 9.15. 300’s, 400’s, 500’s, 600’s check-in counters (P30 level)

Module A

In module A there are 8 check-in counters + 8 auto check-in Iberia counters. The 9th of September 2009 Module A enters into operation.

Figure 9.16. Module A regular and auto check-in counters (P10 level)

<u>Intermodal exchanger</u>

There are 14 check-in counters, currently out of order as the train still does not arrive to the airport (currently under construction 26/08/09)

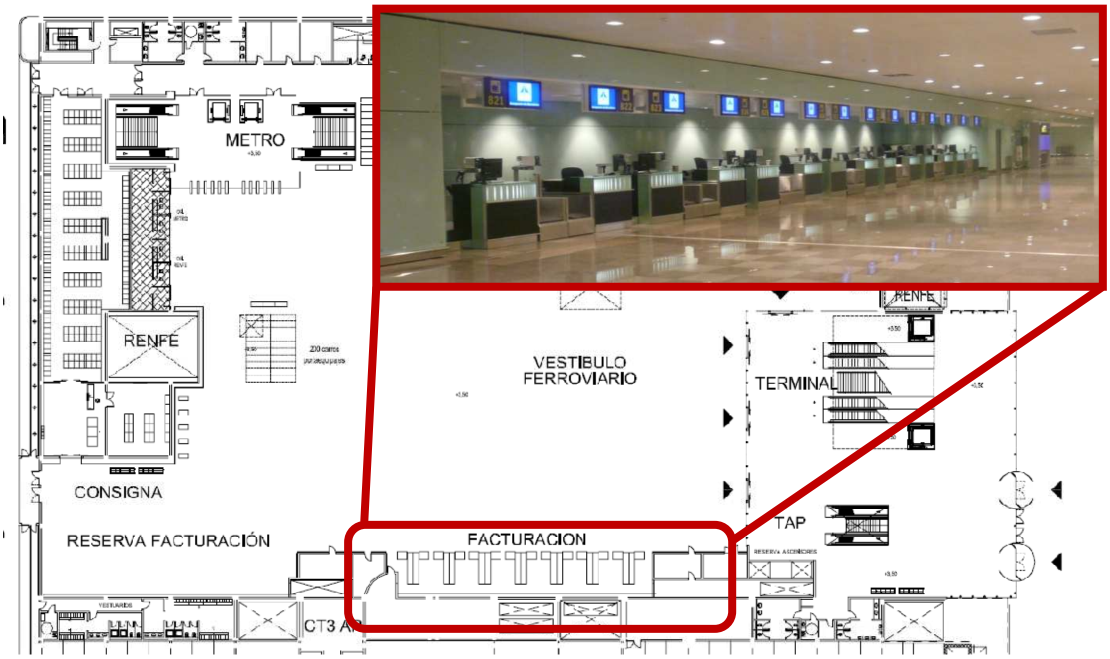


Figure 9.17. Intermodal hall check-in counters (P00 level)

Check-in counters	
P30 level	140[31] + 52 auto check-in
A module	8 + 8 auto check-in Iberia
Intermodal hall (P10 level)	14

Table 9.12. Check-in counters distribution

9.1.3.2.1.2 Capacity assessment

As there is no direct calculation for check-in capacity found in the bibliography, what is going to be done is to calculate how many counters would be needed given the existing ones and see if there is capacity problem or not. Following the methodology described in Annex 5.2.4.2, the capacity of check-in is calculated.

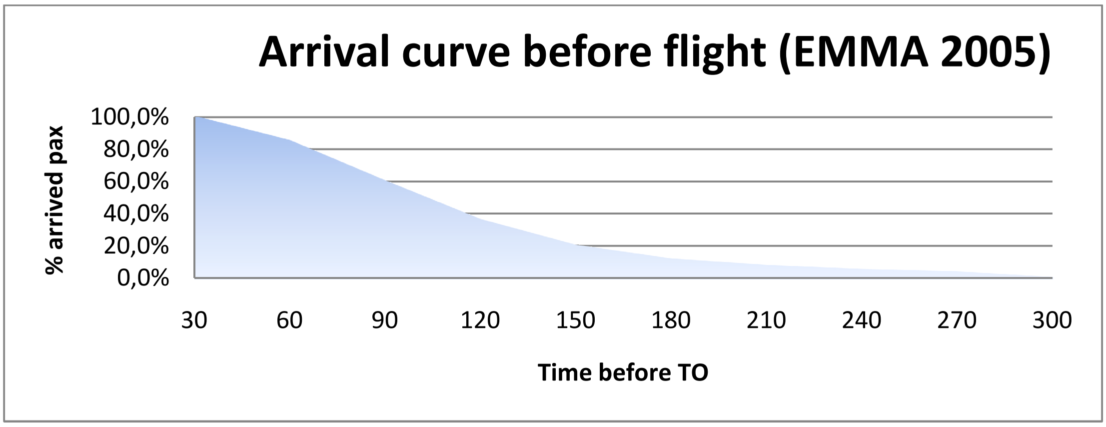
A. Calculate the peak 30 minute demand at check-in

Given that passengers, when they arrive at the airport, the first subsystem they find is check-in, this value can be directly obtained from the departures profile in the operations register:

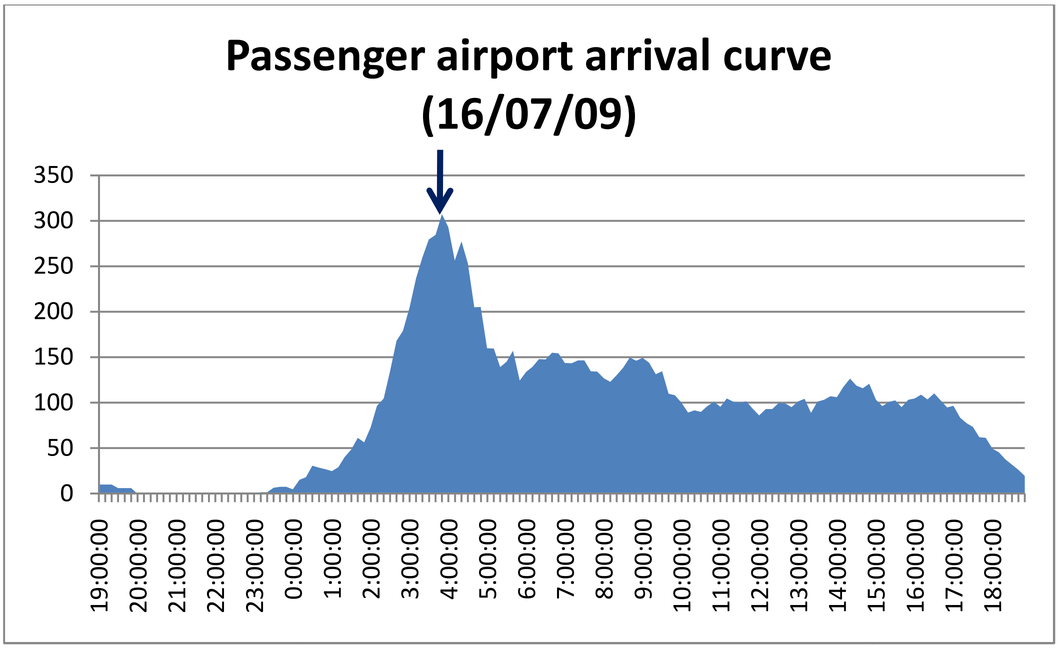
---

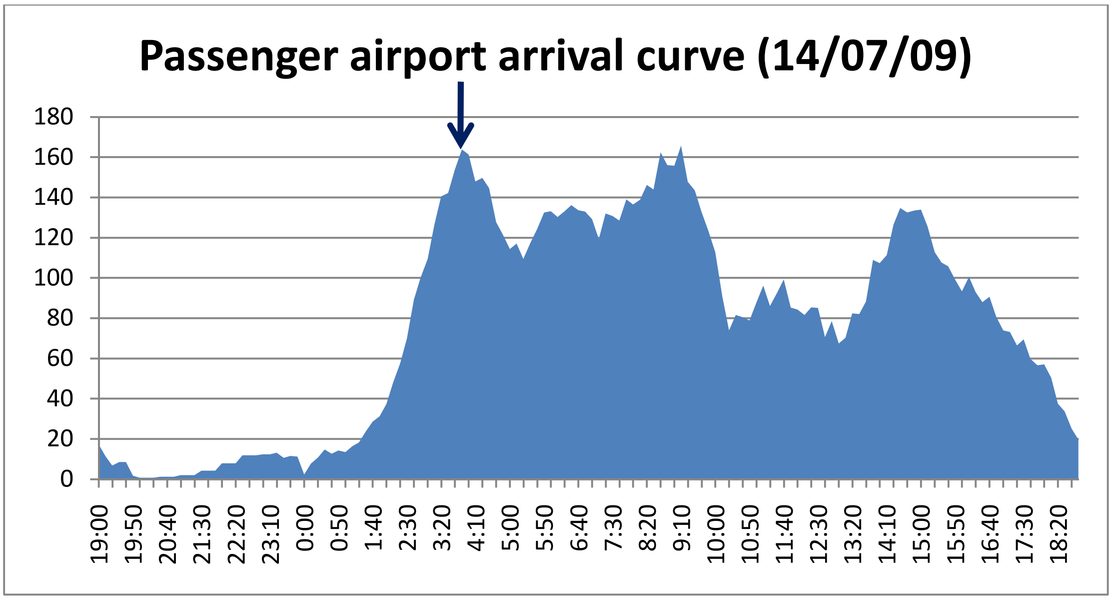
[31] Without taking into account the 200's row (currently out of order)

1. First, separate by 10 minutes the real flights in departure of each day of the week
2. Then, for each flight check which aircraft operated it and check the total number of passengers it can hold and consider a factor of occupation of 0.8
3. Then, from EMMA statistics of 2005 it is known the curve of passengers for BCN airport; apply it on each flight:



4. From each time slot of 10 minutes, search for the maximum. In this case it corresponds to the 16/07/09 at 3:50 am with 307 passengers. In this case it is an isolated peak, so the representative value for the assessments is going to be the second peak day which is the 14/07/09 with **163 passengers**.





5. As information is given every 10 minutes, add the passengers from the previous and next time slots as well. The result is:

Isolated peak day	885 pax in the peak-30 min hour
2nd peak day	479 pax in the peak-30 min hour

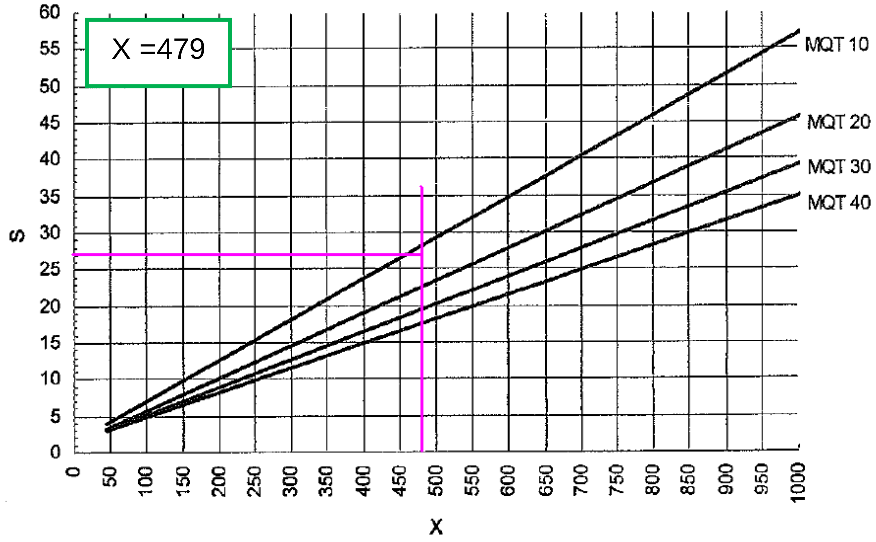
B. Determine the intermediate result S, which takes into account the MQT using the following charts

X is the peak-30 minute at check-in

MQT is the maximum queuing time

On the 26/08/09 measurements and time sampling where taken in situ at the airport, and it was determined that

MQT economic	12 minutes
MQT business	3 minutes



S	
Peak day	50
2nd day	27

C. Calculate the number of economy class (CIY) check-in counters

$$\#CIY = S \times \left(\frac{PTci}{120} \right)$$

The average processing time at check in T1 is PTci =192 sec.

	Samples	Mean
2 pax, 2 bags	3,15 min	3,2 min
2 pax, 1 bag	2,05 min	
2 pax, 2 bags	1,30 min	
4 pax, 0 bags	1,30 min	
2 pax, 3 bags	2,58 min	
3 pax, 1 bag	8 min	
2 pax, 4 bags	4 min	

Table 9.13. Time sampling at Spanair's economic check-in counters

#CIY	
Peak day	80 counters
2nd day	43 counters

D. Calculate the total number of check-in counters CI (including business class counters CIJ)

$$\#CIJ = \#CIY \times 20\% \qquad \#CI = \#CIY + \#CIJ$$

#CIJ	
Peak day	16 counters
2nd day	9 counters

Check-in capacity	
CI (theor) peak day	96
CI (theor) 2nd peak day	52
CI (real)	140

Table 9.14. Check-in current capacity

Conclusions

As can be seen, for the typical case of demand 52 check-in counters would be required, and nowadays 140 are available, so there is more than enough capacity to cope with the demand. Even considering the isolated peak day there are still enough counters. Therefore, there is no capacity problem in terms of check-in subsystem.

The demand that could be absorbed given the actual configuration is:

Demand to be absorbed with current configuration		
PTsc	192	seconds
SC	140	check-in counters
Peak-10 min demand	437	pax/10 min

It is possible to process up to 437 passengers every 10 minutes at check-in (and nowadays the usual peak is about 163 passengers and the experienced isolated peak on 16/07/09 was about 307 passengers, meaning that there is no capacity problem at present).

9.1.3.2.2 Security check capacity

9.1.3.2.2.1 Security check counters distribution

<u>A Module</u>

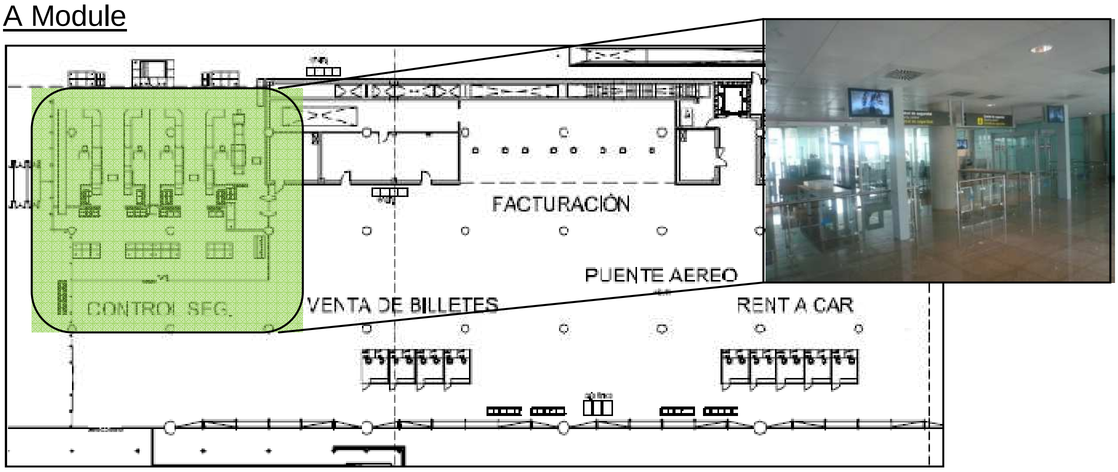


Figure 9.18. Security check counters, P10 level on north dike

There are a total of 4 security checks in the A module.

<u>C Module</u>

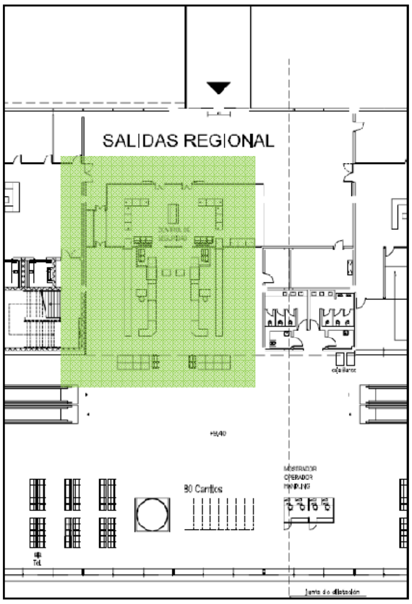


Figure 9.19. Security check counters, P10 level on south dike

There are a total of 2 security checks in the C module.

Transversal dike

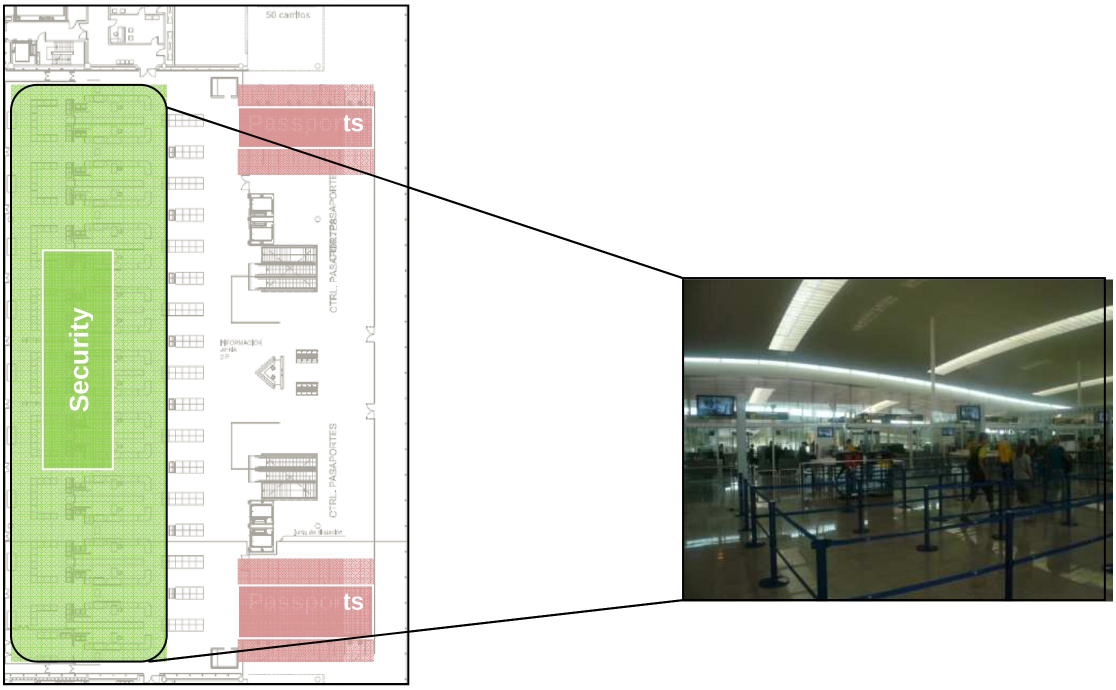


Figure 9.20. Security check counters, P30 level on transversal dike

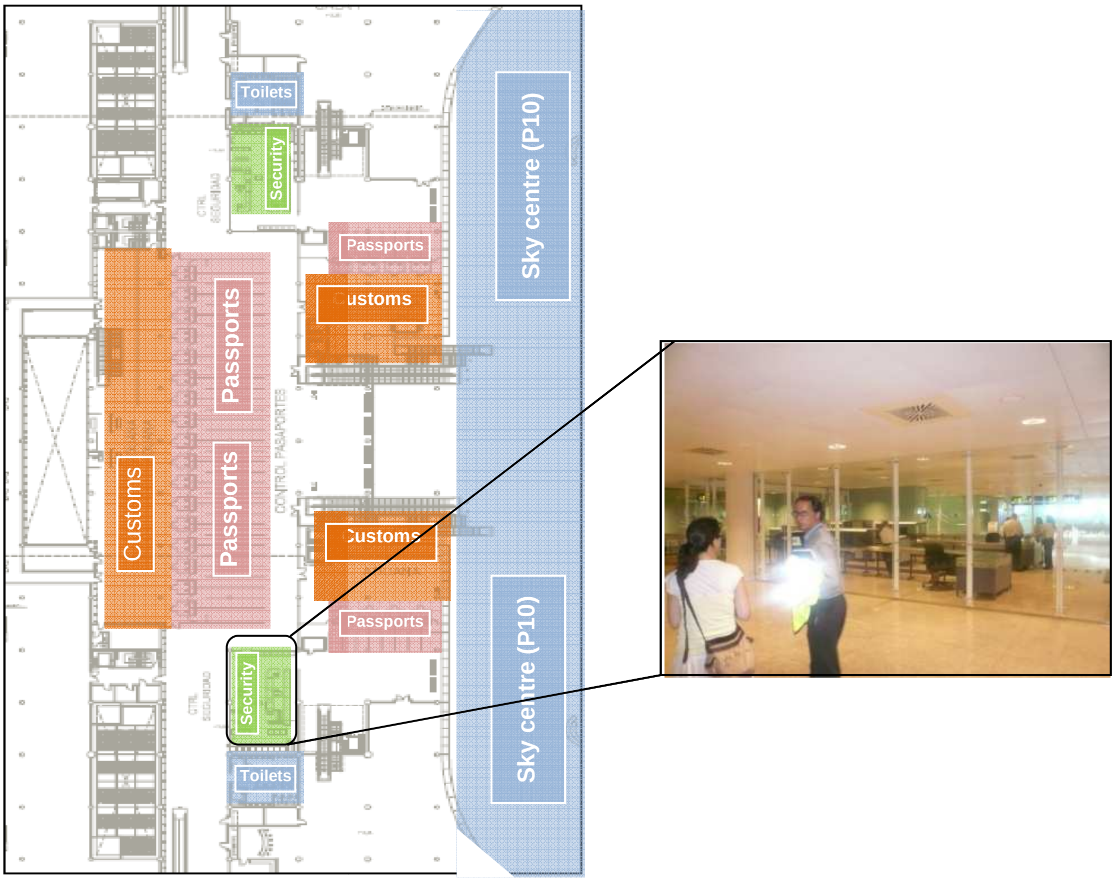


Figure 9.21. Security check counters in P20 level, transversal dike

There are a total of 17 security checks on the 3rd floor (18 on the plan though; one is still to be built) + 4 on the 2nd floor.

