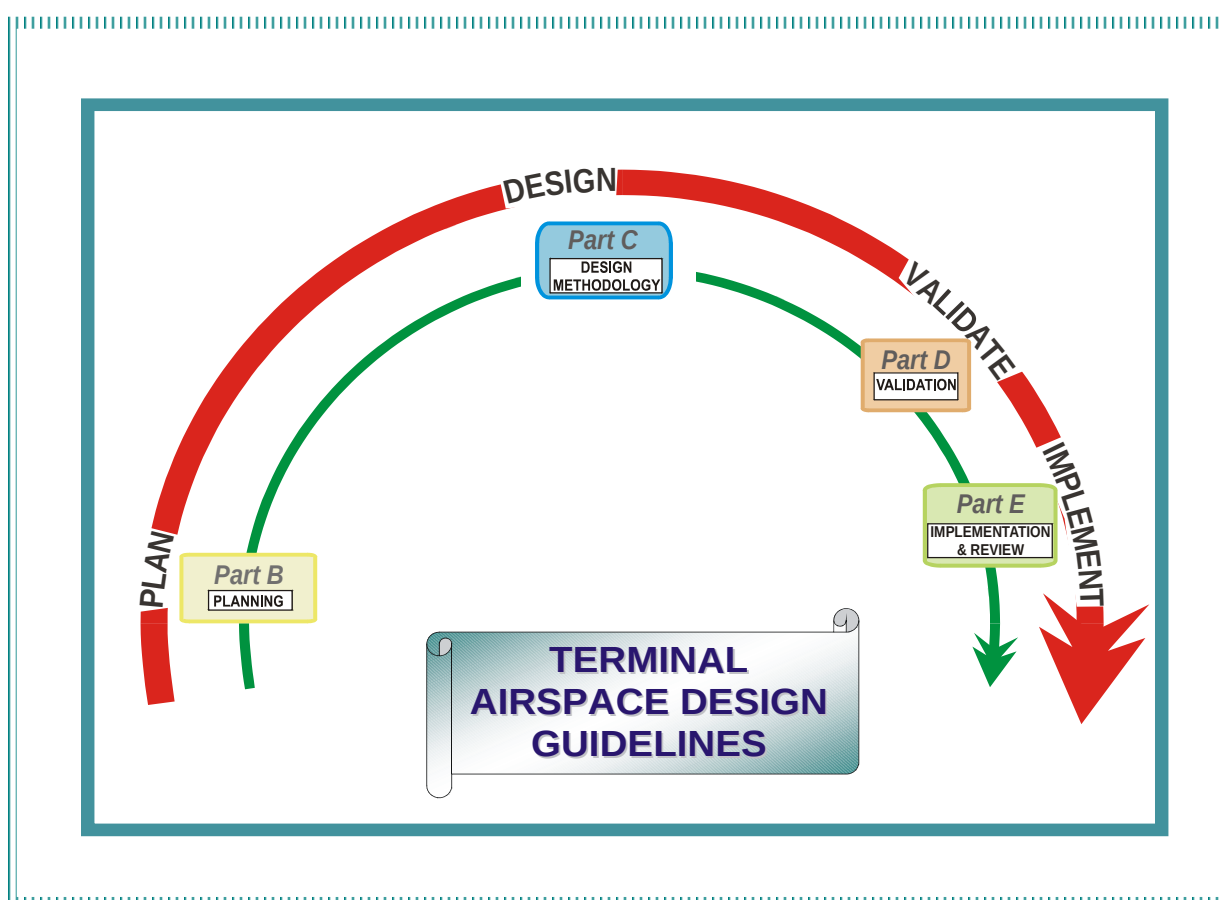


EUROCONTROL AIRSPACE PLANNING MANUAL

SECTION 5

TERMINAL AIRSPACE DESIGN GUIDELINES



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Terminal Airspace Design Guidelines

This 2ND edition of the *Terminal Airspace Design Guidelines* (Eurocontrol, 2005) replaces the first edition which was published in 1998 under the title *Terminal Airspace Design - Guidelines for an Operational Methodology*.

This document is also known as **Section 5** of the **Eurocontrol Airspace Planning Manual** (Amendment 1: 17/01/05).

The electronic version of the full Eurocontrol Airspace Planning Manual can be downloaded from the ONE SKY web site by following [this link](http://www.eurocontrol.int/eatmp/fua/index.html).

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SECTION 5

GUIDELINES FOR TERMINAL AIRSPACE DESIGN

SECTION CHECKLIST

This document is divided into five Parts (A to E); each containing several chapters. As this first checklist constitutes a new Edition (2.0) to the *Terminal Airspace Design Guidelines* within the greater *EUROCONTROL Airspace Planning Manual*, this first checklist provides a list of chapters as opposed to pages and the footer on each page of this new Edition is marked Amendment 1, 17/01/05. When future amendments are made, the checklist will be expanded.

Chapter	Edition Amendment	Date	Chapter	Edition Amendment	Date
Section 5					
5-iii	Amendment 1	17/01/05	D-Ch01	Amendment 1	17/01/05
A-Ch01	Amendment 1	17/01/05	D-Ch02	Amendment 1	17/01/05
A-Ch02	Amendment 1	17/01/05	D-Ch03	Amendment 1	17/01/05
B-Ch01	Amendment 1	17/01/05	D-Ch04	Amendment 1	17/01/05
B-Ch02	Amendment 1	17/01/05	D-Ch05	Amendment 1	17/01/05
C-ChIntro	Amendment 1	17/01/05	D-Ch06	Amendment 1	17/01/05
C-Ch01	Amendment 1	17/01/05	D-Ch07	Amendment 1	17/01/05
C-Ch02	Amendment 1	17/01/05	D-Ch08	Amendment 1	17/01/05
C-Ch03	Amendment 1	17/01/05	E-Ch01	Amendment 1	17/01/05
C-Ch04	Amendment 1	17/01/05		Amendment 1	17/01/05
C-Ch05	Amendment 1	17/01/05		Amendment 1	17/01/05
C-Ch06	Amendment 1	17/01/05		Amendment 1	17/01/05
C-Ch07	Amendment 1	17/01/05		Amendment 1	17/01/05
C-Ch08	Amendment 1	17/01/05		Amendment 1	17/01/05
	Amendment 1	17/01/05		Amendment 1	17/01/05
	Amendment 1	17/01/05		Amendment 1	17/01/05

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Terminal Airspace Design Guidelines

EXECUTIVE SUMMARY

Background

EUROCONTROL's Airspace Strategy for ECAC incorporates operational improvements to terminal airspace design. Even though it may be difficult and inappropriate to attempt to divide en-route and terminal airspace operations, an understanding of both is essential when designing a terminal airspace with a view to improving the capacity of the overall ATM system.