Security check counters	
Transversal dike	21 counters
A module	4 counters
C module	2 counters

Table 9.15. Check-in counters distribution

9.1.3.2.2.2 Capacity assessment

As there is no direct capacity calculation for security check found in the bibliography, what is going to be done is a similar process like for baggage claim and check-in subsystems: it will be calculated how many security desks would be needed given the current demand and it will be discussed whether there is capacity problem or not.

Following the methodology described in Annex 5.2.3 the capacity of security check is calculated.

A. Calculate the peak 10-minute check-in counters throughput

This value can be obtained directly from the operations register, the same way as it was explained for check-in. The **peak 10-minute demand is 163 passengers.**

B. Calculate the number of security check servers

$$\#SC = Peak\ 10\text{-}\mathrm{minute}\ demand\ from\ A \times \left(\frac{PTsc}{600}\right) \quad (10.1)$$

PTSC is the time spent at security check and on 26/08/09 it was measured that:

Samples	Mean
2,5 min	2,2 min
1,15 min	
2,20 min	
2,15 min	
4,48 min	
2 min	
3,30 min	

Table 9.16. Time sampling at security check

After these samples were taken, we realized that the measurements were made wrong, because IATA's suggested value is PTsc = 12 seconds, meaning that what it should had been considered is only the time when the passenger is under the arch and, in case of alarm, the time taken by the guard to manually check the passenger. When the measurements were done, it was considered also the time spent by the passenger to leave his vest, belt, hand bag ect. in the trays. Because of this, **12 seconds** will also be considered.

Security check capacity	
SC (theor)	4
SC (real)[32]	17

Table 9.17. Security check current capacity

Conclusions

Again, in security check there is no capacity problem either because in order to cope with the current demand only 4 counters would be required, and since there are 17 available (only taking into account those immediately after check-in), there is no bottleneck in this subsystem. The demand that could be absorbed considering the current configuration is:

Demand to be absorbed with current configuration		
PTsc	12	seconds
SC	17	security check servers
Peak-10 min demand	850	pax/10 min

It is possible to process up to 850 passengers every 10 minutes at security check (and nowadays the usual peak is about 163 passengers and the experienced isolated peak on 16/07/09 was about 307 passengers, meaning that there is no capacity problem at present).

9.1.3.2.3 Passport control capacity

9.1.3.2.3.1 Passport control desks distribution

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[32] Considering only those at P30 floor

Longitudinal dike

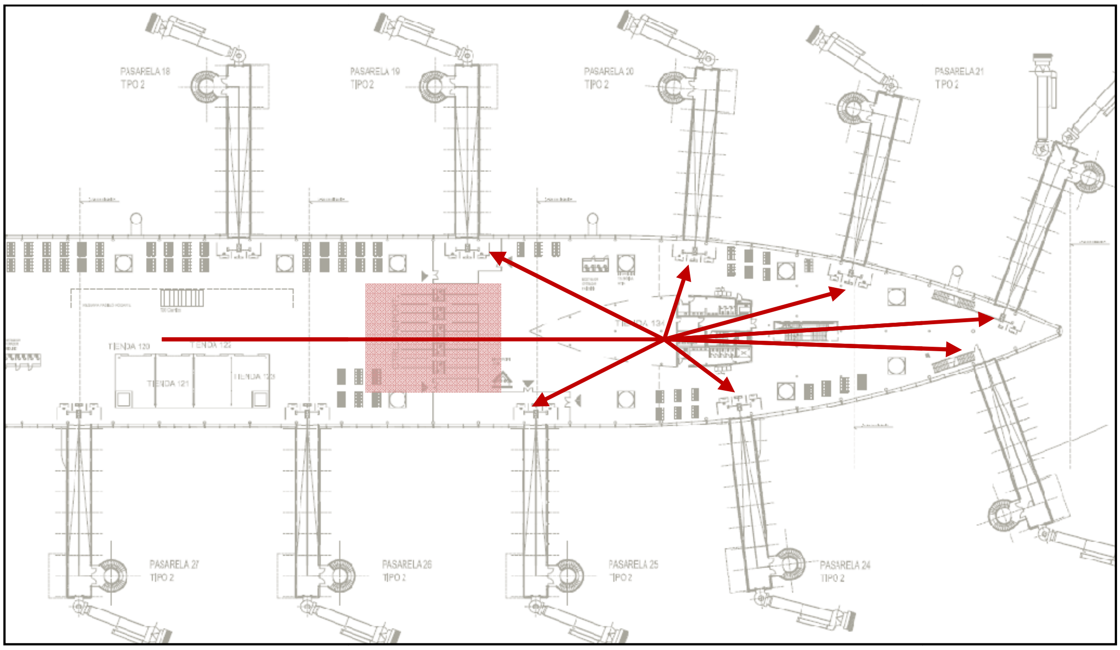


Figure 9.22. Passport control in P10 level, longitudinal dike (B module)

Passenger flows are depicted with arrows: 5 passport counter lines are devoted to international departures and 5 more are dedicated to international landings. There are 10 counters in total in P10 level.

Transversal dike

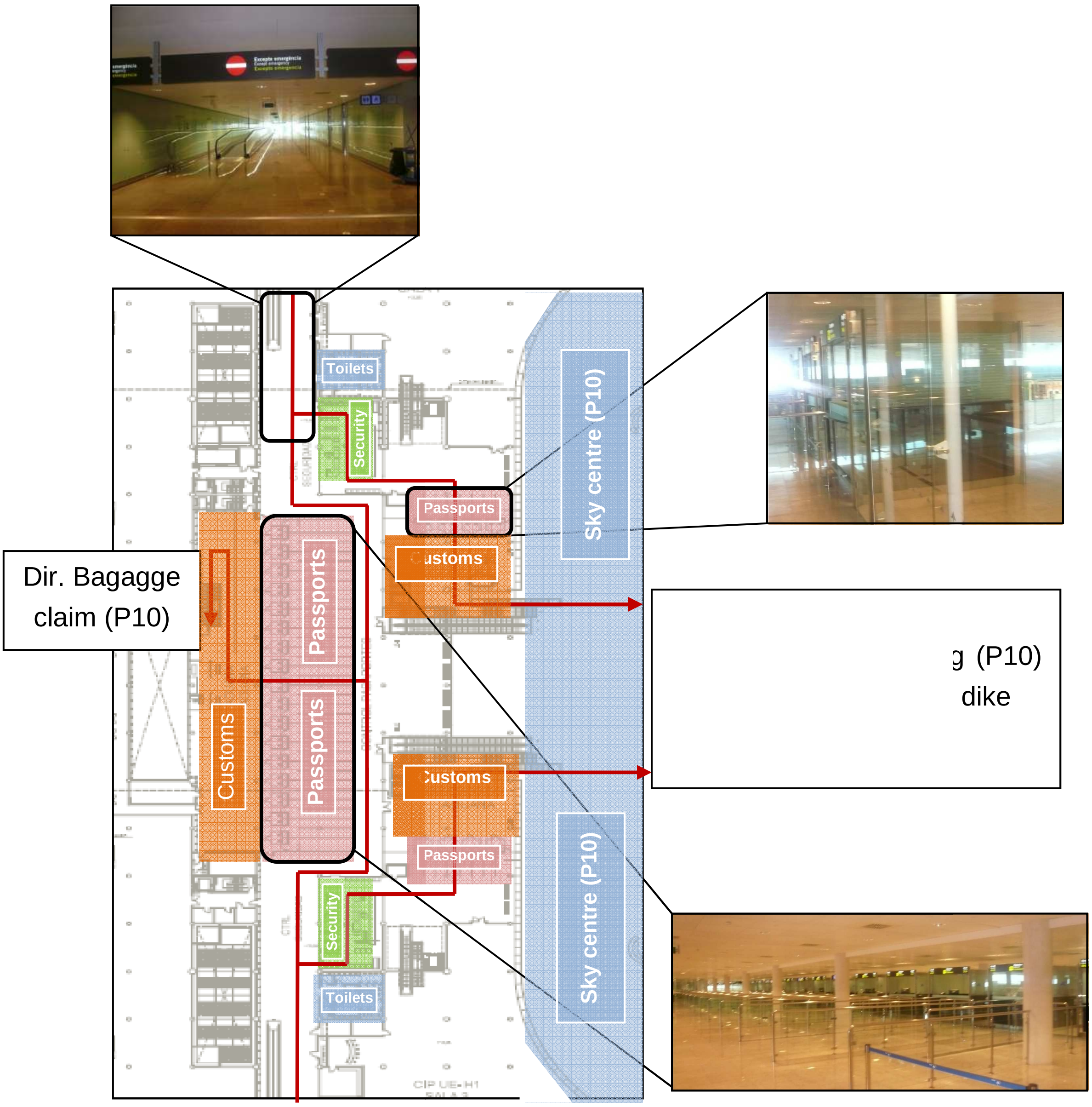


Figure 9.23. Passport control in P20 level, transversal dike

Passenger flows are depicted with arrows:

- Lateral passport counters are for those passengers in transfer (non UE – Schengen). There is a total of 16 counters (8 counters per side)
- Long queue of counters work for arrivals. There are a total of 34 counters.

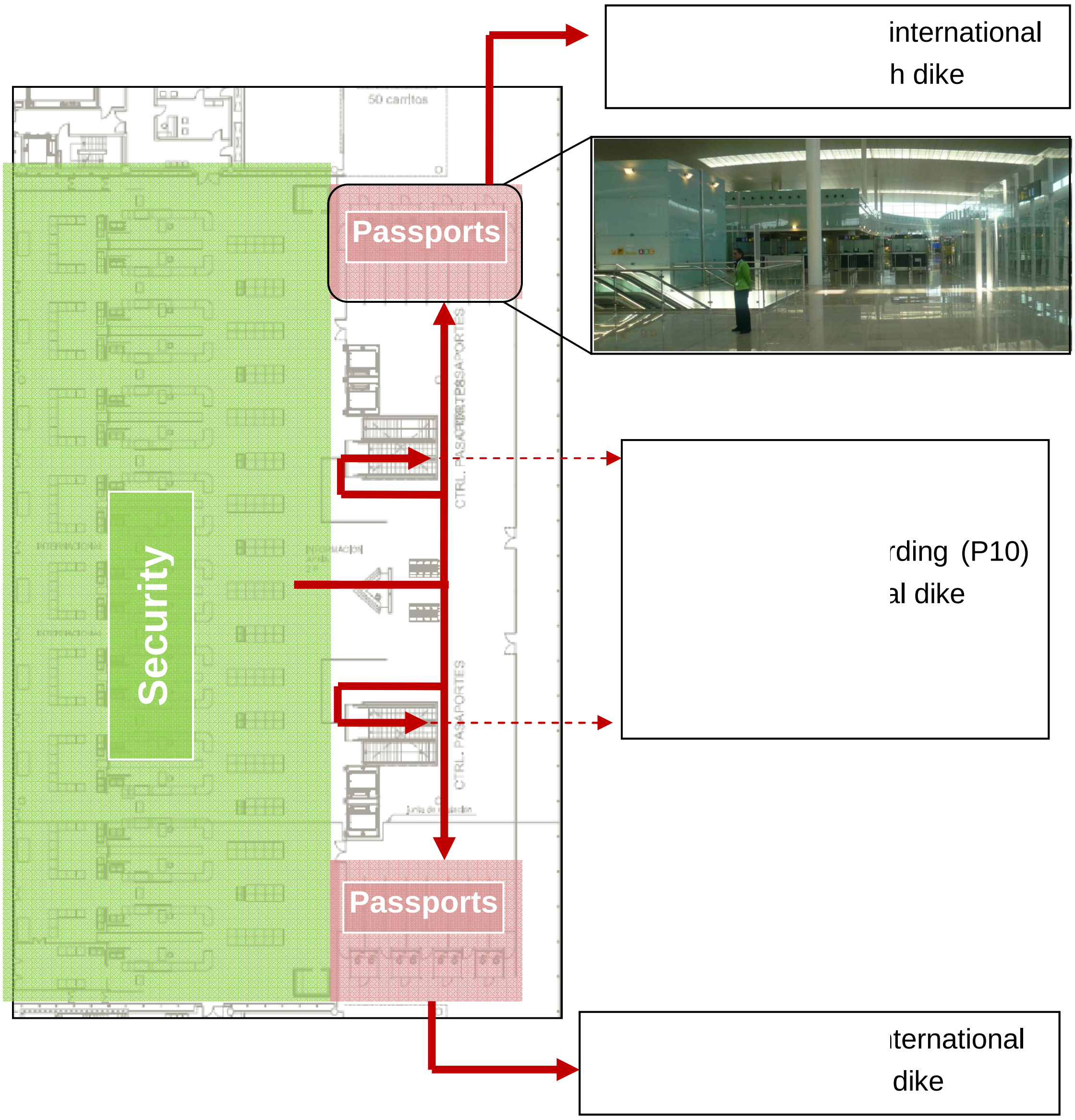


Figure 9.24. Passport controls in P30 level, transversal dike

Passenger flows are depicted with arrows: Both passport counter lines are devoted to international departures. There are 8 counters per side (a total of 16 counters in P30 level).

9.1.3.2.3.2 Capacity assessment

As there is no direct capacity calculation neither for passport control found in the bibliography, what is going to be done is a similar process like for check-in and security check subsystems: it is going to be calculated how many passport control desks would be needed given the current demand and figure out if there is capacity problem or not.

9.1.3.2.3.2.1 Arrivals

Following the methodology described in Annex 5.2.8.2 the capacity of passport controls in arrivals is calculated.

A. Determine the intermediate result S, using the following charts

$$X = \frac{(PHP \times \#\ doors\ used\ to\ exit\ the\ aircrafts)}{100}$$

1. To calculate the passengers at peak time (PHP) search in the operations register the number of scheduled flights that arrive every ten minutes

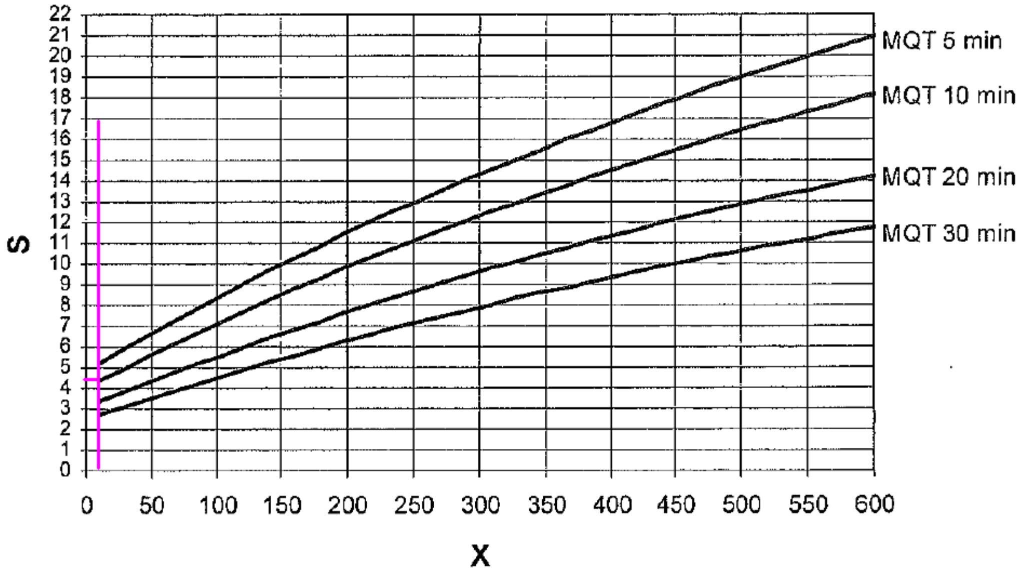
2. For each flight, as it is known the type of aircraft that operated it, find the number of passengers it can hold and consider a load factor of 0.8

3. Count the number of passengers per hour (here the passengers curve cannot be applied because passengers on arrival flights arrive all at once)

4. Find the peak hour. In this case corresponds to the 16/07/09 at 9:00 am with 1448 passengers

5. When it comes to the number of doors used to exit the plane, since boarding bridges are used, the usual number of gates is 1 (for A380 would be at least 2, but currently no A380 has operated in Barcelona's airport)

PHP	1448 pax
Doors	1 door
X	14,48



In this case consider a MQT of 10 minutes → S=4,5

B. Calculate the number of passport control desks required

$$\#PCD = S \times \left(\frac{PTpca}{20} \right)$$

PTpca is the average processing time at passport control arrival in seconds. Unfortunately, on the 26/08/09 (when measurements were taken) no passengers at passport control desks were found, and so, for the assessment IATA'S suggested value of PTpca = 30 seconds will be considered.

Passport control in arrivals capacity	
PCD (theor)	7
PCD (real)[33]	34

Table 9.18. Passport control current capacity (in arrivals)

9.1.3.2.3.2.2 Departures

Following the methodology described in Annex 5.2.8.3 the capacity of passport controls in departures is calculated.

A. Calculate the peak 10-minute check-in throughput

This value can be obtained directly from the operations register, the same way as it was explained for check-in. The **peak 10-minute demand is 163 passengers.**

---

[33] Considering only those in P30 level since they are dedicated to departures

B. Calculate the number of passport control desks

$$\#PCD = Peak\ 10\text{-minute}\ demand\ from\ A \times \left(\frac{PTpcd}{600}\right)$$

PTpcd is the average processing time at passport control in seconds. Like before, IATA's suggested value will be considered, which in this case is PTpcd = 15 seconds.

Passport control in departures capacity	
PCD (theor)	5
PCD (real)[34]	32

Table 9.19. Passport control current capacity (in departures)

Conclusions

Again, it can be observed that neither in arrivals nor departures there is a capacity problem. The demand that could be absorbed considering the current configuration is:

Demand to be absorbed with current configuration		
PTca	30	seconds
PCD arrivals	34	Passport counters
Peak-10 min demand	680	pax/10 min
PTpcd	15	seconds
PCD departures	32	Passport counters
Peak-10 min demand	1280	pax/10 min

Up to 680 passengers every 10 minutes on arrivals and 1280 passengers on departures could be processed.

---

[34] Considering only those in P20 level since they are dedicated to connections and those on P30 that after check-in

9.1.3.2.4 Gate hold room capacity

9.1.3.2.4.1 Seats

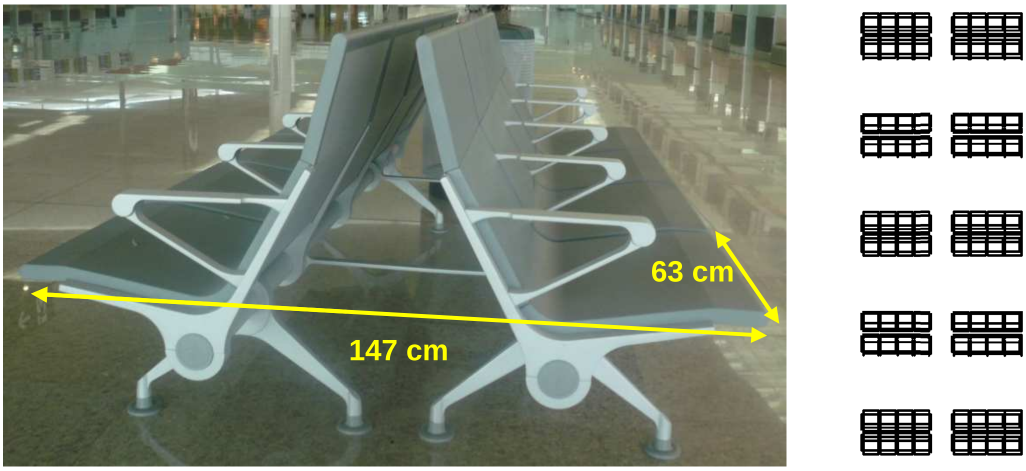


Figure 9.25. Group of seats distribution and size

$$S_{seat} = \frac{1,47}{2} \cdot 0,63 = 0,463m^2$$

GATE GROUP	A	B	C	D	E
Group of seats[35]	194	232	176	152	48
Number of seats	776	928	704	608	192

Table 9.20. Seating distribution in T1

9.1.3.2.4.2 Hold room surfaces

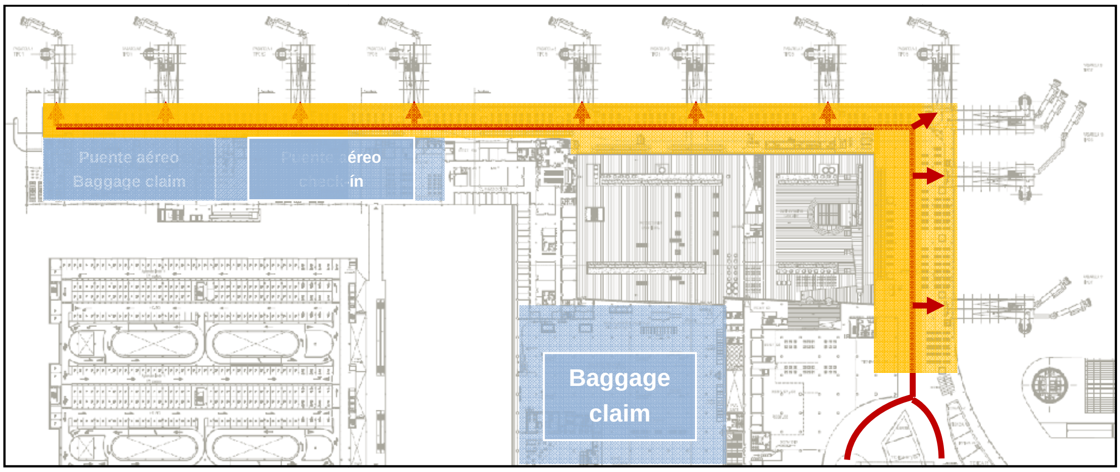


Figure 9.26. A group of gates

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[35] There are 4 seats per block/group of seats

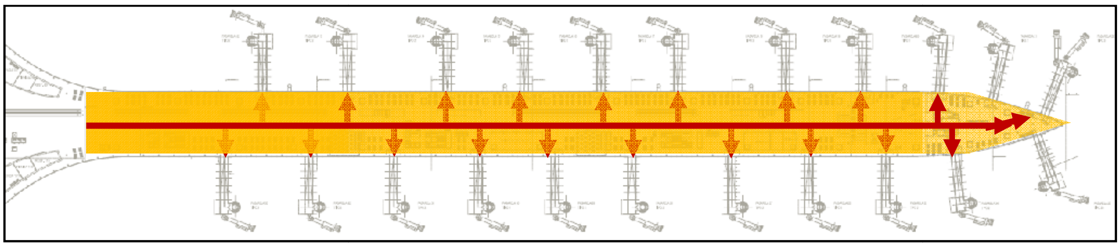

Figure 9.27. B group of gates

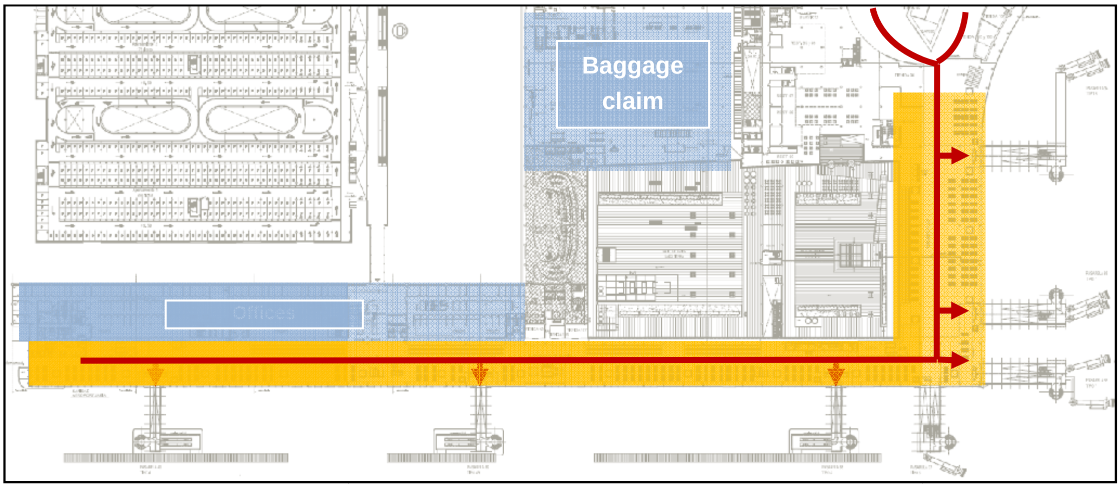

Figure 9.28. C group of gates

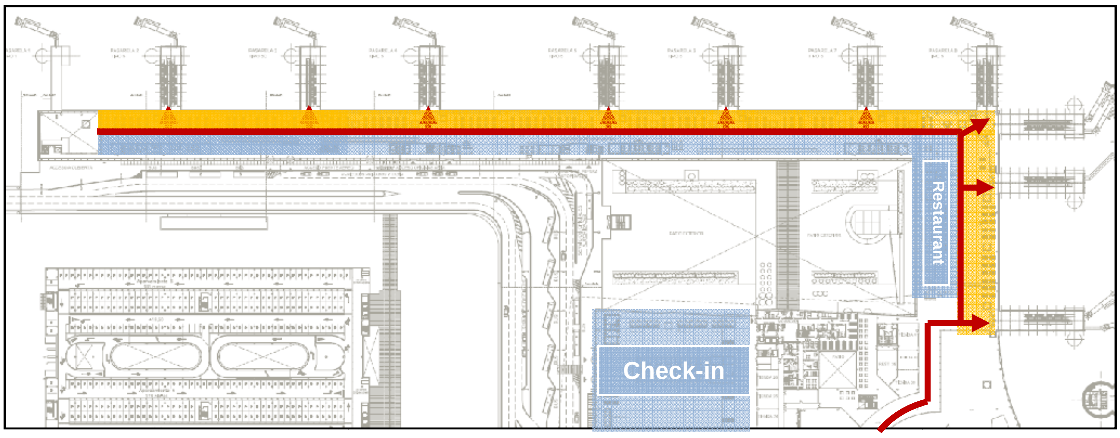

Figure 9.29. D group of gates

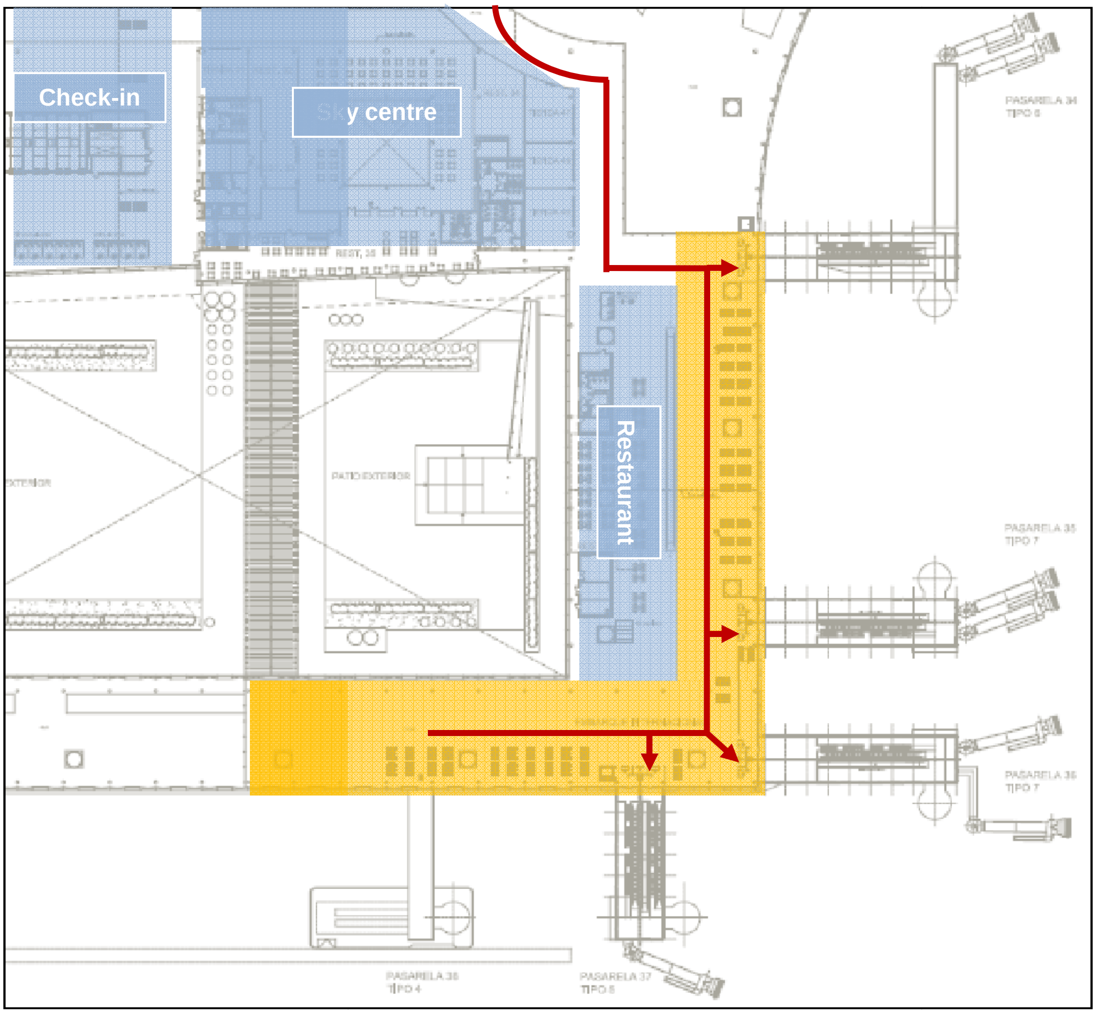

Figure 9.30. E group of gates

GATE GROUP	A	B	C	D	E
Number of seats	776	928	704	608	192
Hold room area (Total) [m^2]	10570,5	14013	13203	5265	3564
Hold room area (Seated) [m^2]	359,32	429,71	325,98	281,53	88,90
Hold room area (Standing) [m^2]	10212	13584	12878	4984	3476

9.1.3.2.4.3 Capacity assessment

Not assessed. Methodology found is not applicable to the BCN case (it does not provide useful information to work with) and, moreover, no data is available for the study.

The only capacity assessment which is possible to do is how many static occupants could be fitted in the hold rooms at the same time, but this is not a significant value since the representative parameter is the *dynamic* capacity (pax/hour for example):

Space per seated pax	1,7 m^2/pax
Space per standing pax	1,2 m^2/pax
Total hold room area (Seated)	1486 m^2
Total Hold room area (Standing)	45134 m^2

$$Capacity_{Hold\ Room} = \frac{1486m^2}{1,7\,m^2/pax} + \frac{45134m^2}{1,2\,m^2/pax} = 38485\,occupants$$

9.1.3.2.5 Waiting area capacity

Not assessed. Methodology found is not applicable to the BCN case (it does not provide useful information to work with) and, moreover, no data is available for the study.

9.1.3.2.6 Connecting passenger transfer capacity

Not assessed. Methodology found is not applicable to the BCN case (it does not provide useful information to work with) and, moreover, no data is available for the study.

9.1.3.2.7 Baggage unit capacity

For baggage claim no method that allows to directly deducting the subsystem capacity from the existing number of carousels has been found. Instead, it will be found out if, given the current conditions, there is any capacity problem in this subsystem. To do this it will be calculated, for arrivals case, how many carousels would be required according to IATA and see if the system is critical or not; for departures, given the number of piers in the terminal, it will be checked if demand schedule can be met or not.

9.1.3.2.7.1 Arrivals

Baggage claim room of T1 is located on P10 floor or main level, and there is a little one in A module dedicated to Puente Aéreo luggage.

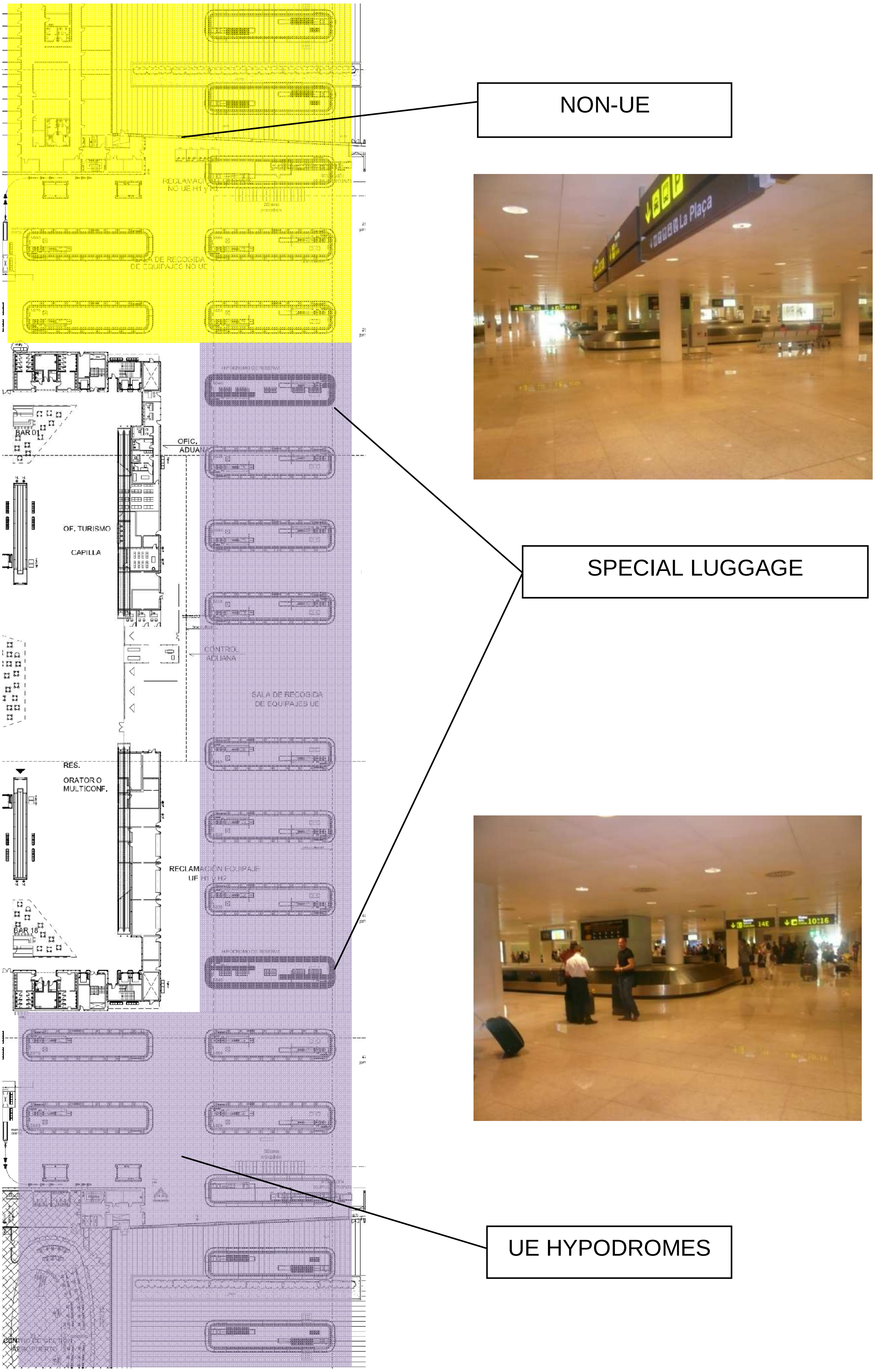

Figure 9.31. Baggage claim carousels B,C,D,E modules flights (P10 level) Luggage is managed by SATE

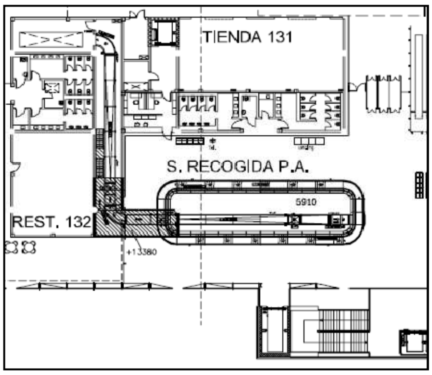

Figure 9.32. Baggage claim carousel of A module for Puente Aéreo flights. (P10 level) Luggage is managed by hand

In total, there are **22** carousels plus the little one in module A. The analysis will not take into account this last small one.

9.1.3.2.7.1.1 Capacity assessment

Following the methodology described in Annex 5.2.2.2, the capacity of the baggage unit is calculated.

For wide body aircraft:

$$BC = \frac{(PHP \times PWB \times CDW)}{60 \times NWB}$$

For narrow body aircraft:

$$BC = \frac{(PHP \times PNB \times CDN)}{60 \times NNB}$$

Where:

CDW	Claim Device occupancy time per wide-body aircraft
CDN	Claim Device occupancy time per narrow-body aircraft
NWB	Number of passengers per wide-body aircraft
NNB	Number of passengers per narrow-body aircraft

<u>Peak Hour Passengers number (PHP)</u>

To find the value of this parameter the following is done:

1. In the operations register, account for every hour of every day of the week the number of arrivals
2. For each flight, determine which aircraft operated it. From this, count the number of passengers it can hold and consider an occupation factor of 0.8
3. Find the hour with highest number of passengers

With this procedure it is determined that the demand peak day is 16/07/09 at 9am, with **1448** pax.

<u>Proportion of passengers arriving by wide and narrow body aircraft (PWB / PNB)</u>

From above it is known which aircraft operated the flights during the peak hour, and from this point on it is easy to know the proportion of narrow to wide bodies. In this case, out of 9 arriving flights, they are all narrow-body. The rest of parameters in the formula are:

Baggage claim capacity		
PHP	1448	pax
PNB	100%	
PWB	0%	
CDW[36]*	45	minutes
CDN*	20	minutes
NWB*	320	pax
NNB*	100	pax
BC wide body	0	units
BC narrow body	4,827	units

Table 9.21. Baggage claim current capacity

9.1.3.2.7.2 Departures

9.1.3.2.7.2.1 Capacity assessment

In departures SATE is the system that manages luggage and there is no possibility to make any quantification assessment regarding its capacity without performing any simulation.

However, it is possible to calculate the maximum number of simultaneous departing flights that the system can serve. Of course, the maximum number of simultaneous flights must be equal to the number of piers. What is going to be done is to check how many flights during the peak hour there are and compare it to the number of piers. Formation piers are located on P00 floor at platform level, and they account a total of **22 piers**:

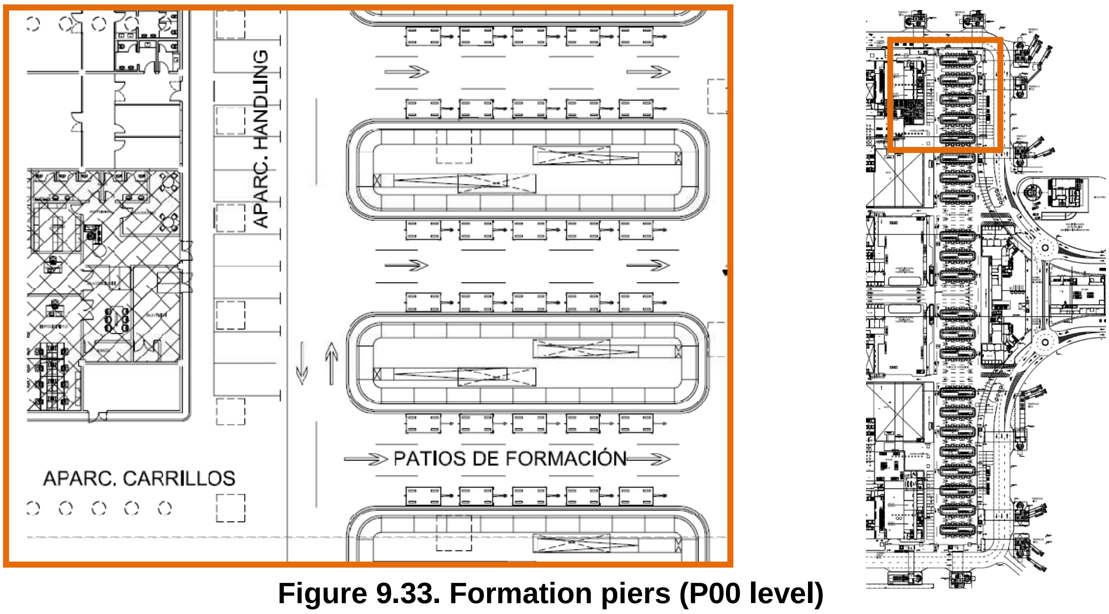

Figure 9.33. Formation piers (P00 level)

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[36] * IATA suggested value is used (refer to Annex 5, section 5.2.1

Piers are sized to fit 4-5 carts, which is the usual maximum for most aircraft (A380 would require 2 already) but given that in July 2009 no A380 operated in BCN, this is not an issue.

During the peak hourly demand (HD) there are only 12 departures (see 9.1.5), and out of the 22 available piers, there is no capacity problem.

<u>Conclusions</u>

Given the current traffic of arrivals, 5 narrow body carousels is enough to cover demand. Since in T1 there are 22 hippodromes, there is absolutely no capacity problem.

Similarly, for departures there are 12 flights during the peak hour, and given that there is a total of 22 piers, there is currently enough capacity.

9.1.3.2.8 Customs and immigration

9.1.3.2.8.1 Customs and immigration counters distribution

<u>Baggage claim room</u>

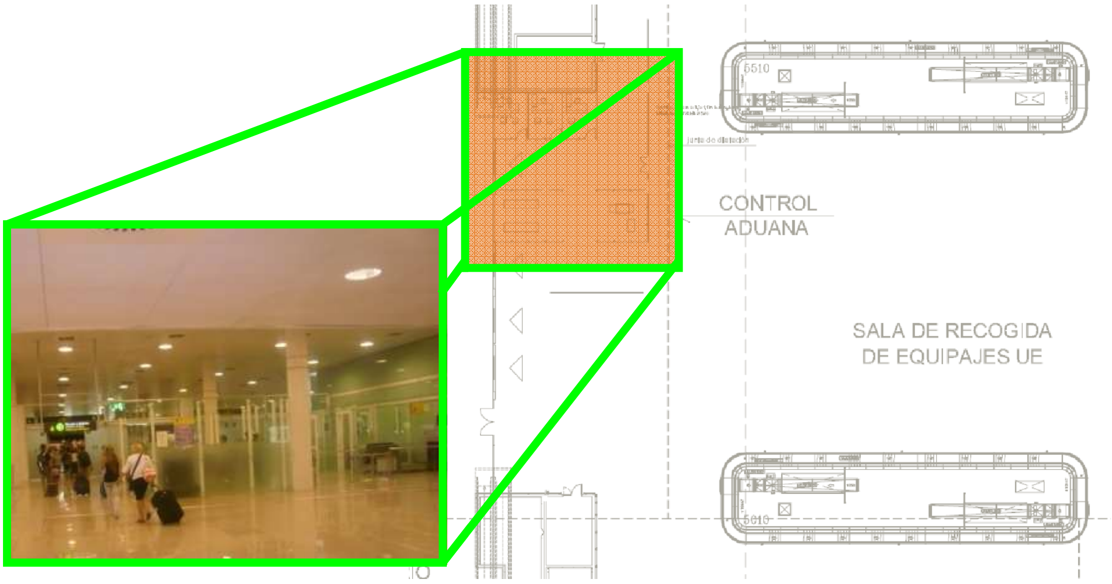


Figure 9.34. Customs and immigration in baggage claim room (P10 level)

Transversal dike

On transversal dike there are 3 hand luggage customs.

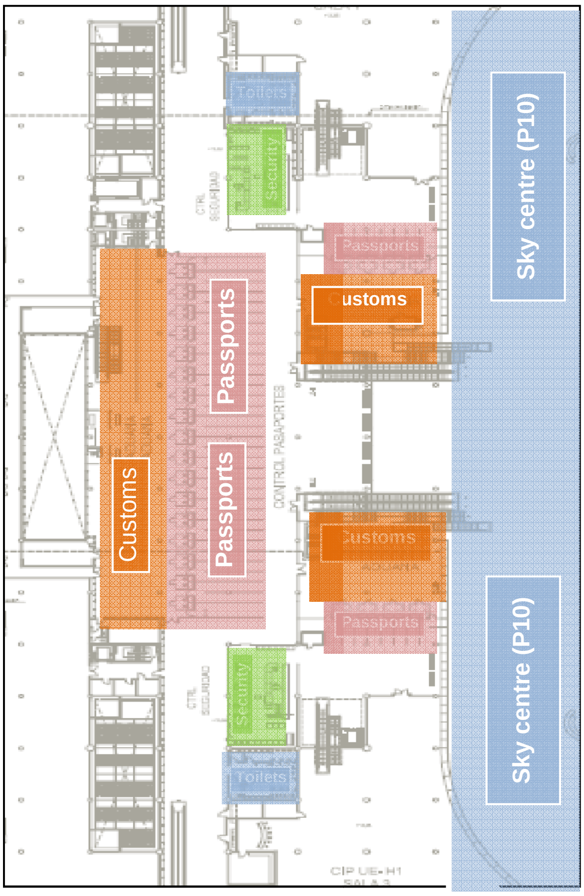


Figure 9.35. Customs and immigration in P20 level, transversal dike

9.1.3.2.8.2 Capacity assessment

Not assessed. Methodology found is not applicable to the BCN case (it does not provide useful information to work with) and, moreover, no data is available for the study.