A document concerning the design of terminal airspace structures cannot be definitive because each structure has unique characteristics and evolves at a different rate. The development of a terminal airspace is also affected by a variety of parameters and these may vary to a large degree. These factors as well as differing policies adopted by States result in a multiplicity of design criteria. Nevertheless, there are many areas of commonality and these have provided a basis for this document.

Much material regarding terminal airspace design is available in several ICAO publications. This document neither repeats nor seeks to replace the ICAO material: it provides, instead, a complementary source of guidance from design conceptualisation to implementation for the European terminal airspace designer.

2nd Edition

This is the second edition of the *Terminal Airspace Design Guidelines* and it replaces Edition 1 of 1998 entitled *Terminal Airspace Design – Guidelines for an Operational Methodology*. This document is also identified as Section 5 of the EUROCONTROL Airspace Planning Manual and published as Amendment 1. Although these *Terminal Airspace Design Guidelines* are comprehensive, there may be aspects of the document which require amendment or expansion and any comments or suggestions would be welcome. These should be addressed to: **EUROCONTROL (AFN-BD), Rue de la Fusée 96, B-1130 Brussels, Belgium.**

Likely users

This second edition was developed by the Terminal Airspace Task Force (TATF) of the Route Network Development Sub-Group (RNDSG) of the Airspace and Navigation Team (ANT). Building upon the foundations provided by the first edition, this document has been written for three audiences.

1. Primarily, **Terminal Airspace Designers** who are tasked with the designing a Terminal Airspace. With this in mind, the document provides comprehensive material relating to the entire design process in a format that allows the designer to 'start' the project at the beginning of the document, and 'conclude' it at the document's end.
2. **Chief of ATC Operations** (or equivalent person) bearing responsibility for all airspace design projects produced by airspace design teams.

Terminal Airspace Design Guidelines

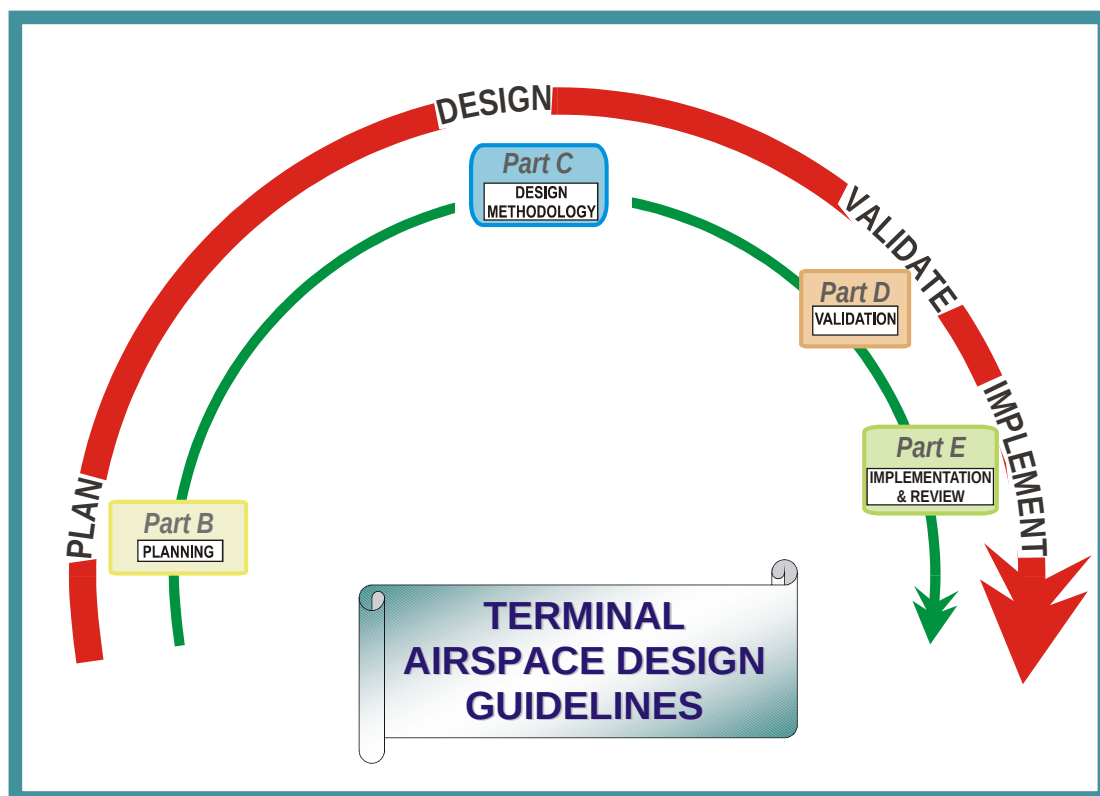
3. **High-level ANSP Managers** whose role is likely to include overseeing and coordinating large projects comprised of several sub-projects, one of which is the (re-)design of a Terminal Airspace. Because it cannot be assumed that these managers are familiar with Terminal Airspace operations, one of the aims of the document has been to provide an overview of the Terminal Airspace Design process.

Document Structure & Use

The document's structure and layout has been determined by the different needs of its intended users. In particular, the structure is aimed at providing a step-by-step user guide for use by Terminal Airspace designers. For this reason, this document is divided into five parts, the most detailed of which is Part C, *The Design Methodology*, intended for terminal airspace designers. It is hoped that this structure and layout clearly identifies the various phases of the design process from conceptualisation to implementation and review.

It is not intended that these guidelines be used as a stand-alone document. As previously stated, this document is a constituent part of the EUROCONTROL Airspace Planning Manual.

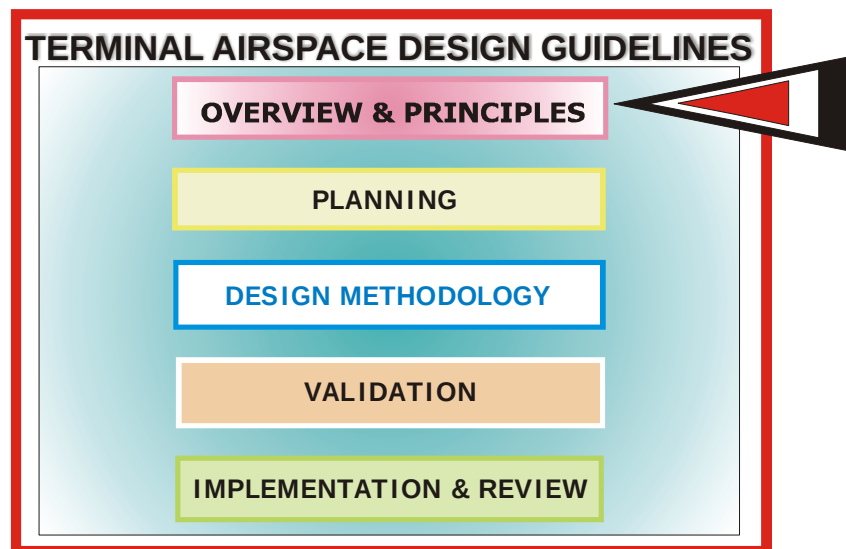
Furthermore, attention is drawn to the fact that these guidelines lay **considerable emphasis on the need for a co-operative and collaborative approach to Terminal Airspace design**. To this end, frequent guidance is contained in this document to follow a co-operative approach to terminal airspace design.