9.1.3.2.9 Arrival hall capacity

In our case, not all the information necessary is available to make an estimate of which dimensions should the arrival hall have, given the arrivals rate and after to compare and validate whether current size meets the level of service requirements of IATA or not.

Anyway, in this case, it is not a critical area in terms of capacity, since the arrival hall of T1 is located in *La Plaça*, which is sized to serve as intermodal interchange point [flows from different origins cross (taxi, bus, car, train (when built), etc..)], it is concluded that, in terms of number of welcome greeters waiting, it is La Plaça is more than able to cope with the influx of guests (and now more than ever that in September 2009 T1 is at its 30% utilization).

In short, arrival hall capacity calculation will not be made but it is expected not to be in critical condition.

9.1.3.2.10 Terminal circulation capacity

Not assessed. It is not possible to execute a simple assessment for terminal circulation capacity; simulations using specific programs are required and, as said already before, this is not the main purpose of this document.

9.1.3.3 Parking capacity

In T1 terminal of Barcelona car parking is grouped into 7 modules, indicated as follows:

Figure 9.36. Parking

9.1.3.3.1 Capacity assessment

Not assessed. Parking area capacity has a secondary repercussion or influence on the landside capacity and it will not be taken into account in the airport capacity assessments.

9.1.3.4 Terminal curb capacity

Not assessed. Methodology found is not applicable to the BCN case (it does not provide useful information to work with) and, moreover, no data is available for the study.

9.1.4 Total capacity of T1 Barcelona's airport

In the following table, current capacity results of T1's subsystems are presented:

Barcelona T1 airport capacity					
AIRSIDE					
Runway	62 ops/h (operative capacity) 90 ops/h (declared capacity) 105 ops/h (maximum capacity)				
Taxiway	-				
Apron	-				
Gate	**A**	**B**	**C**	**D**	**E**
	47 ops/h	120 ops/h	49 ops/h	38 ops/h	13 ops/h
Terminal airspace	-				
LANDSIDE					
Ground access	-				
Passenger terminal					
Arrival hall	No capacity problem				
Baggage claim					
Arrivals	22 carousels out of 5 needed to absorb current demand; no capacity problem				
Departures	22 piers to attend 12 maximum simultaneous flights; no capacity problem				
Check-in	140 check-in counters out of 52 needed to absorb current demand; no capacity problem				
Connecting passenger	-				
Customs and immigration	-				
Gate hold room	-				
Passport control	-				
Arrivals	34 passport control counters out of 7 needed to absorb current demand; no capacity problem				
Departures	32 passport control counters out of 5 needed to absorb current demand; no capacity problem				
Security check	17 security check counters out of 4 needed to absorb current demand; no capacity problem				
Waiting area	-				
Terminal circulation	-				
Terminal curb	-				
Parking	-				

Table 9.22. T1 Barcelona airport component's capacity

Given that on landside there is absolutely no capacity problem in any of the subsystems, the airport's capacity is given by the subsystems on the airside. In this case, it is given by the most restrictive subsystem which is the runway component, since the gates (in total) they can absorb up to 267 ops/h.

Barcelona T1 capacity is 62 ops/h

9.1.5 Efficiency assessment: runway component delay

A good indicator for evaluating the airport's efficiency is an estimation of the delays. Given that runway component is the subsystem which limits the capacity of the airport, the delay introduced by it is a good KPI for efficiency. To perform the assessment the methodology described in 4.7.1 is followed.

1. ***Calculate the hourly capacity of the runway component for the specific hour of interest***

Already done in section 9.1.4. The obtained value was **62 ops/h.**

2. ***Identify the figure number for delay***

Like in the capacity assessment, the figure number selected is:

DIAGRAMA DE PISTAS	DIAG. Nº	SEPARACIÓN ENTRE PISTAS EN PIES	FIGURA Nº			
			PARA CAPACIDAD		PARA DEMORA	
			VFR	IFR	VFR	IFR
S	2	730 ó más	3-4	3-44	3-72	3-91

3. ***Identify the hourly demand (HD) and the peak 15 minute demand (Q) on the runway component***

In order to obtain this value the sum of flight hours is taken (in both arrivals and departures) for each day of the week and the maximum is chosen. Then, from this list of maximums the average value is calculated:

HOURLY DEMAND			
	DEPART	ARRIVALS	D+A
13/07/2009	10	10	20
14/07/2009	10	9	19
15/07/2009	10	12	22
16/07/2009	22	11	33
17/07/2009	10	10	20
18/07/2009	11	10	21
19/07/2009	11	9	20
MEAN	12,00	10,14	22,14

For the Peak 15 min demand there is a little inconvenient, because in our database demand is discretized within 10 minutes intervals but here the demand every 15 minutes is needed. To solve this problem first the peak 10 minutes demand over the whole week is detected (considering take-offs + landings) and then interpolated with the neighbor who has the highest value:

TOTAL FLIGHTS T1			
	5:00:00	5:10:00	5:20:00
13/07/2009	2	4	3
14/07/2009	1	4	3
15/07/2009	2	4	3
16/07/2009	4	8	6
17/07/2009	2	4	3
18/07/2009	1	2	2
19/07/2009	0	1	0

15 MIN PEAK DEMAND		
	10 min	15 min
D+A	8	11

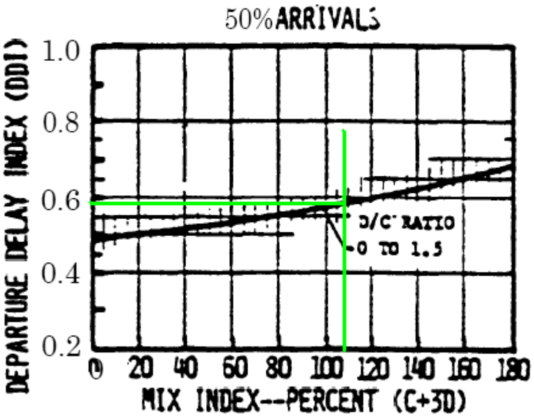
Hourly demand	15 min peak demand
HD	**Q**
22	11

4. *Calculate the ratio of hourly demand to hourly capacity (D/C)*

In this section are considered the values obtained for runway 07L/25R:

D/C ratio
IFR conditions
0.36

5. *Calculate the arrival delay index (ADI) and the departure delay index (DDI)*



Arrival / Departure Delay Indexes	
IFR conditions	
ADI	**DDI**
1	0.58

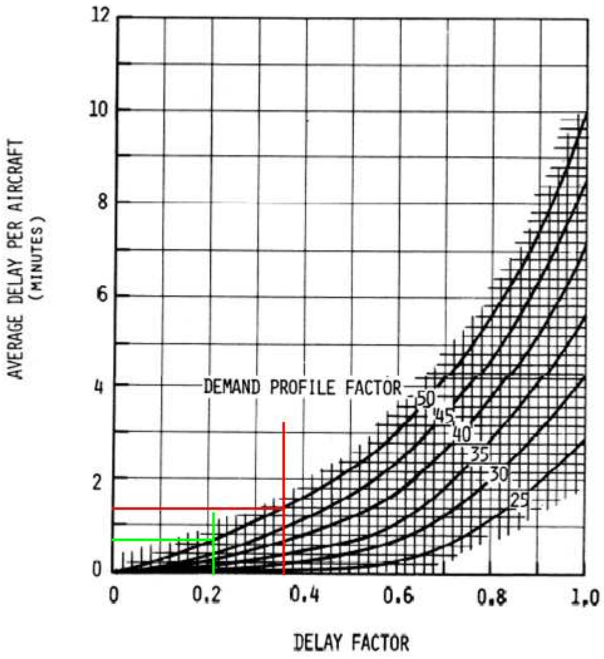
6. *Calculate the arrival delay factor (ADF) and departure delay factor (DDF)*

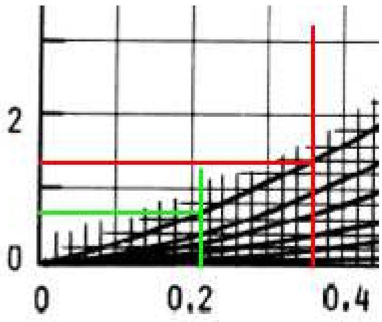
Arrival / Departure Delay Factors	
IFR conditions	
ADF	**DDF**
0.36	0.21

7. *Calculate the demand profile factor (DPF)*

Demand Profile Factor
DPF
49.6

8. *Calculate the average delay for arriving aircraft (DAHA) and departing aircraft (DAHD)*





DAHA / DAHD (min)	
IFR conditions	
DAHA	**DAHD**
1.4	0.7

9. *Calculate hourly delay (DTH)*

Hourly Delay [min/hour]
IFR conditions
18.4

This value corresponds to the accumulated delay during one hour.

Hourly Delay [min/op]
IFR conditions
0.29

If we divide the previous value by the hourly capacity the delayed minutes per flight is obtained.

Conclusions

As this result shows, currently flights experience a mean delay of 17.55 seconds which is not very significative, but when considered along one hour of operation, the airport accumulates an hourly delay of 18.4 min, which should be minimized, since this can lead to significative congestions at some peak frames of the day.

Barcelona T1 efficiency expressed in terms of hourly delay is 18.4 min

10 THE SESAR SCENARIO FOR T1 BARCELONA AIRPORT

10.1.1 SESAR enablers for T1 Barcelona airport

This chapter aims at analyzing the impact of SESAR in terms of capacity and efficiency in airports. To do this, an exhaustive analysis structured in the following steps is run:

1. The entire list of OI Steps affecting KPAs of CAP and EFF that are related to Airport and Time Efficiency Focus Areas (see 6.3.3.3) is obtained From [W17];
2. For each OI, a differentiation whether if it is more related to planning or operation is made;

The justification for this differentiation is that the two fundamental airport processes that really determine the airport's efficiency and depend largely on capacity are Runway and Turnaround, and each of them affects to a different area:

- Runway → Operations
- Turnaround → Planning

It is noteworthy that this list of IOs, which are listed within CAP or EFF (or both) comes directly from the rating done by SESAR. However, the allocation of whether they are related to planning or operation comes from particular analysis and criterion.

From there, Table 10.1 and Table 10.2 are obtained, in which IOs are ordered by Line of change, specifying whether they affect KPAs CAP, EFF or both, and within which Implementation Package are encompassed.

LOC	OI	OI Steps	OIstep title	CAP	EFF	BOTH	IP
L01	Information Management						
	L01-01	Improving Flight Data Consistency and Interoperability					
		DCB-0301	Improved Consistency between Airport Slots, Flight Plans and ATFM Slots			X	IP1
		IS-0101	Improved Flight Plan Consistency Pre-Departure		X		IP1
L03	Collaborative Planning using the Network Operations Planner						
	L03-02	User Driven Prioritization Process					
		AUO-0102	User Driven Prioritization Process (UDPP)		X		IP2
		AUO-0103	Manual User Driven Prioritization Process (UDPP)	-	-	-	IP1
	L03-03	Planning the SBT					
		AUO-0204	Agreed RBT through Collaborative Flight Planning		X		IP2
L04	Managing the Network						
	L04-01	Improving Network Capacity Management Processes					
		DCB-0303	Improved Operations at Airport in Adverse Conditions Using ATFCM Techniques		X		IP1
L07	Queue Management Tools						
	L07-02	Departure Traffic Synchronization					
		TS-0201	Basic Departure Management (DMAN)	X			IP1
		TS-0306	Optimized Departure Management in the Queue Management Process			X	IP2
	L07-03	Managing Interactions between Departure and Arrival Traffic					
		TS-0301	Integrated Arrival Departure Management for full traffic optimization, including within the TMA airspace			X	IP1
		TS-0304	Integrated Arrival / Departure Management in the Context of Airports with Interferences (other local/regional operations)			X	IP2
L10	Airport Throughput, Safety and Environment						
	L10-02	Departure Traffic Synchronization					
		AO-0207	Surface Management Integrated With Departure and Arrival Management	X			IP2
	L10-03	Improving Airport Collaboration in the Pre-Departure Phase					
		AO-0501	Improved Operations in Adverse Conditions through Airport CDM			X	IP1
		AO-0601	Improved Turn-Round Process through CDM			X	IP1
		AO-0602	Collaborative Pre-departure Sequencing			X	IP1
		AO-0603	Improved De-icing Operation through CDM		X		IP1

Table 10.1. List of OI Steps related to turnaround process [S1]

LOC	OI	OI Steps	OIstep title	CAP	EFF	BOTH	IP
L02	Moving from Airspace to Trajectory Based Operations						
	L02-08	Optimizing Climb/Descent					
		AOM-0701	Continuous Descent Approach (CDA)			X	IP1
		AOM-0702	Advanced Continuous Descent Approach (ACDA)			X	IP2
		AOM-0703	Continuous Climb Departure		X		IP1
		AOM-0705	Advanced Continuous Climb Departure		X		IP2
L07	Queue Management Tools						
	L07-02	Departure Traffic Synchronization					
		TS-0203	Integration of Surface Management Constraint into Departure Management		X		IP2
L08	New Separation Modes						
	L08-05	ASAS Self-separation					
		AUO-0504	Self-Adjustment of Spacing Depending on Wake Vortices		X		IP3
L10	Airport Throughput, Safety and Environment						
	L10-01	Improving Safety of Operations on the Airport Surface					
		AO-0103	Improved Runway-Taxiway Lay-out, Signage and Markings to Prevent Runway Incursions		X		IP1
	L10-04	Using Runways Configuration to Full Potential					
		AO-0402	Interlaced Take-Off and Landing	X			IP1
		AO-0403	Optimized Dependent Parallel Operations			X	IP1
		AUO-0701	Use of Runway Occupancy Time (ROT) Reduction Techniques			X	IP1
		AUO-0702	Brake to Vacate (BTV) Procedure	X			IP1
		AUO-0703	Automated BTV using Data link			X	IP2
	L10-05	Maximizing Runway Throughput					
		AO-0301	Crosswind Reduced Separations for Departures and Arrivals			X	IP1
		AO-0302	Time Based Separation for Arrivals			X	IP1
		AO-0303	Fixed Reduced Separations based on Wake Vortex Prediction			X	IP1
		AO-0304	Dynamic Adjustment of Separations based on Real-Time Detection of Wake Vortex			X	IP2
		AO-0305	Additional Rapid Exit Taxiways (RET) and Entries			X	IP1
	L10-06	Improving Operations under Adverse Conditions incl. Low Visibility					
		AO-0502	Improved Operations in Low Visibility Conditions through Enhanced ATC Procedures	X			IP1
		AO-0503	Reduced ILS Sensitive and Critical Areas	X			IP1
		AO-0504	Improved Low Visibility Runway Operations Using MLS			X	IP1

		AO-0505	Improved Low Visibility Runway Operations Using GNSS / GBAS			X	IP2
		AUO-0404	Synthetic Vision for the Pilot in Low Visibility Conditions	X			IP3
	L10-07	Visual Conducted Approaches					
		AUO-0501	Visual Contact Approaches When Appropriate Visual Conditions Prevail			X	IP1
		AUO-0502	Enhanced ATSA-VSA			X	IP1

Table 10.2. List of OI Steps related to runway process [S1]

3. For each OI Step, it is known from [S1] which procedural and system enablers affect this OI Step since institutional and human enablers are not of the interest for this study (see 6.3.2.1.2.6). To this purpose, a list of them sorted by LOC and separated into two tables, Table 10.3 for turnaround and Table 10.4 for runway, is made;

LOC	**ENABLER CODE**	**ENABLER TITLE**
L01	Information Management	
	SYSTEM ENABLERS	
	CTE-C4a	Airport Data links (WIFI, EDGE, GPRS,…)
	CTE-C10	AMHS (ATS Message Handling System)
	CTE-C11a	PENS (Pan European Network Service)
	NIMS-18	Flight Planning management sub-system enhanced to use the latest airspace information
	NIMS-23	Capacity planning and scenario management equipped with tools integrating airport/airline schedule data, to assist ATCCs in optimizing the use of airport holding patterns, to identify other usable capacity
	PROCEDURAL ENABLERS	
	PRO-004	FCM Procedures to ensure that NOP is constantly updated to reflect all changes to the airspace and airspace users planned trajectories
	PRO-221a	FCM Collaborative Procedures linked to Integration of Airport Scheduling with Flow and Capacity Management
	PRO-221b	Airport Operational Procedures linked to Integration of Airport Scheduling with Flow and Capacity Management
	PRO-221c	-
L03	Collaborative Planning using the Network Operations Planner	
	SYSTEM ENABLERS	
	AOC-ATM-04	Data model to allow transfer of trajectory from AOC-ATM system into ATC world with SWIM
	AOC-ATM-11	Modification of AOC-ATM trajectory management system (or new systems) to allow quality of service requested by NOP for pre-flight trajectory automatic integration of new constraints for SBT negotiation
	AOC-ATM-13	Modification of AOC-ATM system to allow CDM processes with ATM world
	ER APP ATC 82	Enhance Local/Sub-regional Traffic and Capacity sub-systems tools to use (full SWIM available) SBT and RBT

	NIMS-02	Ground-ground data communications services for flight plan filing and exchange (e.g. AMHS)
	NIMS-05	Flight Planning management sub-system equipped with route finding and optimization tools
	NIMS-17	Enhanced assistance to flight planning
	NIMS-21	Flight Planning management sub-system enhanced to support 4D and to comply with standards
	NIMS-24	Flight planning sub-system enhanced by acquiring information on real-time events
	NIMS-25	Enhanced interaction of Network DCB sub-system
	NIMS-27	Network DCB sub-system enhanced with improved accuracy of processing real-time data
	PROCEDURAL ENABLERS	
	PRO-094	Airline Operational Procedures for collaborative prioritization of planned departures amongst available slots
	PRO-095	Airline Operational Procedures for modifying RBT including agreed TTA to accommodate selected priorities
	PRO-096a	Airline Operational Procedures for refining the RBT to accommodate constraints arising from new and more accurate information (including Meteo, airspace availability and demand information)
	PRO-097a	Airline Operational Procedures for collaborating on RBT changes with FCM
	PRO-097b	FCM Procedures for collaborating on RBT changes with Airspace Users
L04	Managing the Network	
	SYSTEM ENABLERS	
	GGSWIM-35	Ground-ground data communications services for ATFCM
	PROCEDURAL ENABLERS	
	PRO-043	FCM Procedures to compensate for sudden changes in capacity
L07	Queue Management Tools	
	SYSTEM ENABLERS	
	AERODROME-ATC-08	Independent management of the departure and arrival sequence at the aerodrome
	AERODROME-ATC-10	Enhanced arrival/departure sequence with external aerodrome and CDM, taking into account the user TTA
	AERODROME-ATC-33	Airport Demand and Capacity system enhanced to better handle arrival and departure
	CTE-C2a	Air-Ground existing VDL2 data link
	CTE-C11b	Ground IP Network
	ER APP ATC 110	Enhance AMAN to collaborate with non-local SMAN and DMAN.
	NIMS-02	Ground-ground data communications services for flight plan filing and exchange (e.g. AMHS)
	NIMS-12	Capacity planning and scenario management equipped with tool to identify imbalance between arrivals and departures
	NIMS-24	Flight planning sub-system enhanced by acquiring information on real-time events

	NIMS-25	Enhanced interaction of Network DCB sub-system
	NIMS-26	Enhanced responsiveness of Network DCB sub-system
	NIMS-27	Network DCB sub-system enhanced with improved accuracy of processing real-time data
	NIMS-28	Network DCB sub-system equipped with an improved short term traffic prediction tool, with tools for optimizing re-routing
	PROCEDURAL ENABLERS	
	PRO-051	ATC Procedures (Airport) to assist the Ground Controller in achieving the optimal departure sequence as provided by DMAN Tool
	PRO-123	ATC Procedures (Airport) to update NOP as a result of real-time changes to trajectory resulting from airport movement activities
	PRO-124	ATC Procedures (En-route and TMA) whereby controllers in enroute sectors apply constraints (in-trail, time, speed) to assist in establishing conditions to meet displayed AMAN times
	PRO-125	ATC Procedures (En-route and TMA) to accommodate mixed traffic streams into multiple aerodromes
	PRO-126	ATC Procedures (Airport) whereby ground controllers adjust taxi-out instructions and timings to establish DMAN sequence optimized to mix aircraft from multiple aerodromes
	PRO-127	ATC Procedures (Airport) whereby ground controllers utilize information from the RBT including TTA in determining start-up, pushback priorities and taxi routings
	PRO-187	ATC Procedures Integrated Arrival and Departure Management
	PRO-223	ATC Procedures (Airport) related to Enhancement of Aerodrome Operations Through Departure Management
	PRO-AC-73	Cockpit Procedures related to Enhancement of Aerodrome Operations Through Departure Management
L10	Airport Throughput, Safety and Environment	
	SYSTEM ENABLERS	
	AIRPORT-31	Airport CDM (levels 1, 2 & 3)
	AERODROME-ATC-05	Surface movement data processing system enhanced with processing for collaborative gate and stand management
	AERODROME-ATC-09	Integration of Arrival/Departure sequence management with surface management
	ER APP ATC 51	Enhance AMAN to collaborate with the local SMAN and DMAN.
	PROCEDURAL ENABLERS	
	PRO-073	Airport Procedures to maximize throughput of de-icing stands
	PRO-075	Airport infrastructure and procedures governing de-icing to isolate surface water systems, collect and dispose of run-off, use the least harmful chemical, reduce the quantities required, reduce delays and increase recovered volumes of fluid
	PRO-141	ATC Procedures (Airport) for using taxi planning tools to integrate arrival departure ground movement flows in accordance with AMAN/DMAN times
	PRO-204a	Collaborative Procedures (Airport) for improving Airport Operations in Adverse Conditions
	PRO-204b	Collaborative Procedures (ATC) for improving Airport Operations in

		Adverse Conditions
	PRO-204c	Collaborative Procedures (Airlines) for improving Airport Operations in Adverse Conditions
	PRO-204d	Collaborative Procedures (FCM) for improving Airport Operations in Adverse Conditions
	PRO-213a	CDM information sharing Airport Procedures for turn-around
	PRO-213b	CDM information sharing Airline Procedures for turn-around
	PRO-214a	Airport CDM Procedures for pre-departure sequencing
	PRO-214b	Airline CDM Procedures for pre-departure sequencing

Table 10.3. List of enablers related to turnaround process [S1]

L02	Moving from Airspace to Trajectory Based Operations	
	SYSTEM ENABLERS	
	A/C-04	Flight management and guidance to improve lateral navigation (2D RNP)
	A/C-05	Flight management to improve vertical navigation (barometric VNAV)
	A/C-37	Downlink of predicted trajectory in case of activation onboard of agreed or revise trajectory or in case proposal of onboard preferred trajectory avoiding an up linked area
	AAMS-16	Airspace management system equipped with tools able to deal with flexible use of airspace and free-routing
	CTE-C2a	Air-Ground existing VDL2 data link
	CTE-N3a	ABAS (Aircraft Based Augmentation System)
	CTE-N8	FMS (Flight Management System) performance standards
	ER APP ATC 79	Enhance FDP sub-system to allow continuous descent from defined (approach) fixes
	PROCEDURAL ENABLERS	
	PRO-018	ATC Procedures to allow for changes in airspace usage and TMA sectorization in response to traffic loading conditions
	PRO-020	ATC Procedures to permit the use of CDA during higher traffic volumes
	PRO-079	-
	PRO-090	ATC Procedures for interlacing departure climb profiles and CDA profiles
	PRO-AC-09	Cockpit procedure to perform continuous climbing cruise
	PRO-ENV-15	ASM Procedure to ensure that airspace is designed to avoid unnecessary noise and emissions from non-optimal departure profiles (noise and atmospheric emissions)
L07	Queue Management Tools	
	SYSTEM ENABLERS	
	AIRPORT-33	Provision by the Airport Demand & Capacity of the relevant information to the Aerodrome ATC
	PROCEDURAL ENABLERS	
	PRO-121	ATC Procedures (Airport) to make use of DMAN sequence in establishing ground traffic routing and pushback priorities and timing

	PRO-122	ATC Procedures (Airport) to modify DMAN sequence taking into account real-time events on airports
	PRO-123	ATC Procedures (Airport) to update NOP as a result of real-time changes to trajectory resulting from airport movement activities
L10	Airport Throughput, Safety and Environment	
	SYSTEM ENABLERS	
	A/C-18	Flight management and guidance to support automatic braking according to a pre-defined runway exit
	A/C-23	Synthetic vision on head up display in low visibility conditions.
	A/C-27	Airborne Traffic Situational Awareness to support enhanced ATSA-VSA
	A/C-33	Uplink and automatic loading in onboard navigation system of clearances
	A/C-48	Air broadcast of aircraft position/vector (ADS-B OUT)
	A/C-49	Reception of air broadcast of aircraft position/vector (ADS-B IN)
	AERODROME-ATC-16	Runway Usage Management sub-system enhanced for processing dynamic wake-vortex information
	AERODROME-ATC-30	Surface movement control workstation equipped with a wind shear monitoring tool
	AERODROME-ATC-33	Airport Demand and Capacity system enhanced to better handle arrival and departure
	AERODROME-ATC-35	Surface movement management tools enhanced to process the runway exit proposal to be uplinked to the aircraft
	AERODROME-ATC-42	Runway Usage Management sub-system enhanced for processing static wake-vortex information
	AGSWIM-57	Enhanced air-ground data link communications service supporting different kinds of applications
	CTE-C2a	Air-Ground existing VDL2 data link
	CTE-N4b	GBAS Cat 2-3 initial, GPS L1 based
	CTE-N4c	GBAS Cat 2-3 universal, Galileo and GPS L5 based
	CTE-N6	ILS (Instrumental Landing System)
	CTE-N7	MLS (Microwave Landing System)
	CTE-N9b	HUD (Head up Display) / SVS (Synthetic Vision System)
	CTE-S1	ADS-B (Automatic Dependent Surveillance -Broadcast) Out 1090 Step 1
	CTE-S2a	ADS-B In/Out 1090 (260) to support ATSAW (Airborne Traffic Situational Awareness), ITP (Step 2)
	CTE-S4a	Independent Non-cooperative Surveillance (PSR)
	CTE-S5	Independent Cooperative Surveillance sensors (SSR, WAM)
	CTE-S6	Ground Wake vortex radar
	CTE-S8a	Airborne wake vortex detection
	CTE-S9	Airport Surface Surveillance (SMR, MLAT or ADS-B)
	ER APP ATC 74	Enhance AMAN to provide time-based separation.

	ER APP ATC 118	Enhance AMAN to reduced distance separation in specific conditions
	PROCEDURAL ENABLERS	
	PRO-066a	ATC Procedures to apply new flexibility in application of wake vortex standards
	PRO-066b	ATC Procedures for using time-based separations on approaches
	PRO-067	ATC Procedures for optimizing operations on dependent parallel runways
	PRO-068	ATC Procedures for optimizing mixed mode operations on parallel or converging runways
	PRO-069b	ATC Approach Procedures with reduced ILS sensitive / critical areas
	PRO-069c	ATC Approach Procedures using MLS
	PRO-069d	ATC Approach Procedures using GNSS / GBAS
	PRO-070	ATC Procedures for the application of Visual and Contact approaches where advantages can be achieved
	PRO-143	ATC Procedures (Airport) to plan taxi strategy prior to traffic even landing and broadcast these instructions to the aircraft whilst still on final
	PRO-144	ATC Procedures for Optimization of Arrival and Departures Based on Wake Vortex Detection
	PRO-186	ATC Procedures for Low Visibility RWY Operations
	PRO-188	ATC Procedures (Communications) linked to Optimization of Airport Operations in All Weather Conditions
	PRO-202	AOP Driver Procedures (PDAS) linked to Optimization of Airport Operations in All Weather Conditions
	PRO-205	ATC Procedures (Decision Support Tools) linked to Optimization of Airport Operations in All Weather Conditions
	PRO-206	ATC Procedures (Wind Shear/Micro bursts) linked to Optimization of Airport Operations in All Weather Conditions
	PRO-218b	BTV procedures (Airport)
	PRO-AC-18	Cockpit Procedure to perform automatic braking according to a pre-defined runway exit
	PRO-AC-27	Cockpit Procedure to use Airborne Traffic Situational Awareness to support enhanced Visual Separation on Approach (ATSA-VSA)
	PRO-AC-30	Cockpit Procedure to use as safety net onboard Wake Vortex detection
	PRO-AC-32	Cockpit Procedure to automatically load and comply to up linked constraints or clearances
	PRO-AC-53	Cockpit Procedures to standardize the identification and following of traffic during a visual approach
	PRO-AC-54	Cockpit Procedures to standardize and minimize runway occupancy/exit Procedures
	PRO-AC-63	Cockpit Procedures for the employment of Synthetic Vision devises
	PRO-AC-64	Cockpit Procedures linked to Optimization of Arrivals and Departures based on Wake Vortex Detection
	PRO-AC-65	Cockpit Procedures (Communications) linked to Optimization of Airport Operations in All Weather Conditions
	PRO-AC-67	Cockpit Procedures (SVS) linked to Optimization of the Airport Operations in All Weather Conditions
	PRO-AC-68	Cockpit Procedures (Wind Shear/Microburst) linked to Optimization of Airport Operations in All Weather Conditions

	PRO-AC-74	BTV procedures (Cockpit)
	PRO-AC-75	Cockpit Procedures (AWOP) linked to Optimization of Airport Operations in All Weather Conditions
	PRO-AC-76	Cockpit Procedures (PDAS) linked to Optimization of Airport Operations in All Weather Conditions

Table 10.4. List of enablers related to runway process [S1]

4. From this list of enablers, those that will be applicable to the case of BCN are selected and listed again in two tables, one for turnaround (Table 10.5) and one for runway (Table 10.6). For each enabler it is specified what OI Steps affect it;

LOC	ENABLER CODE	ENABLER TITLE	AFFECTED OI Steps
L01	Information Management		
	SYSTEM ENABLERS		
	CTE-C4a	Airport Data links (WIFI, EDGE, GPRS,…)	IS-0101
	CTE-C10	AMHS (ATS Message Handling System)	IS-0101
	CTE-C11a	PENS (Pan European Network Service)	DCB-0301
	PROCEDURAL ENABLERS		
	PRO-221b	Airport Operational Procedures linked to Integration of Airport Scheduling with Flow and Capacity Management	DCB-0301
L03	Collaborative Planning using the Network Operations Planner		
	SYSTEM ENABLERS		
	NIMS-02	Ground-ground data communications services for flight plan filing and exchange (e.g. AMHS)	AUO-0102 AUO-0204 TS-0306
	NIMS-24 (*)[37]	Flight planning sub-system enhanced by acquiring information on real-time events	AUO-0102 TS-0306
	NIMS-25 (*)	Enhanced interaction of Network DCB sub-system	AUO-0102 TS-0306 TS-0301 TS-0304
L07	Queue Management Tools		
	SYSTEM ENABLERS		
	AERODROME-ATC-08	Independent management of the departure and arrival sequence at the aerodrome	TS-0201
	AERODROME-	Enhanced arrival/departure sequence with external aerodrome and CDM, taking into account the user TTA	TS-0201 TS-0306

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[37] (*) Systems that do not physically work at the airport but that provide interfaces which affect

	ATC-10		TS-0304
	AERODROME-ATC-33	Airport Demand and Capacity system enhanced to better handle arrival and departure	TS-0301
	CTE-C2a	Air-Ground existing VDL2 data link	TS-0301
	CTE-C11b	Ground IP Network	TS-0306
			TS-0304
	ER APP ATC 110	Enhance AMAN to collaborate with non-local SMAN and DMAN.	TS-0304
	NIMS-02	Ground-ground data communications services for flight plan filing and exchange (e.g. AMHS)	AUO-0102
			AUO-0204
			TS-0306
	NIMS-24 (*)	Flight planning sub-system enhanced by acquiring information on real-time events	AUO-0102
			TS-0306
			AUO-0102
	NIMS-25 (*)	Enhanced interaction of Network DCB sub-system	TS-0306
			TS-0301
			TS-0304
	PROCEDURAL ENABLERS		
	PRO-051	ATC Procedures (Airport) to assist the Ground Controller in achieving the optimal departure sequence as provided by DMAN Tool	TS-0201
	PRO-123	ATC Procedures (Airport) to update NOP as a result of real-time changes to trajectory resulting from airport movement activities	TS-0306
	PRO-126	ATC Procedures (Airport) whereby ground controllers adjust taxi-out instructions and timings to establish DMAN sequence optimized to mix aircraft from multiple aerodromes	TS-0304
	PRO-127	ATC Procedures (Airport) whereby ground controllers utilize information from the RBT including TTA in determining start-up, pushback priorities and taxi routings	TS-0306
	PRO-187	ATC Procedures Integrated Arrival and Departure Management	TS-0301
			TS-0304
	PRO-223	ATC Procedures (Airport) related to Enhancement of Aerodrome Operations Through Departure Management	TS-0201
L10	Airport Throughput, Safety and Environment		
	SYSTEM ENABLERS		
	AIRPORT-31	Airport CDM (levels 1, 2 & 3)	AO-0601
			AO-0603
	AERODROME-ATC-05	Surface movement data processing system enhanced with processing for collaborative gate and stand management	AO-0207
	AERODROME-ATC-09	Integration of Arrival/Departure sequence management with surface management	AO-0207
	ER APP ATC	Enhance AMAN to collaborate with the local SMAN and	AO-0207

	51	DMAN.	
	PROCEDURAL ENABLERS		
	PRO-073	Airport Procedures to maximize throughput of de-icing stands	AO-0603
	PRO-075	Airport infrastructure and procedures governing de-icing to isolate surface water systems, collect and dispose of run-off, use the least harmful chemical, reduce the quantities required, reduce delays and increase recovered volumes of fluid	AO-0603
	PRO-141	ATC Procedures (Airport) for using taxi planning tools to integrate arrival departure ground movement flows in accordance with AMAN/DMAN times	AO-0207
	PRO-204a	Collaborative Procedures (Airport) for improving Airport Operations in Adverse Conditions	AO-0501
	PRO-213a	CDM information sharing Airport Procedures for turn-around	AO-0601
	PRO-213b	CDM information sharing Airline Procedures for turn-around	AO-0601
	PRO-214a	Airport CDM Procedures for pre-departure sequencing	AO-0602
	PRO-214b	Airline CDM Procedures for pre-departure sequencing	AO-0602

Table 10.5. List of enablers related to turnaround process applicable to BCN airport case

LOC	**ENABLER CODE**	**ENABLER TITLE**	**AFFECTED OI Steps**
L02	Moving from Airspace to Trajectory Based Operations		
	SYSTEM ENABLERS		
	CTE-C2a	Air-Ground existing VDL2 data link	AOM-0702 AUO-0703
	CTE-N3a	ABAS (Aircraft Based Augmentation System)	AOM-0702 AOM-0703
	PROCEDURAL ENABLERS		
	PRO-020	ATC Procedures to permit the use of CDA during higher traffic volumes	AOM-0702
	PRO-090	ATC Procedures for interlacing departure climb profiles and CDA profiles	AOM-0705
L07	Queue Management Tools		
	SYSTEM ENABLERS		
	AIRPORT-33	Provision by the Airport Demand & Capacity of the relevant information to the Aerodrome ATC	TS-0203
	PROCEDURAL ENABLERS		
	PRO-121	ATC Procedures (Airport) to make use of DMAN sequence in establishing ground traffic routing and pushback priorities and timing	TS-0203
	PRO-122	ATC Procedures (Airport) to modify DMAN sequence taking into account real-time events on airports	TS-0203

	PRO-123	ATC Procedures (Airport) to update NOP as a result of real-time changes to trajectory resulting from airport movement activities	TS-0203
L10	Airport Throughput, Safety and Environment		
	SYSTEM ENABLERS		
	AERODROME-ATC-16	Runway Usage Management sub-system enhanced for processing dynamic wake-vortex information	AO-0304
	AERODROME-ATC-30	Surface movement control workstation equipped with a wind shear monitoring tool	AO-0103 AO-0301
	AERODROME-ATC-35	Surface movement management tools enhanced to process the runway exit proposal to be uplinked to the aircraft	AUO-0703
	AERODROME-ATC-42	Runway Usage Management sub-system enhanced for processing static wake-vortex information	AO-0303
	AGSWIM-57	Enhanced air-ground data link communications service supporting different kinds of applications	AUO-0703
	CTE-C2a	Air-Ground existing VDL2 data link	AOM-0702 AUO-0703
	CTE-N4b	GBAS Cat 2-3 initial, GPS L1 based	AO-0505 AUO-0404
	CTE-N4c	GBAS Cat 2-3 universal, Galileo and GPS L5 based	AUO-0404
	CTE-N6	ILS (Instrumental Landing System)	AO-0503
	CTE-N7	MLS (Microwave Landing System)	AO-0504
	CTE-N9b	HUD (Head up Display) / SVS (Synthetic Vision System)	AUO-0404
	CTE-S4a	Independent Non-cooperative Surveillance (PSR)	AO-0402
	CTE-S5	Independent Cooperative Surveillance sensors (SSR, WAM)	AO-0402
	CTE-S6	Ground Wake vortex radar	AO-0304
	CTE-S9	Airport Surface Surveillance (SMR, MLAT or ADS-B)	AO-0402
	ER APP ATC 74	Enhance AMAN to provide time-based separation.	AO-0302 AO-0303 AO-0304
	ER APP ATC 118	Enhance AMAN to reduced distance separation in specific conditions	AO-0103 AO-0301 AO-0303
	PROCEDURAL ENABLERS		
	PRO-066a	ATC Procedures to apply new flexibility in application of wake vortex standards	AO-0103 AO-0301 AO-0303
	PRO-066b	ATC Procedures for using time-based separations on approaches	AO-0302
	PRO-067	ATC Procedures for optimizing operations on dependent parallel runways	AO-0403

	PRO-068	ATC Procedures for optimizing mixed mode operations on parallel or converging runways	AO-0402
	PRO-069b	ATC Approach Procedures with reduced ILS sensitive / critical areas	AO-0503
	PRO-069c	ATC Approach Procedures using MLS	AO-0504
	PRO-069d	ATC Approach Procedures using GNSS / GBAS	AO-0505
	PRO-070	ATC Procedures for the application of Visual and Contact approaches where advantages can be achieved	AUO-0501
	PRO-143	ATC Procedures (Airport) to plan taxi strategy prior to traffic even landing and broadcast these instructions to the aircraft whilst still on final	AUO-0703
	PRO-144	ATC Procedures for Optimization of Arrival and Departures Based on Wake Vortex Detection	AO-0304
	PRO-186	ATC Procedures for Low Visibility RWY Operations	AO-0502
	PRO-188	ATC Procedures (Communications) linked to Optimization of Airport Operations in All Weather Conditions	AO-0502
	PRO-202	AOP Driver Procedures (PDAS) linked to Optimization of Airport Operations in All Weather Conditions	AO-0502
	PRO-205	ATC Procedures (Decision Support Tools) linked to Optimization of Airport Operations in All Weather Conditions	AO-0502
	PRO-206	ATC Procedures (Wind Shear/Micro bursts) linked to Optimization of Airport Operations in All Weather Conditions	AO-0502
	PRO-218b	BTV procedures (Airport)	AUO-0702

Table 10.6. List of enablers related to runway process applicable to BCN airport case

10.1.2 T1 Barcelona airport capacity & efficiency assessment w/ SESAR

From the list of enablers presented in section 10.1.1 applied to the BCN case, it can be observed that the following major tools of SESAR are involved:

- AMAN / DMAN
- CDM
- Wake Vortex Detection

From each of these, from [S2] is known:

- which KPIs are affected
- In which magnitude (qualitatively) each OI Steps related to the tool is affected (included within CAP / EFF for BCN case) and which particular aspects of the airport are going to be incremented.

Containing all this information, Table 10.7, Table 10.8 and Table 10.9 have been developed.

<table>
<tr><td colspan="2">CDM</td><td colspan="3">Collaborative Decision-Making</td></tr>
<tr><td colspan="5">General description</td></tr>
<tr><td colspan="5">The concept of CDM consists of two high level elements; the sharing of information related to progress of flights and priorities and acting on the shared information.
By enabling decision making based on accurate information, shared in a timely manner, A-CDM increases the overall efficiency of the airport operations and improves predictability, notably in case of bad weather or other unforeseen events. Experience in the airport environment has shown that just by sharing relevant information between partners, common situational awareness and understanding of a situation increases the quality of decisions sufficiently to enable a better use of resources, allow partners to set priorities and improve the predictability of operations, not only in the airport itself, but system wide.</td></tr>
<tr><td colspan="2">Affected airport process</td><td colspan="3">Turnaround</td></tr>
<tr><td rowspan="6">Affected KPIs</td><td rowspan="2">AIRPORT CAPACITY</td><td>CAP.2.OBJ1.IND1</td><td colspan="2">Hourly number of IFR movements</td></tr>
<tr><td>CAP.2.OBJ1.IND2</td><td colspan="2">Daily number of IFR movements</td></tr>
<tr><td rowspan="4">TEMPORAL EFFICIENCY</td><td>EFF.1.OBJ1.IND1</td><td colspan="2">Percent of flights departing on-time</td></tr>
<tr><td>EFF.ECAC.PI 2</td><td colspan="2">Average departure delay per flight</td></tr>
<tr><td>EFF.ECAC.PI 3</td><td colspan="2">Percent of flight with normal flight duration</td></tr>
<tr><td>EFF.ECAC.PI 4</td><td colspan="2">Average extra flight duration</td></tr>
<tr><td>OI Steps</td><td colspan="3">Capacity improvements</td><td>Magnitude</td></tr>
<tr><td>AO-0601</td><td colspan="3">Better quality decisions by all airport partners will ensure that the airport capacity is used more effectively, leading in particular to a reduction of delay due to late inbound (more optimum allocation of stand).</td><td>+</td></tr>
<tr><td>TS-0201</td><td colspan="3">Optimization of departure sequence will allow better utilization of available runway capacity.</td><td>+ + +</td></tr>
<tr><td>TS-0304</td><td colspan="3">Integration of AMAN and DMAN with the CDM processes will improve airport capacity by reducing the effect of interferences between close airports.</td><td>+ + +</td></tr>
<tr><td>TS-0306</td><td colspan="3">With knowledge of the TTA (if applicable), the elapsed time derived from the trajectory, the departure and arrival demand for the runway(s) and the dependent departure route demand from adjacent airports, the system (DMAN) calculates the optimum take-off time and the SMAN will determine the associated start-up and push-back times and taxi route, improving airport's throughput</td><td>+</td></tr>
<tr><td>OI Steps</td><td colspan="3">Efficiency improvements</td><td>Magnitude</td></tr>
<tr><td>AO-0601</td><td colspan="3">Efficiency of airport partners is enhanced as a result of an improved predictability of departures, and the greater stability into planning introduced by the milestone approach.</td><td>+</td></tr>
<tr><td>AO-0603</td><td colspan="3">Better taxiing management, avoiding returns for re-icing, etc.</td><td>+ + +</td></tr>
<tr><td>TS-0304</td><td colspan="3">Integration of AMAN and DMAN with the CDM processes will improve the efficiency of airport operations by reducing the effect of interferences between close airports.</td><td>+</td></tr>
<tr><td>TS-0306</td><td colspan="3">It is expected that during the SESAR time-frame the improving view on the status of the turn-round process will enable valid departure sequences to be built earlier.</td><td>+</td></tr>
</table>