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PART A

TERMINAL AIRSPACE OVERVIEW



CHAPTER 1

- INTRODUCTION -

1.1 THE CONCEPT OF TERMINAL AIRSPACE

There is a requirement to establish an airspace in the vicinity of certain airports to provide an adequate level of safety to aircraft operations. Generally this airspace is established with a view to the provision of an Air Traffic Control Service to aircraft operating under Instrument Flight Rules (IFR) and, where necessary, under Visual Flight Rules (VFR).

Due to the dynamic development of aviation, a complex system of terminology has evolved to describe this airspace established around an aerodrome. Some of these terms are defined by the International Civil Aviation Organisation (ICAO) and others are not. As a means of capturing the various airspace nomenclatures ascribed to such an airspace, this document uses the generic expression *Terminal Airspace*. This term is generic and it is intended that it be understood in a generic sense as it is used by the International Civil Aviation Organisation (ICAO)¹.

There are other reasons for using the expression Terminal Airspace.

One concerns a growing tendency for airspace planners responsible for ATS Routes and Control Areas (CTA) in 'en route' airspace and those responsible for Terminal Control Areas (TMA) to develop 'their' respective airspaces independently. Because of its generic meaning, the concept of Terminal Airspace discourages such division. Intentionally broad in meaning, *Terminal Airspace* both promotes and encourages the co-operative development of *all* airspace as a continuum.

Another reason for using the expression Terminal Airspace is the 'political' or 'lateral' equivalent of the reason cited above. Over time, it has become common-place for air traffic services airspace (ATS) such as a CTA or TMA to be confined within the sovereign airspace of a State. Despite the importance of airspace sovereignty², the broad and generic nature of *Terminal Airspace* intentionally discourages such 'automatic' sovereign divisions. Instead, the development of airspace as a continuum across state boundaries is encouraged. This view of ATS airspace can be traced to ICAO which allows one country to provide air traffic services in the (sovereign) airspace of another. Whilst examples of such arrangements already widely exist in the member states of the European Civil Aviation Conference (ECAC), there could be more such trans-national ATS airspace. Terminal Airspace 'boundaries' need not necessarily coincide with those of sovereign airspace.

1.2 DESIGN

Whilst Terminal Airspace **design** is frequently associated with the construction of IFR Procedures in accordance with obstacle clearance criteria prescribed in PANS-OPS (ICAO Doc. 8168), this document does not use *design* in that sense and therefore, obstacle clearance criteria are not included in this document.

In the context of this document, *design* has a broader meaning: it refers to the Terminal Airspace design **concept** and is concerned with the conceptual design of Terminal Airspace

¹ ATS Planning Manual (Doc. 9426)

² Chicago Convention at Article 1

Terminal Airspace Design Guidelines - Part A

routes, holds, airspace structure and ATC sectorisation in the greater airspace continuum. Consequently, *design* in this document, **precedes** and influences the PANS-OPS phase. That the *design* of a Terminal Airspace should be *planned* is one of the principle tenets of this document, as is the fact that this design should be properly assessed and validated prior to implementation. To this end, this manual provides guidelines on –

- ❑ conceptual design of arrival and departure routes, holding areas, the Terminal Airspace and ATC Sectorisation.
- ❑ qualitative assessment of the design concept; and
- ❑ quantitative assessment and design validation; and
- ❑ implementation planning and review.

Of necessity, the above implies that all of the above are to be completed before PANS-OPS procedure design is undertaken.

Given the above, this document seeks to ensure that the placement of **Terminal Routes and definition of the Terminal Airspace volume is driven by regulatory and ATC operational requirements** and not by exclusive reference to either -

- **mathematical obstacle clearance criteria contained in PANS-OPS** [thus Terminal Routes should *first* meet ATC objectives and PANS-ATM criteria (as well as environmental and user needs), and then be 'enabled' by PANS-OPS design criteria]; or.
- **technology** [thus Terminal Routes should seek to meet ATC objectives and PANS-ATM criteria *first*, and not be predicated upon a particular technology merely because it is available].

In summary, it can be said that *design* in this document promotes the view that the Terminal Airspace volume is the 'resultant' airspace created after the routes have been designed and other institutional requirements taken into account. Thus routes are designed to *first* support the objectives of air traffic control and facilitate the management of air traffic whilst ensuring the protection of IFR flight paths and obstacle clearance.

1.3 SAFETY

Airspace design plays an integral role in the safety of the totality of the air traffic management system. As such, design of a Terminal Airspace is aimed primarily at ensuring that safety is improved or at least maintained by the design of or changes to the design of Terminal Airspace. This requirement is embodied both in ICAO and EUROCONTROL text.

At a global level, ICAO places an obligation upon States to meet stringent safety requirements. These requirements, which are not exclusive to airspace design are stated in Annex 11 at para. 2.26 *ATS Safety Management* which reads in its first paragraph (at 2.26.1) that "*States shall implement systematic and appropriate ATS safety management programmes to ensure that safety is maintained in the provision of ATS within airspaces and at aerodromes.*"

From this 'starting point', flow many other requirements detailed variously in ICAO PANS-ATM (Doc. 4444), and, at European level, in the EUROCONTROL Safety and Regulatory Requirements (ESARRs 3 and 4).

From a strategic perspective, both global and regional strategies may be described as safety centred in that these strategies give weight to and support unequivocally the Safety objectives set at both global and regional level. In Europe, from an airspace design perspective, the EUROCONTROL ATM2000+ may be viewed as the 'parent' strategy which is detailed in the EUROCONTROL Airspace Strategy for ECAC.

Terminal Airspace Design Guidelines - Part A

1.4 THE TERMINAL AIRSPACE CHALLENGE

In the period to 2015, air traffic demand in the ECAC area is forecast to double to 15.8 million movements per annum.

Resolution of En Route-type delays:

Whilst many delays and bottlenecks have traditionally been generated by what is known as the en-route environment, this has not normally been associated with arriving and departure traffic flows for airports. However, as programmes for the enhancement of the en-route structure have been progressively introduced (e.g. Basic Area Navigation (B-RNAV) and Reduced Vertical Separation Minimum, (RVSM)), the percentage of delays occurring in the upper airspace is reducing and, increasingly, a higher percentage of delays will be attributed to airports and their associated Terminal Airspace infrastructure. It is anticipated that this focus will occur as early as 2005.

Competing interests

Even though it is tempting to consider traffic growth as the only challenge facing Terminal Airspace in the future, this view is incomplete. Indeed, the pressures placed upon Terminal Airspace in the future are likely to exacerbate an increasingly complex situation particularly when viewed together with the overriding requirement to ensure safety irrespective of air traffic increases. The challenges facing Terminal Airspaces of the future include:

- ❑ satisfying increasing demands made on the **air traffic services** to ensure that capacity is (at least) maintained, that delays are minimised and safety assured;
- ❑ satisfying increasing requirements to ensure protection of the **environment**³;
- ❑ satisfying diverse requirements of various airspace **users** (which includes the increased use of regional airports to accommodate the proliferation of low-cost carrier operations);
- ❑ developing cost-effective technological **enablers** for air traffic control, environmental protection and airspace users to both support their respective needs and overcome any **constraints** that they might face;

Therefore, from a Terminal Airspace perspective, it is becoming increasingly important to ensure that the Terminal Airspace serving major airports actively address these emerging realities.

That the diverse interests of the Terminal Airspace 'participants' do not always coincide is a reality. Where, for example, ATC may prefer to use a particular runway in order to maximise capacity, flight paths to and from this runway may be considered unsatisfactory because of the environmental impact. Similarly, the preference of commercial air transport and airport operators for making continuous descent approaches to an airport – so as to minimise fuel burn and minimise environmental impact – these can be difficult for ATC to accommodate effectively in high-density Terminal Airspace where speed control limitations are frequently imposed upon arriving flights for traffic sequencing. Consequently, it is natural that tensions can and do arise as a result of the competing interests between these three groups – and that these need to be dealt with.

Added to this complexity is the reality that competing interests exist not only *between* the various Terminal Airspace 'participants' but *within* each of these groups. Examples are shown diagrammatically in Figure 1 - 1. From an ATC perspective, the 'triangular' interests of the Regulator, the air navigation service provider (ANSP) and social could refer to the challenges that may be encountered by any of the three 'parties' in meeting the requirements

³ Traditionally, TMAs sought to address only the operational needs of **air traffic control**. This changed after the 1970s, when one of the effects of the oil crisis was to increase an awareness of the needs of, in particular, the commercial air transport airspace **user**. Most recently, in the years following the Kyoto Protocol, it has become incumbent on the aviation industry as a whole and on airports in particular to minimise adverse impact upon the **environment**.

Terminal Airspace Design Guidelines - Part A

of the other. Even when taken in isolation, internal ‘tensions’ may exist within any one of these three interested parties. For example, the ‘social’ part of the ATC triangle can be viewed in several ways

- ❑ difficulties experienced by ANSPs in obtaining personnel to staff remote areas;
- ❑ competition between different ANSPs within one State;
- ❑ tensions between staff from ‘major’ and ‘minor’ ATC stations or between en-route and terminal controllers (alluded to in para 1.1);
- ❑ competing interests of ATC, environmental interests and/or PANS-OPS designers (see para 1.2);

1.4.1 TERMINAL AIRSPACE DESIGN CHALLENGES

From the above, it is possible to create a (non-exhaustive) though quite specific list of the challenges facing the Terminal Airspace planner and designer in particular:

- ❑ increasing tendency of ‘independent’ or ‘insular’ airspace design on the part of ‘specialist’ en-route or Terminal airspace planners and States;
- ❑ tradition of PANS-OPS designers determining route placement without the necessary consideration for ATC operational requirements;
- ❑ tradition of confining Terminal Airspace within the sovereign airspace of a state; competing interests between air traffic control, environmental mitigation and the diverse requirements of airspace users;
- ❑ developing cost-effective technological enablers for air traffic control, environmental protection and airspace users to both support their respective needs and overcome any constraints that they might face.

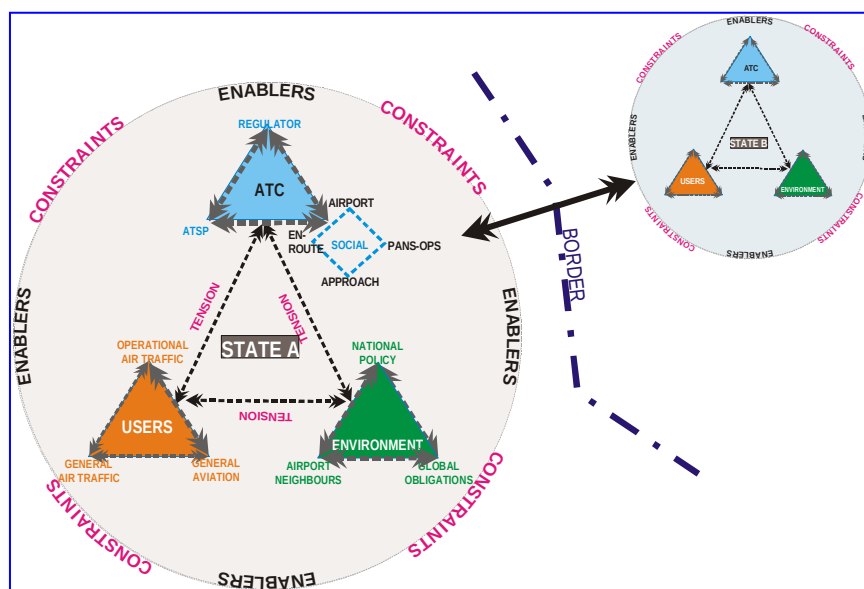


Figure 1 - 1: Challenges – Present and Future

Terminal Airspace Design Guidelines - Part A**1.5 MEETING THE CHALLENGE**

Whilst the difficulties created by these challenges will certainly become more acute if action is not taken by airspace planners and designers and regulators – many of these difficulties can be overcome by meaningful **collaboration** and **co-operation**. This is not limited to Terminal Airspace planners and designers working their way through a checklist of things to be done; it suggests a willingness to undertake the design process as part of a multi-disciplinary team that will negotiate openly and adapt to meet each other's needs *without* compromising safety.