Table 10.7. CDM impact on capacity and efficiency at airports

<table>
<tr><td>AMAN/DMAN</td><td colspan="3">Arrival Manager / Departure Manager</td></tr>
<tr><td colspan="4">General description</td></tr>
<tr><td colspan="4">AMAN and DMAN are queue management tools aimed at optimizing the traffic, including provision of assistance to the controller within the TMA to manage mixed mode runway operations, and identify and resolve complex interacting traffic flows.
The arrival management tools will build the arrival sequence, once the flight passes the sequencing horizon. Moreover, they will continue to be implemented to integrate the En-Route part of the flight (AMAN extended in En-route).
Departure Management tools are implemented in airports and are synchronized with the pre-departure sequence (DMAN and Pre-departure) and with AMAN (if it has been implemented on the airport) to manage mixed mode runway operations, and identify and resolve complex interacting traffic flows (AMAN/DMAN integration).</td></tr>
<tr><td colspan="2">Affected airport process</td><td colspan="2">Turnaround, Runway</td></tr>
<tr><td rowspan="6">Affected KPIs</td><td rowspan="2">AIRPORT CAPACITY</td><td>CAP.2.OBJ1.IND1</td><td>Hourly number of IFR movements</td></tr>
<tr><td>CAP.2.OBJ1.IND2</td><td>Daily number of IFR movements</td></tr>
<tr><td rowspan="4">TEMPORAL EFFICIENCY</td><td>EFF.1.OBJ1.IND1</td><td>Percent of flights departing on-time</td></tr>
<tr><td>EFF.ECAC.PI 2</td><td>Average departure delay per flight</td></tr>
<tr><td>EFF.ECAC.PI 3</td><td>Percent of flight with normal flight duration</td></tr>
<tr><td>EFF.ECAC.PI 4</td><td>Average extra flight duration</td></tr>
<tr><td>OI Steps</td><td colspan="2">Capacity improvements</td><td>Magnitude</td></tr>
<tr><td>TS-0201</td><td colspan="2">Optimization of departure sequence will allow better utilization of available runway capacity.</td><td>+ + +</td></tr>
<tr><td>TS-0304</td><td colspan="2">Integration of AMAN and DMAN with the CDM processes will improve airport capacity by reducing the effect of interferences between close airports.</td><td>+ + +</td></tr>
<tr><td>AO-0207</td><td colspan="2">Combining AMAN and DMAN together with SMAN as a unique entity and combining it with CDM processes, especially at airports with runways used for both arriving and departing flights, will improve aerodrome throughput and efficiency</td><td>+ + +</td></tr>
<tr><td>AO-0301</td><td colspan="2">The reduction of dependency on wake vortex operations under suitable weather conditions, will lead to reduced arrival / departure intervals, with a positive effect on delays (efficiency) and runway throughput (capacity)</td><td>+ + +</td></tr>
<tr><td>AO-0302</td><td colspan="2">Constant time based separations (LIV & STIV) independent of crosswind conditions and wake vortex existence are introduced to replace the distance criteria currently used to separate trailing aircraft on the approach beyond the wake vortex of the leading aircraft. The intent is to mitigate the effect of wind on final approach sequencing so as to achieve accurate and more consistent final approach spacing, and recover most of the capacity lost under strong headwind.</td><td>+ + +</td></tr>
<tr><td>AO-0303</td><td colspan="2">In the applicable situations, the controller uses reduced aircraft separations derived from forecasted wake vortex behavior, maximizing runway throughput</td><td>+ + +</td></tr>
<tr><td>AO-0304</td><td colspan="2">Dynamic adjustment of separations based on real-time detection of wake vortex allows to use runways at a higher rate when vortex</td><td>+ + +</td></tr>
</table>

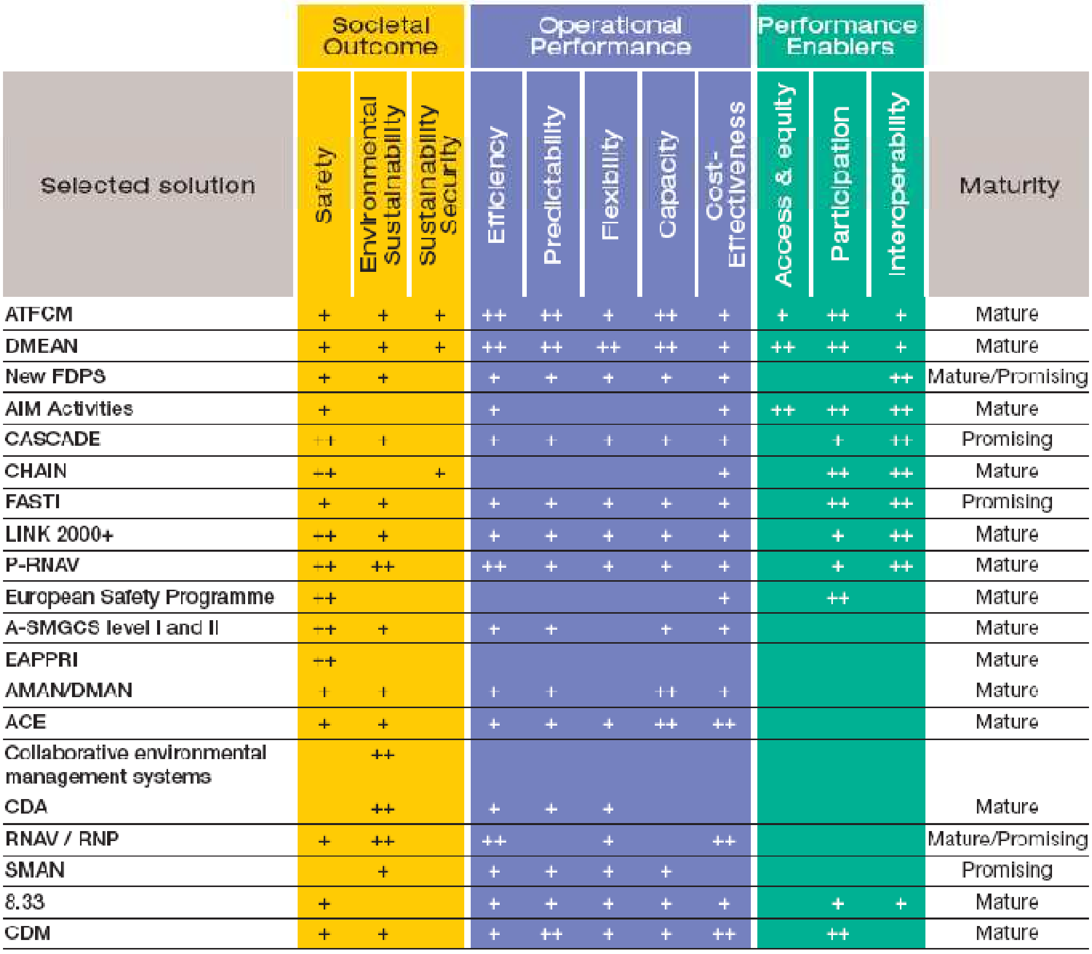
	presence on the runway is low, incrementing its throughput	
OI Steps	**Efficiency improvements**	Magnitude
AO-0103	Improves the use of taxiways and runways	+
AO-0207	Combining AMAN and DMAN together with SMAN as a unique entity and combining it with CDM processes, especially at airports with runways used for both arriving and departing flights, will improve aerodrome throughput and efficiency	+
AO-0301	The reduction of dependency on wake vortex operations under suitable weather conditions, will lead to reduced arrival / departure intervals, with a positive effect on delays (efficiency) and runway throughput (capacity)	+
AO-0302	Time based separation criteria improves the efficiency on how runway aircraft spacing is used	+
AO-0303	In the applicable situations, the controller uses reduced aircraft separations derived from forecasted wake vortex behavior, improving the use of runways	+
AO-0304	Dynamic adjustment of separations based on real-time detection of wake vortex allows to use runways at a higher rate when vortex presence on the runway is low, incrementing its usage efficiency	+
TS-0203	To improve the effectiveness of DMAN including the optimization of ground movement traffic in order to reduce the additional constraint of the airport surface capacity	+ + +
TS-0304	Integration of AMAN and DMAN with the CDM processes will improve the efficiency of airport operations by reducing the effect of interferences between close airports.	+

Table 10.8. AMAN/DMAN impact on capacity and efficiency at airports

Wake Vortex Detection			
General description			
The lifting surfaces of all aircraft produce wake vortices to some extent. The vortex created by a large aircraft can have a catastrophic effect on a small airplane following closely behind. Protection against wake vortex turbulence hazards requires that a large distance be maintained behind heavy aircraft during takeoff and landing operations. To ensure safety, spacing is currently determined assuming worst-case vortex conditions. In order to improve the capacity of airports to handle the expected increasing amount of traffic, the knowledge about the safety issues for wake vortexes mitigation has to be improved. Currently, safety distances are very conservative and depend only on category size of aircrafts, without taking into account local wind now casting. The final goal is to develop a wake vortex alert system for controllers to ensure operationally in all weather conditions adaptive appropriate not oversized separation rules.			
Affected airport process	Runway		
Affected KPIs	**AIRPORT CAPACITY**	**CAP.2.OBJ1.IND1**	Hourly number of IFR movements
		CAP.2.OBJ1.IND2	Daily number of IFR movements
	TEMPORAL EFFICIENCY	**EFF.1.OBJ1.IND1**	Percent of flights departing on-time
		EFF.ECAC.PI 2	Average departure delay per flight
		EFF.ECAC.PI 3	Percent of flight with normal flight duration
		EFF.ECAC.PI 4	Average extra flight duration
OI Steps	**Capacity improvements**		Magnitude
AO-0301	The reduction of dependency on wake vortex operations under suitable weather conditions, will lead to reduced arrival / departure intervals, with a positive effect on delays (efficiency) and runway throughput (capacity)		+ + +
AO-0303	In the applicable situations, the controller uses reduced aircraft separations derived from forecasted wake vortex behavior, maximizing runway throughput		+ + +
AO-0304	Dynamic adjustment of separations based on real-time detection of wake vortex allows to use runways at a higher rate when vortex presence on the runway is low, incrementing its throughput		+ + +
OI Steps	**Efficiency improvements**		Magnitude
AO-0303	In the applicable situations, the controller uses reduced aircraft separations derived from forecasted wake vortex behavior, improving the use of runways		+
AO-0304	Dynamic adjustment of separations based on real-time detection of wake vortex allows to use runways at a higher rate when vortex presence on the runway is low, incrementing its usage efficiency		+
AO-0103	Improves the use of taxiways and runways		+
AO-0301	The reduction of dependency on wake vortex operations under suitable weather conditions, will lead to reduced arrival / departure intervals, with a positive effect on delays (efficiency) and runway throughput (capacity)		+

Table 10.9. Wake Vortex Detection impact on capacity and efficiency at airports

Importantly, each of these tools achieves a local improvement (those in Table 10.7, Table 10.8 and Table 10.9) that later on is reflected on KPIs (global representation). The qualitative expected global contribution by SESAR from their individual implementation is specified in [B30], recopied here as Figure 10.1:



	Societal Outcome			Operational Performance					Performance Enablers			
Selected solution	Safety	Environmental Sustainability	Sustainability Security	Efficiency	Predictability	Flexibility	Capacity	Cost-Effectiveness	Access & equity	Participation	Interoperability	Maturity
ATFCM	+	+	+	++	++	+	++	+	+	++	+	Mature
DMEAN	+	+	+	++	++	++	++	+	++	++	+	Mature
New FDPS	+	+		+	+	+	+	+			++	Mature/Promising
AIM Activities	+			+				+	++	++	++	Mature
CASCADE	++	+		+	+	+	+	+		+	++	Promising
CHAIN	++		+					+		++	++	Mature
FASTI	+	+		+	+	+	+	+		++	++	Promising
LINK 2000+	++	+		+	+	+	+	+		+	++	Mature
P-RNAV	++	++		++	+	+	+	+		+	++	Mature
European Safety Programme	++							+		++		Mature
A-SMGCS level I and II	++	+		+	+		+	+				Mature
EAPPRI	++											Mature
AMAN/DMAN	+	+		+	+		++	+				Mature
ACE	+	+		+	+	+	++	++				Mature
Collaborative environmental management systems		++										
CDA		++		+	+	+						Mature
RNAV / RNP	+	++		++		+		++				Mature/Promising
SMAN		+		+	+	+	+					Promising
8.33	+			+	+	+	+	+		+	+	Mature
CDM	+	+		+	++	+	+	++		++		Mature

Legend
blank = neutral; + = positive impact; ++ = substantially positive impact

Figure 10.1. Assessment of the level of contribution of selected solutions to KPAs and their maturity

It is to mention, that the quantitative analysis (in %) of the improvement that each enabler and KPI will represent for CAP and EFF for the BCN airport case should be performed once all developments provided by SESAR have been implemented.

However, it is possible to present a picture of how this capacity and efficiency improvement is going to be executed over time. Figure 10.2 and Figure 10.4 represent this evolution.

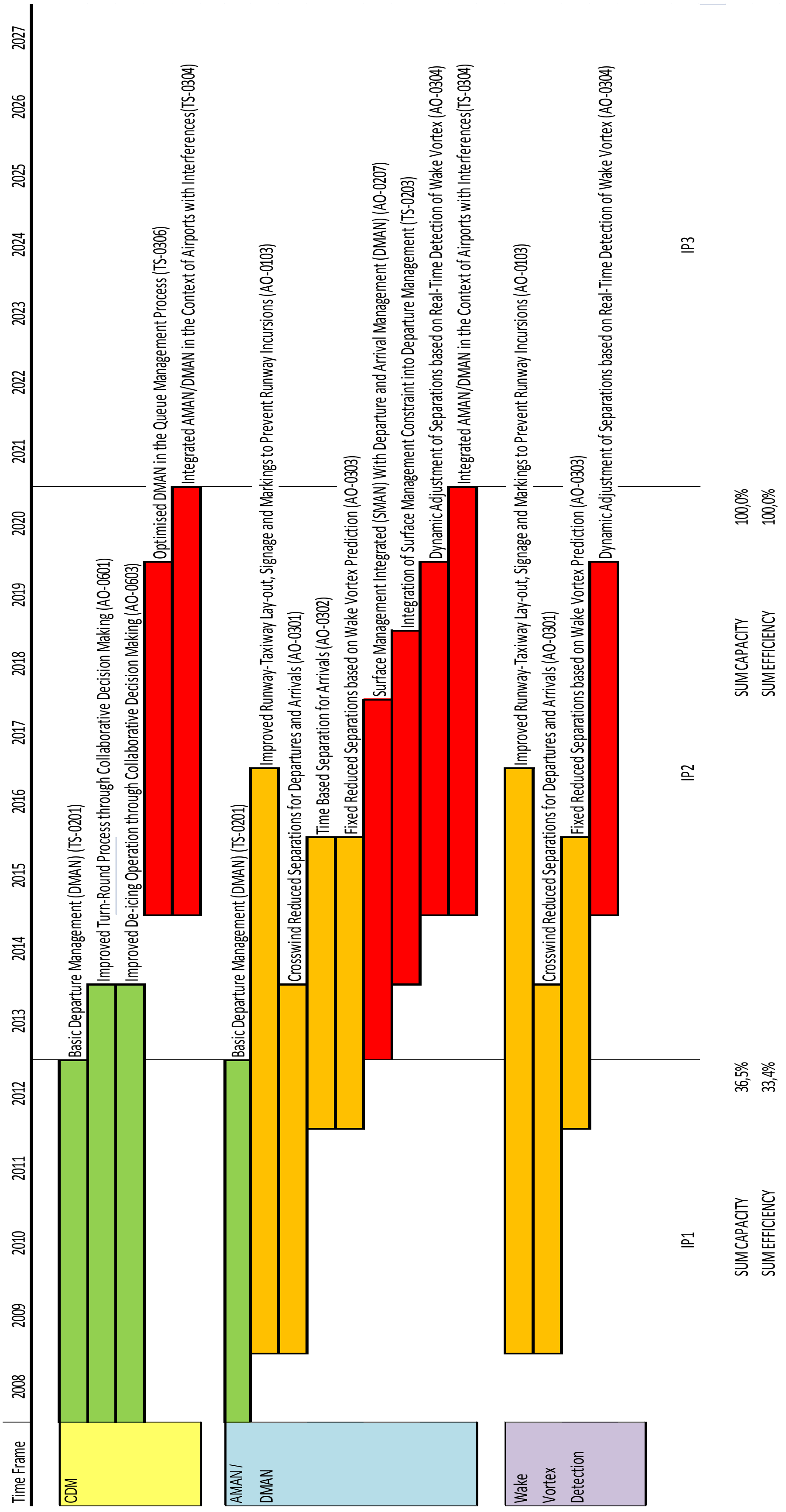


Figure 10.2. OI Steps applicable to BCN T1 airport case sequenced over time

In Figure 10.2 it can be seen that each OI Step affecting BCN airport is depicted as a function of its execution time and duration. Each OI Step is included in a different Concept Story Board.

The SESAR Concept Story Board presents the list of OI steps according to 6 distinct ATM service levels:

- Base Line (Level 0 and 1)

Service level 0 consists of rolling out current best practices and deploying available technologies, aiming at providing the processes and system support for efficient collaborative planning and timely decision making across the network.

Service Level 1 aims to achieve the required interoperability between ATM partners to enable smooth migration to trajectory-based operations.

- Time Based Operations (Level 2)

Service Level 2 introduces the fundamental changes to the progressive implementation of an information rich and information sharing environment with SWIM supporting the Shared Business Trajectory.

- Trajectory Based Operations (Level 3)

The use of free routing is extended, and a new model of airspace categories will be introduced to pave the way to target two categories contemplated in the SESAR Concept of Operations. This is complemented by airspace organizations measures for an extensive dynamic management of En-Route and terminal airspace. ATC automation will benefit from full use of 4D shared trajectory environment, thus making it possible the implementation of a full set advanced controller tools as well as further assistance to controller in support of precision trajectory operations and effective queue management.

- Performance Based Operations (Level 4)

Service Level 4 contributes to the transition to the ATM Target Concept with full implementation of enhanced trajectory management through 3D precision clearances for user preferred trajectories and of ASAS cooperative separation applications. For airports remote tower operations are introduced and specific procedures based on synthetic vision system are defined.

- SESAR Vision (Level 5)

Main features of Service Level 5 will be the implementation of 4D Precision Trajectory Clearances and the introduction of ASAS Self-Separation in a mixed mode environment.

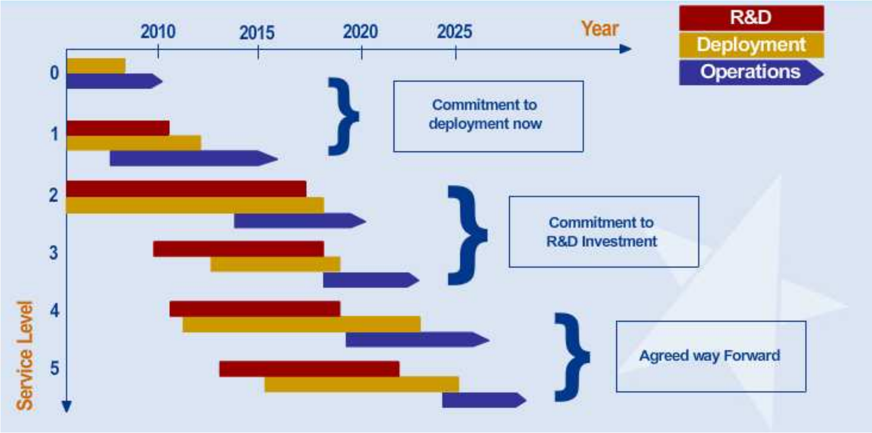


Figure 10.3. ATM Service Levels deployment [W1]

In Figure 10.2, the OI Steps of interest represent three service levels: SL0 (in green), SL1 (in orange) and SL2 (in red). Each phase of service level improves capacity and efficiency as follows:

	CAP	EFF
SL0	18%	20%
SL1	39%	35%
SL2	42%	45%
	100%	100%

Table 10.10. Capacity and efficiency evolution per ATM Service Level

It can be seen that SL1 represents the largest evolution for BCN's airport capacity and SL2 for BCN's airport efficiency.

To have a better idea on how is this improvement evolving over time (since service levels have no fixed time definition); it is interesting to look at its status at the end of each Implementation Package (which are fix defined over time instead)[38]:

IP1	covers ATM service levels 0 and 1 (roughly)
IP2	covers ATM service levels 2 and 3 (roughly)
IP3	covers ATM service levels 4 and 5 (roughly)

---

[38] Recall Figure 6.14 and section 6.3.2.1.2.2

Again, for the BCN case, only IPs 1 and 2 are influenced, and the percentage evolutions is:

	IP1		IP2	
	CAP	EFF	CAP	EFF
% increment	36,5%	33,4%	63%	66,6%
% completion	36,5%	33,4%	100,0%	100,0%

Table 10.11. Capacity and efficiency evolution per Implementation Package

which means that the biggest improvement happens during IP2 (from 2012 on). Finally, a more detailed yearly evolution is depicted in Figure 10.4:

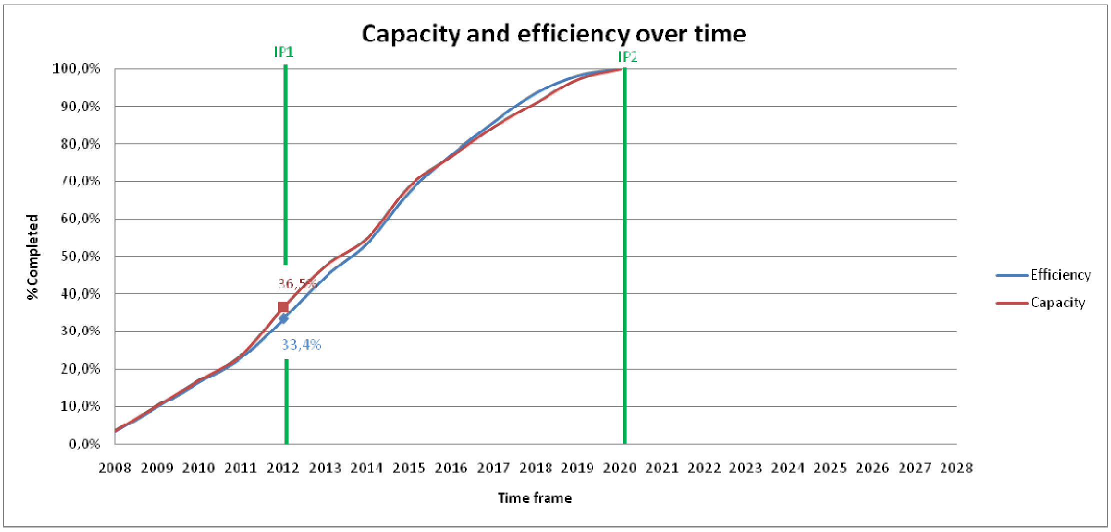


Figure 10.4. Capacity and efficiency at T1 Barcelona airport over time

It is worth remembering that in section 6.4.3 it was explained that the capacity increase expected by D4 over time is:

- up to +20%, depending upon infrastructure configuration once IP1 is completed;
- from 8% to 30% at the end of IP2 depending on the runway system category.