Collaboration and co-operation are the foundations upon which this document is built. As such, this document is intended to equip the Terminal Airspace designer with the means to successfully design a Terminal Airspace. The Terminal Airspace design 'toolkit' for air traffic controllers contained in this document is comprised of –

- ❑ **General Principles of Terminal Airspace Design (Part A)**
- ❑ **Project Planning (Part B),**
- ❑ **Design Methodology (Part C)**
- ❑ **Assessment & Validation (Part D)**
- ❑ **Implementation and Review (Part E)**

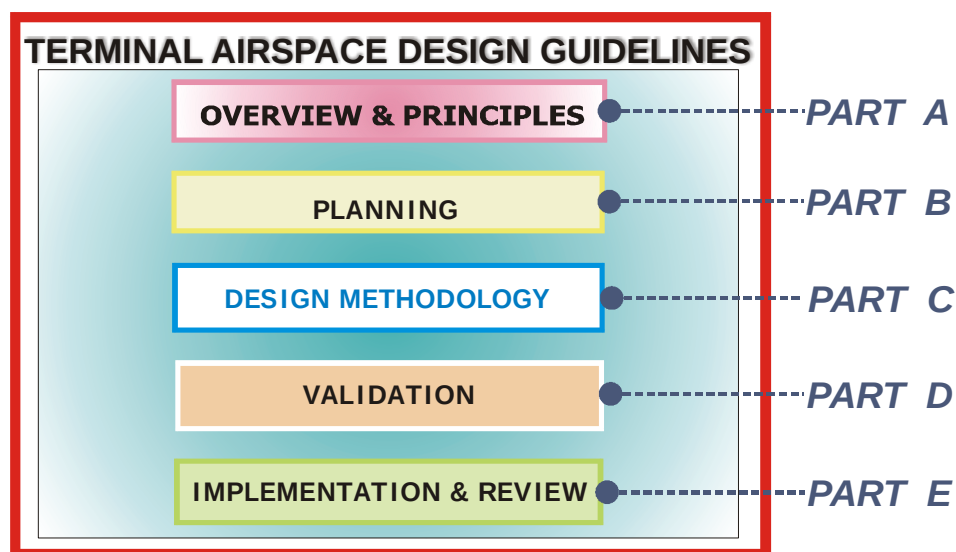


Figure 1 - 2: Terminal Airspace Design 'Toolkit'

Terminal Airspace Design Guidelines - Part A

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CHAPTER 2

- GENERAL PRINCIPLES -

2.1 INTRODUCTION

Recognising that the design of Terminal Airspace is subject to many considerations which vary from location to location dependent upon local requirements, it is nevertheless possible to lay down broad principles of Terminal Airspace design which can be adopted as policy at STATE level. This chapter describes General Principles of design which may be viewed as providing the policy framework for Terminal Airspace design .

None of these principles should be viewed in isolation: inasmuch as a Terminal Airspace is part of the whole airspace continuum, each principle is also an integral part of the whole.

2.2 PRINCIPLES

Six General Principles can be viewed as the cornerstones of the Terminal Airspace design process. Of these principles, only Principle 1 (and its sub-principle P1.1) is prescriptive in that it stems from an ICAO Standard contained in Annex 11 (complemented by provisions in PANS-ATM Doc. 4444).

Listed below in shaded text, these principles and their sub-principles are elaborated upon in the paragraphs which follow.

P.1	<u>SAFETY SHALL BE ENHANCED OR AT LEAST MAINTAINED BY THE DESIGN OF (OR ALTERATION TO) A TERMINAL AIRSPACE. THIS PRINCIPLE INCLUDES A RECOMMENDATION TO-</u>
P.1.1	COMPLY WITH ICAO STANDARDS, RECOMMENDED PRACTICES AND PROCEDURES
P1.2	SUBJECT ANY TERMINAL AIRSPACE DESIGN (OR CHANGE) TO A SAFETY ASSESSMENT.
P1.3	ANALYSE, EVALUATE AND VALIDATE ANY DESIGN (OR CHANGE) TO TERMINAL AIRSPACE.

P.2	<u>TERMINAL AIRSPACE DESIGN SHOULD BE DRIVEN BY OPERATIONAL REQUIREMENTS. THIS INCLUDES RECOMMENDATIONS TO -</u>
P.2.1	BALANCE THE INTERESTS OF AIR TRAFFIC CONTROL AND AIRSPACE USERS IN ACCORDANCE WITH STATE POLICY (also see P.3.1);
P.2.2	PROMOTE THE USE OF THE FLEXIBLE USE OF AIRSPACE CONCEPT (FUA) WHERE APPROPRIATE.

P.3	<u>WITHOUT PREJUDICE TO PRINCIPLE P.1, WHETHER AND TO WHAT EXTENT CONSIDERATION SHALL BE GIVEN TO ENVIRONMENTAL IMPACT WHEN DESIGNING A TERMINAL AIRSPACE IS TO BE DECIDED BY STATE POLICY. THIS IMPLIES REQUIREMENTS FOR -</u>
P.3.1	STATE POLICY MAKERS AND REGULATORY AUTHORITIES TO PROVIDE GUIDELINES FOR ENVIRONMENTAL MITIGATION.

Terminal Airspace Design Guidelines - Part A

P.4	THE DESIGN OF A TERMINAL AIRSPACE SHOULD BE UNDERTAKEN IN A <u>COLLABORATIVE MANNER</u>. THIS IMPLIES RECOMMENDATIONS THAT -
P.4.1	TERMINAL AIRSPACE DESIGN PROJECTS SHOULD BE UNDERTAKEN BY MULTI-DISCIPLINARY PROJECT TEAMS WHICH INCLUDE REPRESENTATIVES OF AIRSPACE USERS, OPERATIONAL CONTROLLERS FROM ACROSS ATC DISCIPLINES AS WELL AS A PANS-OPS DESIGN SPECIALIST.
P.5	TERMINAL AIRSPACE SHOULD BE DESIGNED, WHERE POSSIBLE, SO AS TO BE INTEGRATED INTO THE <u>AIRSPACE CONTINUUM</u> BOTH VERTICALLY AND Laterally WITHOUT BEING CONSTRAINED BY STATE BOUNDARIES
P.6	TERMINAL AIRSPACE SHOULD BE DESIGNED FOLLOWING A CLEAR <u>DESIGN METHODOLOGY</u> WITHIN THE GREATER CONTEXT OF A TERMINAL AIRSPACE DESIGN PROCESS.

2.2.1 P.1 - SAFETY

P.1	<u>SAFETY</u> SHALL BE ENHANCED OR AT LEAST MAINTAINED BY THE DESIGN OF (OR ALTERATION TO) A TERMINAL AIRSPACE. THIS PRINCIPLE INCLUDES A RECOMMENDATION TO-
P.1.1	COMPLY WITH ICAO STANDARDS, RECOMMENDED PRACTICES AND PROCEDURES
P1.2	SUBJECT ANY TERMINAL AIRSPACE DESIGN (OR CHANGE) TO A SAFETY ASSESSMENT.
P1.3	ANALYSE, EVALUATE AND VALIDATE ANY DESIGN (OR CHANGE) TO TERMINAL AIRSPACE.

It is a fundamental premise that the design of Terminal Airspace should ensure, be conducive to and supportive of safe operations within the airspace. Furthermore, ICAO Annex 11 requires any design (or modification) of any aspect of an airspace to be subjected to a safety assessment. To these ends, ICAO PANS-ATM states (at Page 2-3):

2.6 SAFETY ASSESSMENTS 2.6.1 Need for safety assessments 2.6.1.1 A safety assessment shall be carried out in respect of proposals for significant airspace reorganizations, for significant changes in the provision of ATS procedures applicable to an airspace or an aerodrome, and for the introduction of new equipment, systems or facilities, such as: a) a reduced separation minimum to be applied within an airspace or at an aerodrome; b) a new operating procedure, including departure and arrival procedures, to be applied within an airspace or at an aerodrome; c) a reorganization of the ATS route structure; d) a resectorization of an airspace; e) physical changes to the layout of runways and/or taxiways at an aerodrome; and f) implementation of new communications, surveillance or other safety-significant systems and equipment, including those providing new functionality and/or capabilities.	<i>Note 1.— A reduced separation minimum may refer to the reduction of a horizontal separation minimum, including a minimum based on required navigation performance (RNP), a reduced vertical separation minimum of 300 m (1 000 ft) between FL 290 and FL 410 inclusive (RVSM), the reduction of a radar separation or a wake turbulence separation minimum or reduction of minima between landing and/or departing aircraft.</i> <i>Note 2.— When, due to the nature of the change, the acceptable level of safety cannot be expressed in quantitative terms, the safety assessments may rely on operational judgement.</i> 2.6.1.2 Proposals shall be implemented only when the assessment has shown that an acceptable level of safety will be met.
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Terminal Airspace Design Guidelines - Part A

Principle P.1.3 which speaks to the analysis, evaluation and validation of any design suggests that a **qualitative** analysis and evaluation be undertaken before **quantitative** analysis, evaluation and validation. The reason for recommending this sequence of action is as follows: a **qualitative analysis and evaluation** of an airspace refers to the process whereby it is determined to what extent the airspace designed meets international standards, recommended practices and Terminal Airspace design guidelines. At the most basic level, the **qualitative** phase may be described as the 'drawing board' stage where inconsistencies are detected and impracticable elements of the design are discarded by expert judgement of the airspace designers. As importantly, passing through this phase reduces the likelihood of resources being wasted at the **quantitative** stage normally undertaken by means of (expensive) real-time simulation. Furthermore, sound qualitative analysis and evaluation ensures that viable designs can be thoroughly analysed and evaluated at the quantitative phase.

2.2.2 P.2 - OPERATIONAL REQUIREMENTS

P.2	TERMINAL AIRSPACE DESIGN SHOULD BE DRIVEN BY <u>OPERATIONAL REQUIREMENTS</u>. THIS INCLUDES RECOMMENDATIONS TO -
P.2.1	BALANCE THE INTERESTS OF AIR TRAFFIC CONTROL AND AIRSPACE USERS IN ACCORDANCE WITH STATE POLICY (also see P.3.1);
P.2.2	PROMOTE THE USE OF THE FLEXIBLE USE OF AIRSPACE CONCEPT (FUA) WHERE APPROPRIATE.

This principle aims to undo the existing practice of the airspace design process whereby route placement within a Terminal Airspace is determined either exclusively by technology or driven (sometimes exclusively) by PANS-OPS design criteria. As such, this principle requires that consideration of the airspace concept forms part of the process whereby ATM/CNS enablers are identified, and that this conceptual phase precedes the PANS-OPS design stage.

2.2.3 P.3 - STATE POLICY

P.3	WITHOUT PREJUDICE TO PRINCIPLE P.1, WHETHER AND TO WHAT EXTENT CONSIDERATION SHALL BE GIVEN TO ENVIRONMENTAL IMPACT WHEN DESIGNING A TERMINAL AIRSPACE IS TO BE DECIDED BY <u>STATE POLICY</u>. THIS IMPLIES REQUIREMENTS FOR -
P.3.1	STATE POLICY MAKERS AND REGULATORY AUTHORITIES TO PROVIDE GUIDELINES FOR ENVIRONMENTAL MITIGATION.

This principle seeks to address the increasing challenge being presented to ATC and/or Airport Operators to minimise adverse Environmental impact. In many instances, these difficulties could be overcome were ANSPs to be provided with clear guidelines which have been decided by STATE policy makers at government level.

Terminal Airspace Design Guidelines - Part A

2.2.4 P.4 - COLLABORATION

P.4	THE DESIGN OF A TERMINAL AIRSPACE SHOULD BE UNDERTAKEN IN A <u>COLLABORATIVE</u> MANNER. THIS IMPLIES THAT -
P.4.1	TERMINAL AIRSPACE DESIGN PROJECTS SHOULD BE UNDERTAKEN BY A MULTI-DISCIPLINARY PROJECT TEAM MADE UP OF OPERATIONAL CONTROLLERS FROM ACROSS ATC DISCIPLINES AS WELL AS A PANS-OPS DESIGN SPECIALIST.
P.4.2	THE DESIGN TEAM SHOULD CONSULT WITH AIRSPACE USERS.

This Principle addresses one of the major challenges identified in Chapter 1 by advocating co-operation between the different ATM disciplines and between air traffic services and users (P2.1 and P2.2) during the Terminal Airspace design process. The stage at which consultation with airspace users is undertaken should be identified by the design team e.g. airspace users tend to be involved in the design process at an early stage when the operational requirements stem from the users, and at a later stage when the operational requirements are related to ATM.

The above requirement for collaboration is not limited to the ATS and Users: it extends to all interested parties referred to in Chapter 1, and therefore include but are not limited to:

- ❑ Air Traffic Services i.e.
 - ATC Planners and designers of the Terminal Airspace to be designed
 - ATC Terminal Airspace Planners from adjacent Terminal Airspaces
 - ATC En Route Airspace Planners
 - Aerodrome Control Planners
 - PANS-OPS designers;
- ❑ Users
 - Commercial air transport operators;
 - Military and civil
 - General Aviation (including VFR operations and recreational flying)
- ❑ Environmental (see P.3, above)
- ❑ Airport authorities
- ❑ Regional Authorities
- ❑ Controller Associations
- ❑ Authorities responsible for safety and environmental regulations.

Terminal Airspace Design Guidelines - Part A

2.2.5 P.5 - AIRSPACE CONTINUUM

P.5	TERMINAL AIRSPACE SHOULD BE DESIGNED, WHERE POSSIBLE, SO AS TO BE INTEGRATED INTO THE <u>AIRSPACE CONTINUUM</u> BOTH VERTICALLY AND Laterally WITHOUT BEING CONSTRAINED BY STATE BOUNDARIES
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- Both vertically and laterally, Terminal Airspace should be viewed as part of the airspace whole. This means that the routes, airspace volume and sectorisation must be compatible with other routes, volumes and sectorisation schemes. Of necessity, this principle lends weight to the principle which promotes a collaborative approach to Terminal Airspace design (P.4).