In our case, this theoretical increase would mean that the following values could be reached:

2009	2013 (end IP1)	2020 (end IP2)
62 ops/h	74 ops/h	80 ops/h

Table 10.12. Barcelona's airport capacity theoretical increase over time

So, to sum up, it is clear that both capacity and efficiency of BCN's airport are going to increase in the coming years thanks to the SESAR program. What is uncertain for now is how much capacity and efficiency will be incremented (150%, 200%...), but what can be said is that within this improvement, both will experience the biggest evolution rate from 2012 on until their entire completion on 2020.

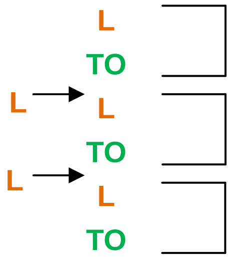
11 SESAR'S BENEFITS FOR T1 BARCELONA AIRPORT

11.1.1 Runway capacity improvement

One of the most limiting subsystems at the airport of Barcelona is its runways.

CDA procedures, which SESAR introduces, could increase the landing capacity of the runways, given that aircraft would describe a more optimal and accurate descent profile, it would be possible to reduce the separation between aircraft in the landing sequence (as long as a Wake Vortex Detection subsystem is available to help preventing accidents).

The problem is that Barcelona airport presents a series of severe restrictions on takeoff phase which strongly limit the increase in capacity of its runways. Because of this, take off sequencing could not vary even this significant increase in landings. It could be arranged for example, by fitting landings of small aircraft in between each sequence of "one landing for every take off" (but this would mean that the current segregated mode would be kept):



A solution could be to operate in independent operations regime, as this would represent an increase of the airport's capacity up to **93 ops / h**[39] (a 50%) for both runways, but there are series of problems that prevent this:

1. 3rd runway is too short and jumbos like B747 have to take-off from the long runway, which implies that a sequencing of aircraft must exist, and therefore, NO independent operations.

2. ICAO defines a minimum separation criteria between aircraft in 2nd segment that, unfortunately, given the defined take-off procedures (immediate turn towards the sea) cannot be met in case of independent operations:

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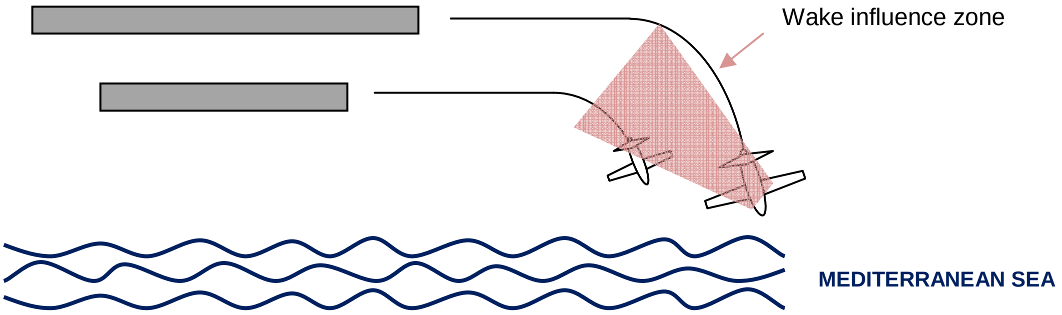
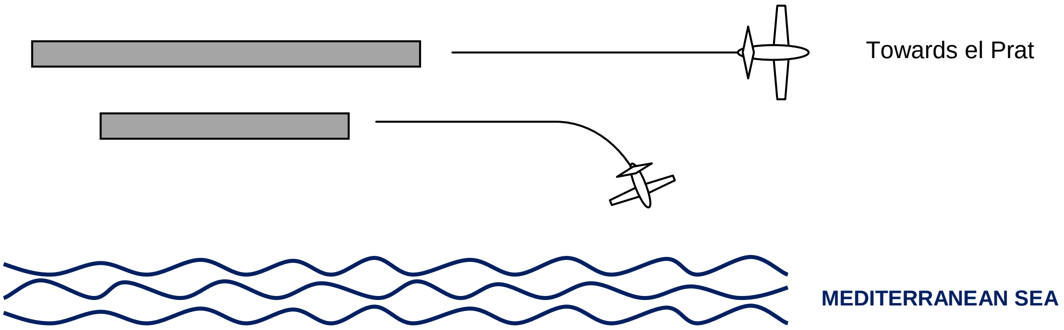
[39] See Annex 7



It can be seen that separation is too short and A320 is completely affected by the wake vortexes coming from B747, and this makes independent operations to be not operable.

Possible solutions could be:

- To perform take-offs from the long runway in straight line towards El Prat, but, even if it is not allowed nowadays already, the City Hall of El Prat would never authorize that fully-loaded B747s pass over the city in their way to the cruise level, mostly because of noise and risk danger reasons.



- Another option would be to climb with a very high gradient so that when the plane would pass over El Prat it would be already at a high altitude and there would be no environmental noise affecting the city. But such gradient implies a very high fuel consumption (30%) which airlines would not like to pay and, in addition, more pollution is generated.

3. Finally, the problematic situation with Gavà and Castelldefels neighborhoods that was already described in 9.1.2.1.1 has already introduced the eastern / western configurations due to noise issues that obviously do not allow an independent operations configuration.

As a result, no matter where the wind blows or what aircraft concerned, there is always a procedure that is limited and makes the operation of the airport to be sequenciated. AENA has already done this study and they noticed that it will never be possible to overcome 80 to 82 operations/hr.

Then, for allowing TRUE independent operations a 4th runway should be built literally in the sea, and therefore separation criteria would be accomplished. In this case, the operation of the airport would be: 4th runway + the two current parallel ones operating in a segregated mode.

As a conclusion, **SESAR could improve the hourly number of landings at Barcelona's airport, but because of current airspace limitations this improvement could not be reached only by means of runway capacity** since the airport is "closed" in terms of noise in the takeoff phase.

11.1.2 Delay reduction

According to the document [B9] of Eurocontrol, CDM implementation can bring a **3% improvement in terms of delay at the airport** (this value corresponds to a baseline scenario and according to expert's judgment). Qualitatively, this 3% of delay improvement could lead to a reduction of 3% of buffer time in the long term.

So, as a conclusion, **SESAR CDM will improve the efficiency of T1 Barcelona airport by a 3% of reduction in delays,** which in values means to achieve new delay rates of **17.8 min delay per hour or 17 seconds delay per flight.**

12 ENVIRONMENTAL IMPACT

The Air Transport Industry is an environment minded industry. Continuous research work in all relevant domains - to reduce noise and gaseous emissions that contribute to climate change – is conducted and spends considerable budgets on finding solutions. New technology and ambitious improvement programs, both on infrastructure, systems and services have resulted in:

- significant reduction of aircraft noise and emissions
- improved fuel efficiency
- lighter structures

At the same time the challenges are more and more demanding. With constant traffic growth, environmental impact requires even more sophisticated management and interaction from the points of view of societal expectations and economic importance.

ATM is concerned with environmental impact of aviation at every stage of the flight. Emissions might be reduced through the implementation of an efficient route network, flexible use of airspace, reduced holding and reduced taxiing. Noise has been significantly reduced over the last decades through extensive modernization program conducted by all of the engine manufacturers.

Improved fuel efficiency directly reduces emissions and lighter and larger structures carry more payload more efficiently.

12.1 Some basics

CO_2

It is thickening the Earth’s natural CO2 blanket. The amount of CO2 globally emitted by an aircraft depends on different parameters. Average: for every ton of jet fuel burnt, approx. 3.15 tons of CO2 are emitted.

NOx

It tends to cause increased ozone concentration (O3) thus enhancing the global warming effect. But its life time is shorter and its effects more local.

Water vapor

In certain conditions, aircraft moving through the atmosphere cause white condensation trails (contrails). They form in the upper troposphere and have an overall global warming effect. In certain conditions, contrails can contribute to the formation of cirrus clouds. Current research results suggest that the global warming effect might be quite substantial.

Other aircraft emissions

- soot and sulphate particles are involved with the formation of contrails
- hydrocarbons react with NOx and sunlight and participate in the formation of ozone

12.2 Environment KPAs

Environmental Sustainability is an area, which is composed of many different influence factors, some being directly linked to other KPAs and addressed within those KPAs performance targets. In particular, CO_2 emissions are directly linked to the Flight Efficiency, which addresses the impact of improved flight operations on fuel consumption (e.g. impact of more direct routes on reduction of fuel consumption).

The objective for environmental sustainability of a 10% reduction target was related to CO_2 emissions: since those are directly proportional to the fuel burnt (“molecular effects”), creating a specific CO_2 Performance Indicator that just replicates a Fuel Efficiency Performance Indicator would be simply confusing. However, it is equally clear that, within the trade-off analysis between KPAs, the Efficiency KPA values shall aggregate both the direct price of fuel and the CO_2 impact it has on environment.

Regarding the other environmental influence factors, such as noise, further work will be needed since the noise impact is intrinsically linked to the airport profile (layout, proximity to urbanized zones and procedures used) and aircraft characteristics. In addition to the results established by the SESAR Consortium, other on-going research in this field (e.g. regarding gaseous emissions, contrails) should in the future allow to consolidate the performance target values for the Environment Sustainability KPA, taken to mean achieving a balance between environmental, social and economical impacts and imperatives whilst serving demand.

The ATM Target Concept will significantly contribute to the reduction of the environmental impact that can be attributed to ATM in terms of noise, local air quality, fuel burn and CO_2 emissions.

Key environmental strengths of the ATM Target Concept are:

- the drive for trajectory efficiency from gate-to-gate which will lead to reduced fuel use;
- improved navigation capability and trajectory management which will allow for improved noise control; and

- Collaborative Environment Management that is provided with high quality and up to date information.

However, there is a trade-off between further environmental improvements and operational KPAs. For instance, the aim to develop regional airport capacity may have adverse environmental implications in terms of the number of people affected by noise, induced aircraft lower load factors, and increased ground transport impacts.

12.2.1 Environment Focus Areas

SESAR D2 Initial Focus Areas are:

FA	OBJ	KPI	TGT	
ENV.1	Environmental constraint management			
	OBJ1	Ensure that a higher percentage of proposed ATM constraints will be subjected to an environmental/socio-economic assessment		
		IND1	Percentage of proposed ATM constraints which has been subjected to an environmental/socio-economic assessment	
			TGT1	All proposed environmentally related ATM constraints will be subject to a transparent assessment with an environment and socio-economic scope
	OBJ2	After proposal of ATM constraints, ensure that in more cases the best alternative solution from a European Sustainability perspective is adopted		
		IND1	Percentage of cases in which the best alternative solution from a European Sustainability perspective is adopted	
			TGT1	Following the environmental/socio-economic assessment, the best alternative solutions from a European Sustainability perspective are seen to be adopted in all cases.
ENV.2	Best ATM Practice in environmental management			
ENV.3	Compliance with environmental rules			
	OBJ1	Increase the degree in which local environmental rules affecting ATM are respected		
		IND1	Percentage of cases in which local environmental rules affecting ATM are respected	
			TGT1	Local environmental rules affecting ATM are to be 100% respected
ENV.4	Atmospheric impacts			
	OBJ1	Reduce the gaseous emissions which are attributable to inefficiencies in ATM service provision		
		IND1	Amount of CO2 emissions which is attributable to inefficiencies in ATM service provision	
		IND2	Amount of NOx emissions which is attributable to inefficiencies in ATM service provision	
		IND3	Amount of H2O emissions which is attributable to inefficiencies in ATM service provision	
		IND4	Amount of particulate emissions which is attributable to inefficiencies in ATM service provision	
	OBJ2	Minimize other adverse atmospheric effects (e.g. contrails) to the extent possible		
ENV.5	Noise impacts			
	OBJ1	Minimize noise emissions for each flight to the extent possible		
	OBJ2	Minimize noise impact for each flight to the extent possible		

Table 12.1. Environment Focus Areas [S2]

12.2.2 ECAC Performance Indicators for Environment

At European level, ENV addresses to reduce the environmental impact per flight by applying air traffic management measures.

KPI	TGT
Fuel burnt	Total annual amount of fuel burnt divided by number of movements
	Reduction by 10% of the total amount of fuel burnt
Annual CO_2	Total annual amount of CO_2 divided by number of movements
	Reduction by 10% of the annual amount of CO_2
Annual H_2O	Total annual amount of H_2O divided by number of movements
	Reduction by 10% of the annual amount of H_2O
Annual SO_x	Total annual amount of SO_x divided by number of movements.
	Reduction by 10% of the annual amount of SO_x
Annual NO_x	Total annual amount of NO_x divided by number of movements.
	Reduction by 10% of the annual amount of NO_x
Annual HC	Total annual amount of HC divided by number of movements
	Reduction by 10% of the annual amount of HC
Annual CO	Total annual amount of CO divided by number of movements
	Reduction by 10% of the annual amount of CO

Table 12.2. ECAC Performance Indicators for Environment

12.2.2.1 Proposed KPIs for Airport Environment

ENV.ECAC.APT.	Definition
PI 1	Amount of CO_2 emitted below 3000ft per flight movement (average)
PI 2	Amount of NO_x emitted below 3000ft per flight movement (average)
PI 3	Amount of SO_x emitted below 3000ft per flight movement (average)
PI 4	Amount of CO emitted below 3000ft per flight movement (average)
PI 5	Amount of HC emitted below 3000ft per flight movement (average)
PI 6	Amount of PM_{10} emitted below 3000ft per flight movement (average)
PI 7	Amount of $PM_{2.5}$ emitted below 3000ft per flight movement (average)
PI 8	Surface areas where those pollutants exceed elementary limits (concentration maps on annual average)
PI 9	Number of Population inside those surface areas (population maps frozen at Baseline year to exclusively capture aviation influence)

Table 12.3. ECAC Performance Indicators for Airport Environment

12.3 The eternal triangle

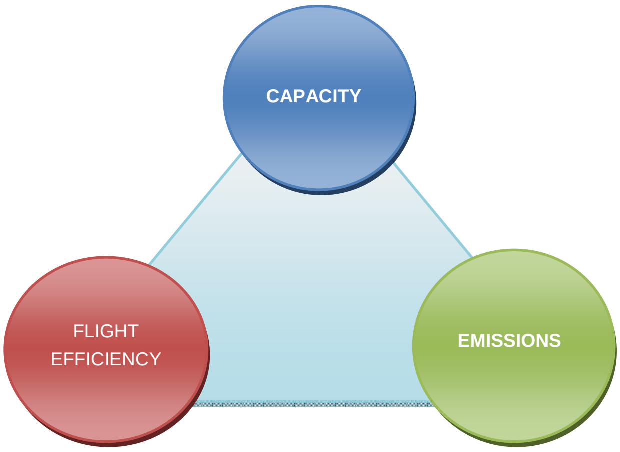


Figure 12.1. Capacity, flight efficiency and emissions: the eternal triangle

The need to strike the right balance between performance in flight efficiency, emissions and capacity will remain a key challenge in the near future.

With the traffic build-up in the 1990s and the increase in delays, some concepts such as Reduced Vertical Separation Minima (RVSM) had the benefit of increasing capacity and improving flight efficiency. Having the freedom to put routes anywhere has resulted in the design of routes which spread out the traffic for capacity reasons, with a somewhat negative effect on flight efficiency, increasing the overall route length and preventing aircraft from flying their preferred vertical flight profiles (and increment emissions as well).

Nowadays, aircraft operators reverted to looking at how to make profit for a change and started to ask for capacity without flight inefficiencies, i.e. they resisted the introduction of routes which were longer than the ones they replaced and complained about the capping of flights at uneconomical flight levels. Also, environmental concerns became something more than airport noise issues and EUROCONTROL developed emission mitigation projects such as CDA in SESAR to deal with such concerns.

However, delays are still the principal performance indicator.

12.3.1 SESAR's environmental challenges in numbers

Improved airspace design and sectorization solutions will be required in the coming years to address both capacity and flight-efficiency challenges.

Between 1999 and 2008, while traffic grew a 27%, the capacity of the network increased by 47% reducing total en-route ATFM delays by 66%. In parallel, routes flown were shortened by an average of approximately 5 km. Together these improvements generated 3.5 million tons of CO2 savings per year. Currently, the European ATS route network is only 3.5% longer than the great-circle distances (for intra-European flights).

As a result of the combination between traffic growth and delay targets, the European ATM network will need a capacity increase of approximately 30% over the next five years. Airspace design will be one of the major contributors to this capacity increase (around 15%).

In terms of flight efficiency, the results previously mentioned indicate that, between 2008 and 2010, flying distances will be reduced by approximately 12 million NMs, representing the equivalent of 72,000 tons of fuel saved, or reduced emissions of 240,000 tons, or €60 million.

Figure 12.2. SESAR's environmental targets

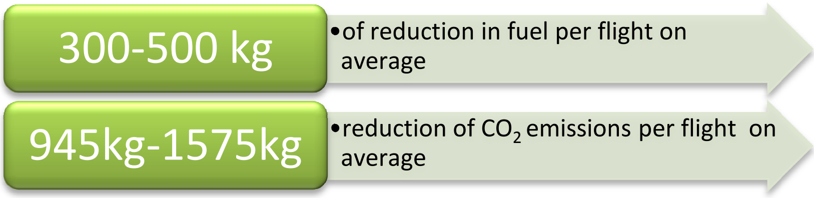


Figure 12.3. SESAR's environmental general values

12.4 SESAR's tools for qualitative analysis of the environmental constrains to growth

There is an emerging view that international or regional agreements on environmental limits (noise, air quality and climate change/global warming) that should be reached as soon as possible. For this, EP3 defines the following areas for analysis:

- Global Emissions (Green House Gas emissions (GHG), Global Warming, Climate Impact etc.);
- Noise (dB, exposed population);
- Local Air Quality (Particulate Matter (PM), Hydrocarbons (HC), Volatile Organic Compounds (VOC), Ozone, etc.); and
- Meteorology (not a performance area)

Each of the first three areas aims to provide wide environmental performance information for ECAC at Airport, TMA, En-Route, Network and Local layers.

12.4.1 Global Emissions

Global Emissions measure the complete set of emissions produced by only the aircraft along its complete mission execution. This is done on a flight by flight base. A typical application is for example the assessment of the emissions produced at one day by all movements over Europe.

12.4.1.1 Problematic

Aircraft emissions are a major issue for the EU given the projected doubling of air traffic related carbon dioxide emissions between 1990 and 2010 and the EU Kyoto commitment to cut GHG emissions by 8% below 1990 levels by 2010.

Air transport’s climate impact has two main agents playing an important role:

- Carbon dioxide from aircraft burning fossil fuels; and
- Other effects in the upper atmosphere, linked to emissions of NO_x, particles and water vapor.

These impacts derive from primary emissions that are present in the aircraft engine exhaust gases as they leave the aircraft and secondary emissions that are produced in the atmosphere by chemical reactions that use the primary emissions either as a reactant or a catalyst.

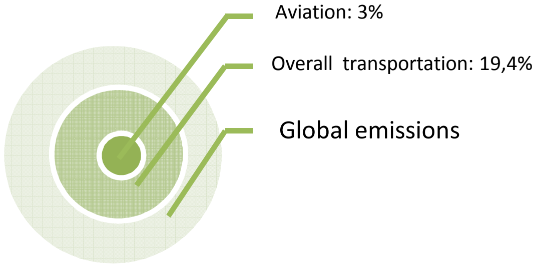


Figure 12.4. Contribution to GHG

Current estimates suggest that air traffic’s contribution to climate change could be larger than originally thought, due to cirrus cloud enhancement, although considerable uncertainties remain.

12.4.1.2 Solutions

In the near to midterm, improving fuel efficiency is the most potentially rewarding mitigation approach to directly reducing or limiting air transport’s climate impacts.

There is an emerging view that aviation's single biggest environmental challenge is that of mitigating its effects on global warming. This is principally an en-route issue (even if not covered in this report).

Early action to reduce carbon dioxide over the long term is essential, but at the same time, priority to reducing the uncertainty over the effects of contrails, cirrus cloud and NO_X should be given.

Flying at altitudes or along routes that minimize the chance of contrail production might reduce the chance of enhancing cirrus cloud, although it would lead to an increase in CO_2 emissions and entail significant ATM problems.

In the near future, there is some interest on the use of voluntary measures. There is also interest in carbon dioxide emissions charges.

12.4.2 Local air quality (LAQ)

LAQ assessments usually include the aircraft emissions from its Landing and Take Off cycle, Auxiliary Power Unit emissions, engine testing, passenger surface access to airports, fuel storage, background concentrations, emissions of ground vehicles and equipment and buildings etc.

12.4.2.1 Problematic

European air quality standards generally become more stringent in response to the adverse effects of local air pollution on human health, and, as a consequence LAQ is re-emerging as an increasingly important environmental issue at airports.

In 2005 and again in 2010, local authorities governing the community areas around airports, amongst others, will need to comply with EU-wide limits for specified pollutants. Projections indicate that this may be difficult for certain major EU airports. There are also early signals that aviation will need to comply with other wider air quality standards, such as those of the World Health Organization (WHO), possibly as early as 2010.

It is also clear that under some growth scenarios a number of European airports may have air quality problems over the long term, at 2030.

Aviation emissions impacts are distinct from noise impacts for a variety of reasons. These include a broader range of time scales over which the effects can occur (from a day to 1000 years) and a broader range of scales over which the effects are felt (local, regional and global). As a whole, emissions are expected to increase in relation to traffic growth, and to constitute a greater proportion of both the global man-made climate impact and local contributions to regional emissions around airports.

12.4.2.2 Solutions

There are substantial technological research programs in Europe and the USA aimed at delivering low NO_x technologies.

12.4.3 Noise

The standard methodology for noise assessment is the production of noise maps around airports according to specific noise metrics. These metrics address noise impact of airport inbound and outbound movements, either at a single-event level or for a complete traffic sample. Noise assessment covers the aircraft contribution only, excluding any other sources such as ground vehicles, etc.

12.4.3.1 Problematic

Community noise and its associated quality of life, health, congestion and environmental effects, as well as local (air) pollution can act to constrain the growth of aviation in the near future as well as over the long term. Their specific impact depends primarily on three factors:

- The patterns of aviation operational activity;
- The size, dimension and placement of airport facilities; and
- Public and policy acceptance of aviation as a generator of economic and social wealth.