2.2.6 P.6 - DESIGN METHODOLOGY

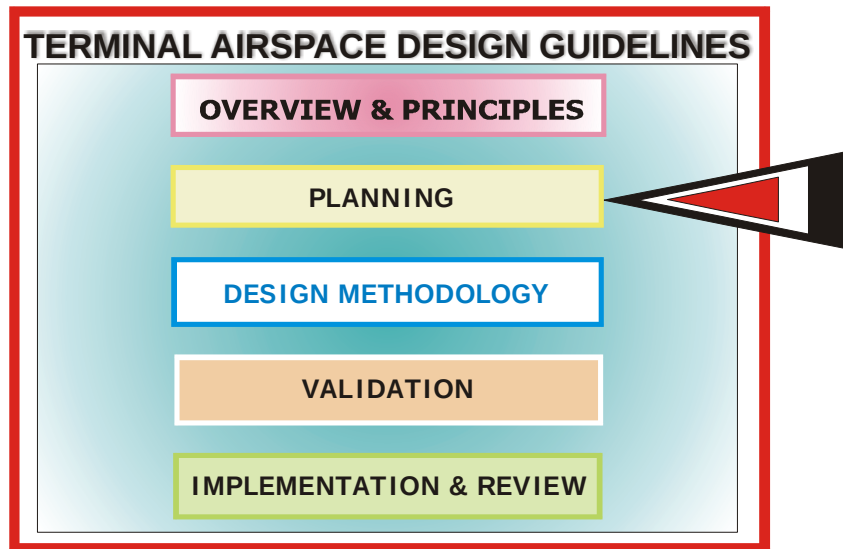
P.6	TERMINAL AIRSPACE SHOULD BE DESIGNED FOLLOWING A CLEAR <u>DESIGN METHODOLOGY</u> WITHIN THE GREATER CONTEXT OF A TERMINAL AIRSPACE DESIGN PROCESS.
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Whatever the Terminal Airspace Design Methodology, Design Guidelines or Project Management process used when undertaking a design of (or an alteration to) a Terminal Airspace, the Methodology, Guidelines and Process should be clear and easy to follow. An overview of this principle is explained in Part B.

Terminal Airspace Design Guidelines - Part A

PART B

PLANNING



CHAPTER 1

– WORKING ARRANGEMENTS –

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Terminal Airspace Design Guidelines - Part B

INTRODUCTION

This Chapter constitutes the first of two chapters in Part B. It provides an introduction to Terminal Airspace design project planning by presenting examples of different working arrangements. To this end, various **sample managerial frameworks** within which Terminal Airspace projects may be developed are identified, as are the effects that these frameworks have on managerial structures. These samples have been selected because they are relatively common and generic. This said, however, they are only examples; other managerial frameworks can – and do – exist.

Note: Because this document neither attempts nor purports to be a project management handbook, the subject of project planning is provided in both chapters with a view to assisting the organisation and planning of Terminal Airspace design projects by the Terminal Airspace design team. With the design team in mind, these discussions cover managerial and planning aspects at various levels but emphasis is laid upon the Terminal Airspace design project and team.

1.1 MANAGERIAL FRAMEWORKS

As far as planning is concerned, it is necessary to recognise that Terminal Airspace design projects can be undertaken in various managerial ‘frameworks’. Primarily, this is because design projects are undertaken for different reasons i.e. projects are triggered by different requirements. As a means of illustrating this reality – and to lay the foundations for the rest of this chapter – three **sample ‘types’** of managerial frameworks are distinguished in the context of Terminal Airspace Design projects. As previously stated, however, these framework ‘types’ are examples only – as are the names attributed to them:

- ❑ **Major infrastructure projects:** This management ‘framework’ of a Terminal Airspace design project envisages a situation where **the Terminal Airspace design project is one of several sub-projects being undertaken** to achieve a single goal such as the opening of a new runway at an airport. These sorts of projects are usually high profile and involve extensive planning and management of a multitude of aspects from calls for tender to budgets, contracts, implementation and review. These projects tend to span over several years.

Characteristically, design projects undertaken within such a managerial framework are most frequently **initiated by a policy decision, usually at some level of government**, and these project are usually of considerable scale and duration.

- ❑ **External Directive projects:** This type of managerial framework involves situations where a Terminal Airspace design project is launched in response to requirements that are not strictly related to air traffic management or user requirements but rather to specific – and often politically loaded – requirements. The most typical example is where, for example, environmental mitigation measures are ordered by a court which results in a requirement to re-designed certain arrival and/or departure routes

As with Major Infrastructure projects, these types of projects can also be high profile and on occasion, politically sensitive. This said, however, External Directive projects otherwise stands in complete contrast to major infrastructure projects. Most notably, External Directive projects tend to be ‘high-speed and ‘high-pressure’ i.e. the interval between project start and end can (typically) be a matter of a few months. For their part, design projects undertaken within the External Directive managerial framework are characterised by the fact that the design team’s actions have the potential to carry significant political implications.

Terminal Airspace Design Guidelines - Part B

- **ATM projects:** The narrowest managerial 'framework' is one where a **Terminal Airspace design project is launched as a direct consequence of an operational requirement which has been identified either by air traffic management or airspace users.**

Typically, these requirements are related to safety and/or capacity. Significantly, these projects are not directed by a Project Steering Group (see para. 1.2), even though they may (exceptionally) span over several years.

Several remarks may be made at this stage:

- [i] If the design of a Terminal Airspace is to be successfully and safely implemented, careful planning of a Terminal Airspace design project is a pre-requisite of *any* project, irrespective of the 'type' of managerial framework;
- [ii] As will become evident in Chapter 2, as well as Part C (as per the Principles stated at Part A, Chapter 2), a collaborative approach to Terminal Airspace design is (increasingly) becoming mandatory in various States – and is very much encouraged from a pan-European perspective. This co-operation should not be exclusive e.g. limited to ATM or Airspace Users.
- [iii] Irrespective of the managerial framework within which the Terminal Airspace design team is to work, changes to or the new design of a Terminal Airspace (particularly arrival/departure route and holding patterns) are becoming more difficult to implement due to environmental considerations.

1.2 MANAGEMENT STRUCTURES

It is natural that the differences between types of managerial framework be reflected in the management structure of different Terminal Airspace design projects. As a consequence, planning is also affected by the managerial structure which stems from a particular managerial framework.

For purposes of this discussion, three levels of management structure may be identified in the context of these managerial frameworks. They are called the **Project Steering Group**, **Operational Manager** and the **Terminal Airspace design team**.