These impacts have become important in Europe and currently occur for the most part, but not exclusively, at the major airport hubs.

12.4.3.2 Solutions

Fleet renewal will help to reduce or stabilize the effects of aircraft noise impacts, but, however, noise constraints are predicted increase steadily thereafter on a European scale, over the next twenty years, driven by the congestion related effects of air traffic growth and the increasing urbanization of Europe’s population.

12.5 SESAR’s greener sky: the AIRE program

One of the top priorities of the SESAR program is to reduce by 10% the environmental impact per flight.

To take an example of a Stockholm – New York flight operated with an Airbus A330, current consumption is about 46,000 kg of fuel, equivalent to 144,000 kg of CO_2. As a result of greener air traffic management, savings are estimated to be in the range of 10%, meaning in this case 4,600 kg of fuel, or 14,400 kg of CO_2.

The *Atlantic Interporeratibility Initiative to Reduce Emissions* (AIRE) is a program designed to improve energy efficiency and lower engine CO_2 emissions and aircraft noise by developing environmentally friendly air transport operations on transatlantic routes under an agreement between the European Commission and the US FAA. The SESAR JU is responsible for its management from a European perspective, under the authority of the European Commission.

Under this initiative, 17 industry partners will work collaboratively to perform integrated flight trials and demonstrations validating solutions for the reduction of CO_2 emissions for ground movements and terminal and oceanic operations to test novel green flight procedures under real conditions.

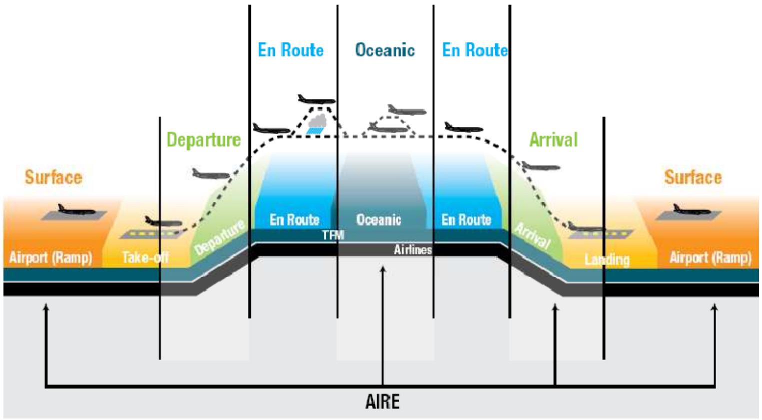


Figure 12.5. AIRE: a gate-to-gate view [B31]

12.5.1 Ground movement

On average, aircraft are responsible for only about half of the emissions produced at and around airports. The airport-related emission sources are generally categorized under aircraft emissions (aircraft engines and auxiliary power units), aircraft handling emissions (mainly ground support equipment, airside traffic, and aircraft de-icing and refueling). Infrastructure or stationary sources (surface de-icing, power/heat generation plant, construction activities, etc.) and all vehicle traffic sources associated with the airport on access roads.

12.5.2 Terminal

Airports are one of the bottlenecks of the present air traffic management system. Air traffic flows are managed on a first-come, first-served basis leading to unnecessary fuel burn, as air traffic control often requires aircraft to level off and hold at intermediate altitudes during descent. “Green” approach CDAs and green climb trials at Madrid, Paris CDG and Stockholm airports involving DSNA, Thales, AVTECH, LFV, Novair, Egis Avia, AENA, INECO, Iberia and Air France are planned. The first “required navigation performance“ CDA approach ever to be performed in Europe is now planned at Stockholm’s Arlanda airport in cooperation with Airbus.

12.5.3 Oceanic

In the present system, ever-increasing traffic flows between Europe and North America are leading to inefficient fuel consumption, fewer accepted pilot requests and airline schedule disruptions. Trials for “green” oceanic procedures and techniques (speed, horizontal and lateral flight profile optimization) are performed.

12.6 Environmental factors affecting airport capacity

Environmental constraints have increasingly become an integral part of airport capacity. Environmental issues remain a major impediment to achieving maximum airport throughput. Without their successful resolution it will be impossible to deliver sufficient capacity.

As traffic grows, therefore, predictions say that the noise climate around airports will increase from about 2010 onwards. At the same time, EU limits on local air quality will be introduced and these can also be expected to constrain airports' ability to grow.

12.6.1 Global emissions: CDA procedures

In the absence of an internationally agreed definition of Continuous Descent Approach, Eurocontrol proposes the following: “CDA is an aircraft operating technique in which an arriving aircraft descends from an optimal position with minimum thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions.

As local conditions require, CDA may comprise any of the following:

- Standard Terminal Arrival Routes (STARs), including transitions, which may be designed with vertical profiles. The routes may be tailored to avoid noise-sensitive areas as well as including the vertical profile and the provision of Distance To Go (DTG) information;
- Provision of ‘distance from touchdown’, also referred as DTG, information by ATC during vectoring; or
- Combination of these: STARs being used in low traffic density, and DTG estimates being issued by ATC as and when radar intervention is required - e.g. during busy periods.

<u>Basic CDA:</u> The tactical procedure where ATC provides DTG information during vectoring is also known as “Basic CDA” or “B-CDA”.

<u>Advanced CDA:</u> The term “Advanced CDA” (A-CDA) is generally referring to further developments of CDA, involving Precision Area Navigation (P-RNAV) procedures, and appropriate sequencing tools to allow their use even in high density traffic situations.

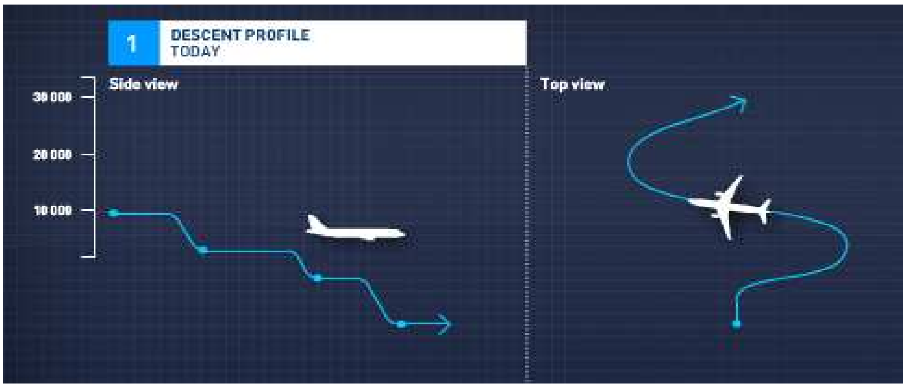


Figure 12.6. Descent profile today [W1]

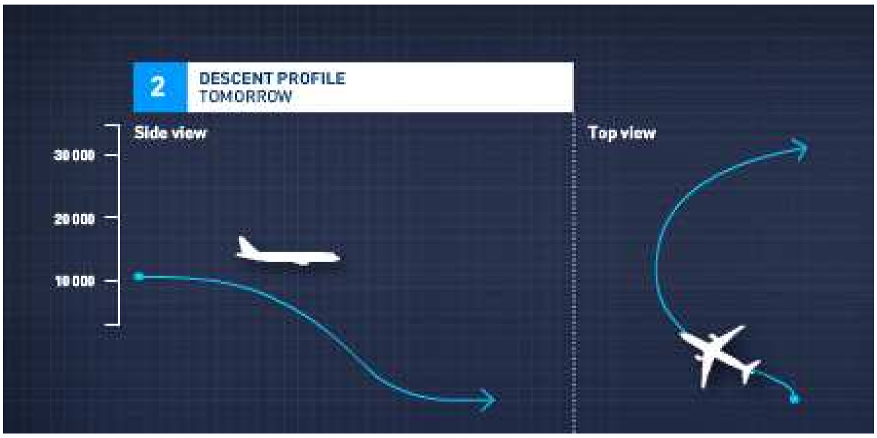


Figure 12.7. SESAR descent profile CDA [W1]

Continuous climbs and descents are two procedures that Eurocontrol expects will save time, fuel and carbon emissions. There will be a continuous climb out to the optimum flight level, then from top of descent, a continuous-descent approach. The greening issue has influenced this procedure. By following these procedures, hundreds of tons of fuel can be saved collectively every day.

As for TMA design, Eurocontrol figures show that if CDAs were to be implemented, at least 20% of European airports, annual savings to airlines would be approximately 120,000 tons of fuel, i.e. 400,000 tons CO2 per year which equates to €100 million. Additional savings could be generated through the implementation of TMA airspace redesign projects. The resulting benefits cannot be estimated as they depend on local situations.

12.6.2 Noise

It is clear that aircraft noise near airports is an issue that will not go away. Community noise and other environmental capacity impacts are already influencing the growth and development of certain European airports and therefore limiting the capacity of the entire air traffic system. At some key EU airports, noise constraints have become as important as ATC and runway capacity constraints. Some EU airports declare noise as one of the factors dictating capacity limits generally.

12.6.3 Air Quality

The contribution from aircraft engines in particular to nitrogen oxide (NO_x) is increasing again, so that air quality, particularly where related to potential health effects, is becoming another factor that limits airport capacity expansion and the ability to meet future traffic growth in the near future and over the longer term.

Current measurements and modeling of local air quality at airports show that road traffic is the major contributor to NO_x levels affecting communities around airports. Access to airports by express rail services as means to reduce car access will therefore become a major requirement for further airport expansion.

12.7 SESAR's environmental impact on T1 Barcelona airport

SESAR, as mentioned throughout this document, defines several factors or agents in the airport environment that have direct or indirect influence on the environment in terms of capacity and efficiency:

(a) New landing procedures (CDA)

After the construction in 2004 of the 3rd runway of BCN's airport, the neighborhoods of Gavà and Castelldefels (literally on the way of approach and takeoff paths) complained for excessive noise levels.

The initial idea for building this last runway was to execute independent operations and thus to increase the airport's airside capacity significantly. However, noise impact now is playing a key role, and this is the reason why runway operations configuration is a bit special, as explained in section 9.1.2.1.

So, this is a clear example of how noise constrains have a direct impact on constraining an airport's capacity. However, SESAR introduces a very interesting procedure called CDA that, if implemented appropriately, could increase landing capacity of the runways as explained in 11.1.1, and this would imply that:

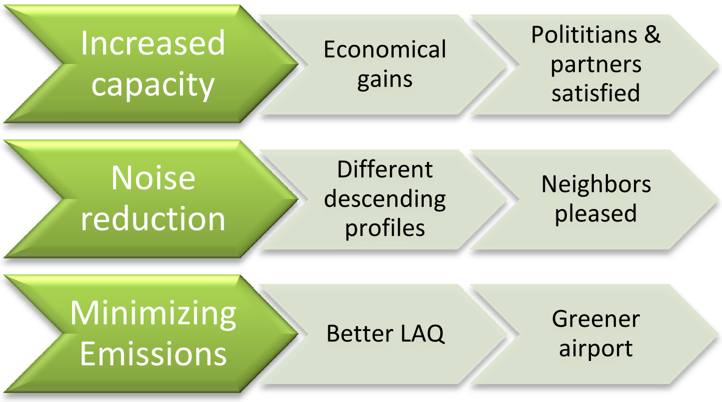


Figure 12.8. CDA's benefits for Barcelona's airport

(b) Optimization of aircraft and vehicles movements

SMAN will have a definitive influence in reducing emissions due to taxiing and movements of other mobile agents operating on the airside of the airport.

(c) Procedural improvements

Enhancements on turnaround or handling processes and the introduction of DMAN, AMAN and SMAN tools will improve efficiency as well as reducing emissions.

The following table presents the compilation of inefficiencies per flight phase, and the corresponding weighted effect in terms of fuel used.

Flight phase	Inefficiency	% Fuel used in phase	Weighted inefficiency
Horizontal en-route	6%	67%	4%
Vertical en-route	3%	67%	2%
TMA	10%	13%	1%
Ground	10%	20%	2%
Total inefficiency			9%

Table 12.4. Inefficiencies per flight phase

(d) New infrastructures

As a final remark, it was mentioned in Annex 6 that there is an existing project which pretends the construction of a new satellite around the new control tower by 2013. By increasing the capacity of Barcelona's airport in terms of enlarging its infrastructures has a big impact on its natural surroundings, namely its marshals and autochthonous bird species.

In the following pictures it can be seen the evolution of Barcelona's airport infrastructures and, at the same time, the reduction of its rich and green environment:

Figure 12.9. Barcelona Airport in 1992 (remodeled terminal for Olympic Games)

Figure 12.10. Barcelona Airport in 2009 (T1 terminal construction) [S3]

Figure 12.11. Future Barcelona Airport in 2013 (Satellite and Airport city)

It is clear that sometimes, enriching a country by feeding its demand turns to be a downfall for its natural resources. Fortunately, SESAR's premises include improving capacity and efficiency of the airports without contemplating any infrastructure enlargements, and this is a very positive point in favor for SESAR and its sustainability.

To sum up, SESAR can increase the capacity and efficiency of T1 while minimizing the environmental impact of aviation on the surroundings of Barcelona's Airport by implementing its new tools and procedures.

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

This study presents a real case study for evaluating the impact of SESAR enhancements on the capacity and efficiency of the Barcelona – El Prat Airport by analyzing the impact of the future SESAR enablers on the capacity and efficiency indicators and by evaluating the effectiveness and the applicability of the SESAR concept on increasing its capacity and efficiency.

As predicted by Eurocontrol, according to the expected growth of air traffic in the next years, SESAR turns to be more than necessary for the survival of European airspace. This important increase will affect the airport of Barcelona as well, and the present study shows that its current capacity of 62 operations per hour (given by the runway component since it is the most limiting subsystem) and its efficiency of 18.4 minutes delay per hour on the runway component will be not enough to absorb the future traffic, even if operating at best performance.

This study concludes that both capacity and efficiency of Barcelona's Airport are going to increase in the coming years thanks to the new systems and procedures of the SESAR Program.

- Thanks to new approach procedures (CDA), Barcelona's landing capacity will be incremented, but because of current airspace limitations this improvement could not be reached by means of runway capacity since the airport is "closed" in terms of noise in the takeoff phase.

- Thanks to SESAR CDM, delays will be reduced by a 3%, in means of improving Barcelona's efficiency, which in values means 17.8 min delay per hour.

Both factors will experience their biggest evolution rate from 2012 on until their entire completion on 2020 (63% for capacity and 67% for efficiency). This theoretical increase would mean, for example, that a capacity of 80 operations per hour could be reached by 2020. In terms of Service Levels, SL1 represents the largest evolution for capacity and SL2 for efficiency.

In terms of environment, SESAR will increase the capacity and efficiency of the Airport of Barcelona while minimizing the environmental impact of aviation on the surroundings of the airport by implementing its new environmental tools and procedures.

Finally, it is expected that the implementation of SESAR will represent an additional a cost for Barcelona's Airport in investment and maintenance of the new systems. To this effect, a business case is presented, containing the analysis of the costs derived from implementing the SESAR requirements in the airport and the balance with the benefits obtained.

CBA results show that Airport CDM is a solid investment given its technical applicability and economic viability, since benefits are 4 times bigger than implementation costs and the payback period is within only 2 years, which means that after the first year of implementation, during the second year the airport would already experience incoming benefits. All this at a nearly non-existent financial loss risk.

To sum up, SESAR is an extremely positive option for the Airport of Barcelona, since it brings the necessary increases in capacity and efficiency in order to cope with future scenarios and gives substantial economic benefits.

13.2 Recommendations

After concluding this study, a couple of issues should be considered:

1. As mentioned before, when talking about airspace and noise at take-off limitations, independent operations would be a definitive option for the Airport of Barcelona in terms of capacity, but for allowing TRUE independent operations a 4th runway should be built literally in the sea, and therefore separation criteria would be accomplished .

2. The Airport should really consider to implement CDM on its management system, since it has been demonstrated that is essential for improving the efficiency of the airport and, moreover, it brings important benefits as well.

13.3 Innovation

This study is innovative because:

This is the first time

- that such study has been done

Introduces new methods

- for evaluating efficiency gains in airports when introducing SESAR's new systems and procedures

It is about SESAR

- which is an innovative concept by itself

Brings to Catalan airports a detailed approach

- about the future technology and new procedures of the ATM concept in Europe

13.4 Next Steps

Given the status and the limitations encountered during the execution of this study, some of the next steps to be performed are:

1. The quantitative analysis (in %) of the improvements that SESAR enablers will represent for the Airport of Barcelona should be performed in the midterm, once all developments provided by SESAR have been implemented. Moreover, this turns to be an open issue for future projects.

2. As mentioned in the CDM Cost Benefit Analysis document, CDM should be implemented at the Airport, starting from now (2010) and by following three different phases, as shown in the following Gantt chart:

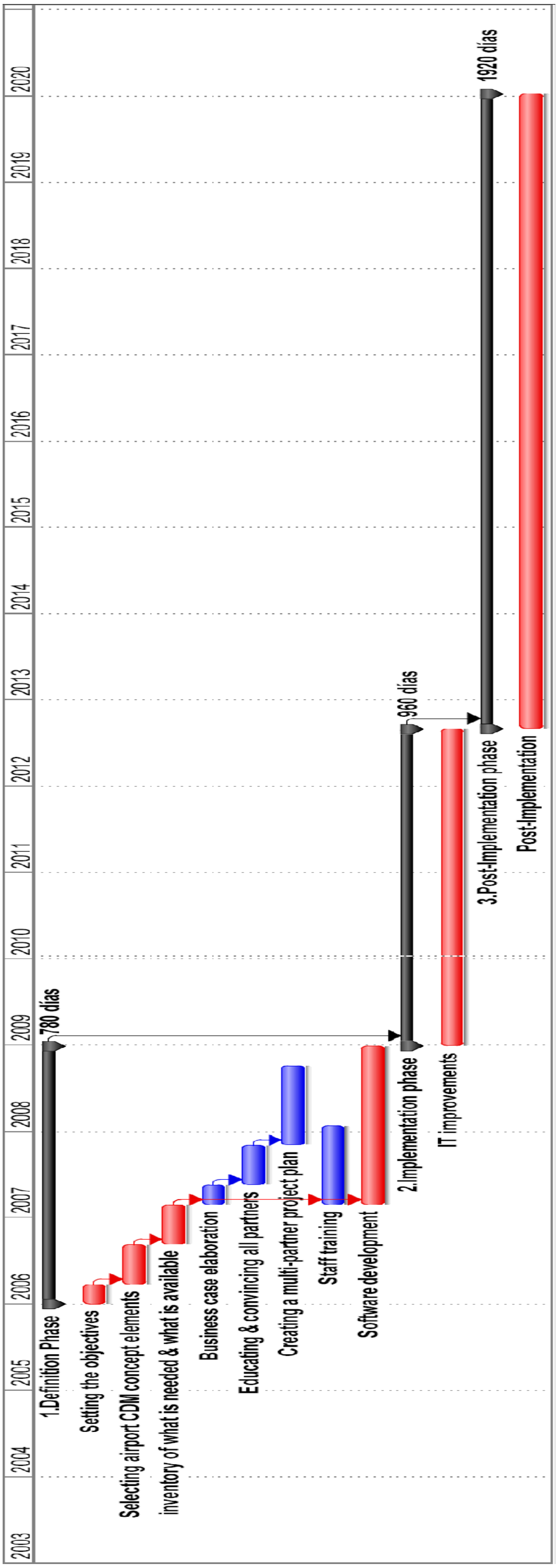


Figure 13.1. CDM implementation process at Barcelona's airport

14 ACRONYMS

ABAS	Aircraft Based Augmentation System
A-CDA	Advanced Continuous Descent Approach
ACL	ATM Capability Levels
ADS-B/-C	Automatic Dependent Surveillance -Broadcast / -Contract
AENA	Aeropuertos Españoles y Navegación Aérea
AIS	Aeronautical Information Service
AMAN	Arrival Manager
AMHS	ATS Message Handling System
ANSP	Air Navigation Service Provider
AO	Airport Operators
AOC	Airline Operational Control / Airlines Operations Centre
ASAS	Airborne Separation Assistance Systems
ASL	ATM Service Levels
ASPA	Airborne Spacing
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Service
ATSA	Airborne Traffic Situation Awareness
BIC	Best In Class
BTV	Brake to Vacate
CDA	Continuous Descent Approach
CDM	Collaborative Decision Making
CNS	Communications, Navigation and Surveillance
ConOps	Concept of Operations
DMAN	Departure Management
DOD	Detailed Operational Description
DTG	Distance To Go
FAA	Federal Aviation Agency
FCM	Flow and Capacity Management
FDP	Flight Data Processing
FMS	Flight Management System
FUA	Flexible Use of Airspace
GBAS	Ground Based Augmentation System
GHG	Green House Gas
GNSS	Global Navigation Satellite System
HUD	Head up Display

IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrumental Flight Rules
ILS	Instrumental Landing System
IMC	Instrumental Meteorological Conditions
IOC	Initial Operational Capability
IP	Implementation Packages
KPA	Key Performance Area
KPI	Key Performance Indicators
LAQ	Local air quality
LoC	Line of Changes
LVC	Low Visibility Conditions
MLS	Microwave Landing System
NOP	Network Operation Plan
OAT	Operational Air Traffic
OI	Operational Improvements
P2P	Peer-to-peer
PENS	Pan European Network Service
P-RNAV	Precision Area Navigation
PSR	Primary Surveillance Radar
PTC	Precision Trajectory Clearances
QoS	Quality of Service
R&D	Research & Development
RBT	Reference Business/Mission Trajectory
RET	Rapid Exit Taxiways
RNP	Required Navigation Performance
ROT	Runway Occupancy Time
RVSM	Reduced Vertical Separation Minima
RWY	Runway
SBT	Shared Business Trajectory
SES	Single European Sky
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
SMAN	Surface Manager
SSR	Secondary Surveillance Radar
STAR	Standard Terminal Arrival Routes
SVS	Synthetic Vision System
SWIM	System Wide Information Management
TGT	Target Operational Concept
TMA	Terminal Control Area

TTA	Target Time of Arrival
UDPP	User Driven Prioritization Process
VDL	VHF Data-Link
VNAV	Vertical Navigation
VSA	Visual Separation on Approach
WAM	Wide Area Multi-lateration
WBS	Work Breakdown Structure
WHO	World Health Organization
WP	Work Program

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