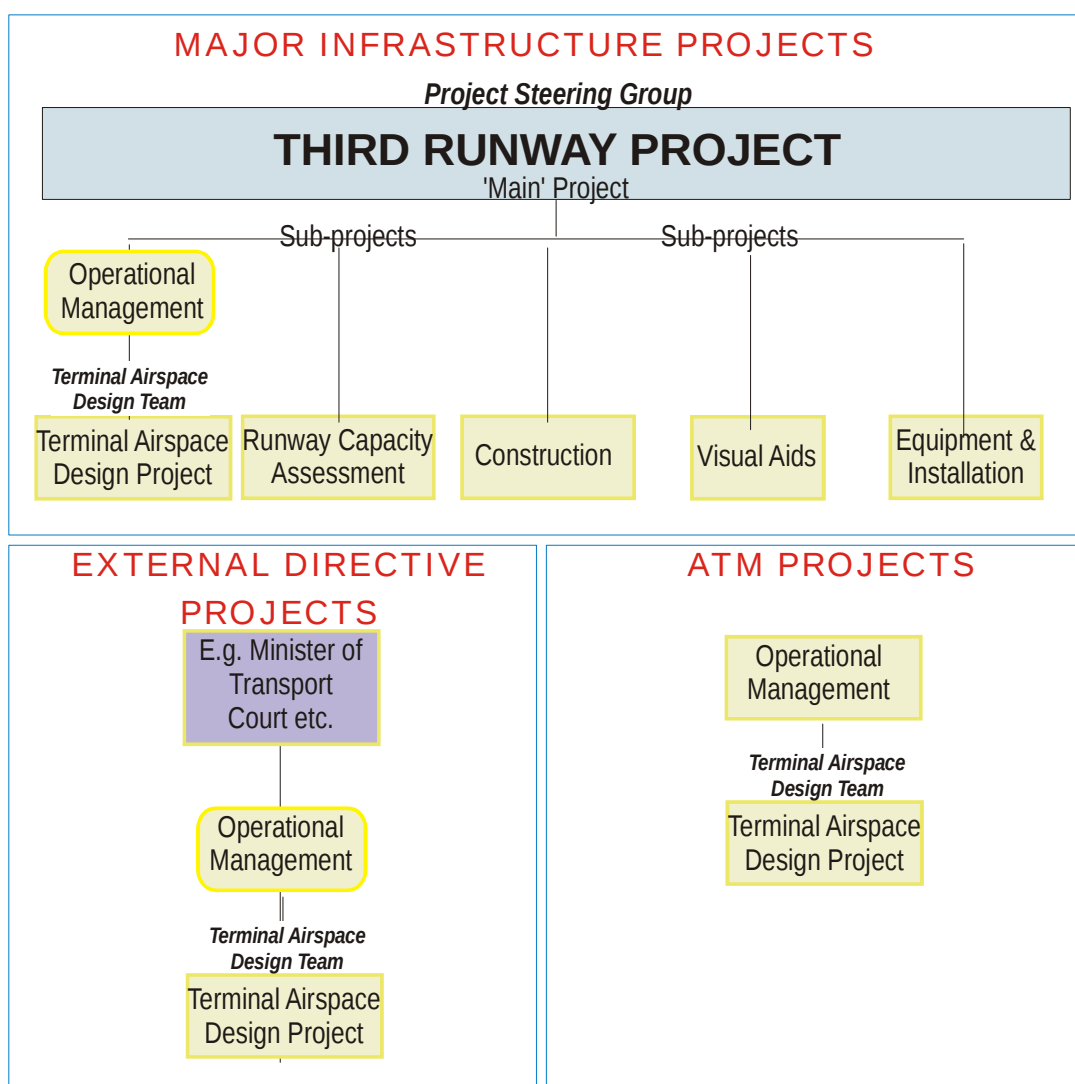
Note: In this context, Operational Manager is a generic term. Depending on internal arrangements, the Operational Manager can be the Chief of the ATC Centre, Chief of Airspace Development, etc.

In the diagram on the next page, the following differences in reporting structure are shown:

With a Major Infrastructure project structure, the Terminal Airspace design team is accountable to the Operational Manager (e.g. Chief of ATCC, or Chief of Airspace Projects) who in turn acts as an interface between the Project Steering Group and the specialist design team.

In turn, with External Directive managerial structures the Terminal Airspace design team is usually accountable to the Operational Manager. As such, the managerial framework is usually as light as with ATM Projects, but such, 'accountability' often reaches beyond the ANSP.

Reporting structures associated with ATM Projects are usually lighter and two levels are envisaged i.e. Operational Manager and the Terminal Airspace design team.

Terminal Airspace Design Guidelines - Part B**Figure 1 - 1: Sample Types of Managerial Frameworks**

For completeness, the roles of the Project Steering Group, Operational manager and Terminal Airspace design team are briefly elaborated in the context of managerial frameworks. As will be seen, this impacts upon planning.

1.2.1 PROJECT STEERING GROUP

As far as the Terminal Airspace design team is concerned, the **Project Steering Group** associated with a Major Infrastructure project, may be considered to be the project's high-level overseer and prime mover. The Project Steering Group sets strategic objectives, identifies the necessary sub-projects, implementation time scales, ensures that project dependencies are identified and that the appropriate expertise is drawn together to work on the large-scale project. Amongst other things, the Project Steering Group sets up working arrangements. This includes 'delegating' responsibility for specialist work to specialist teams. In the case of Terminal Airspace design, the actual design activity is delegated to a Terminal Airspace Design Team.

Terminal Airspace Design Guidelines - Part B

1.2.2 OPERATIONAL MANAGER

The Operational Manager is most likely to lead the Terminal Airspace design team. Whereas the **operational manager** is at a level below the Project Steering Group in a Major Infrastructure project, the operational manager is most likely to lead the project in other instances. The extent of the Operational Manager's role alters according to the managerial framework: In a Major Infrastructure project, the Operational Manager ensures coherency between Strategic/Project Objectives (see next Chapter) set by the Project Steering Group and design objectives defined by the Terminal Airspace design team and also acts as interface between the Project Steering Group and the design team. In External Directive projects, the operational manager's role can be more demanding: with these projects, this manager may represent the design team in meetings that are politically charged, interprets the requirements of one group to the other whilst taking overall responsibility for ensuring that the final (design) result is safe.

1.2.3 TERMINAL AIRSPACE DESIGN TEAM

Central to this particular document is the ***Terminal Airspace Design team***. In management and reporting terms, the Terminal Airspace design team bears responsibility for planning, development, validating and implementing changes to the airspace design. Nevertheless, the extent of the design team's managerial responsibilities and how the team operates is largely determined by the type of managerial framework of a particular project (this is usually a function of the way in which an ANSP is organised). For example –

In a **Major Infrastructure project** managerial framework it is the Project Steering Group that determines the time scales for implementation, the implementation date, general scope of the project and strategic objectives. Similarly, the PSG also sets up working arrangements, identifies (sub-) project teams, dependencies between them as well as a reporting structure and project milestones. In this managerial framework, the Terminal Airspace design team, while relieved of certain managerial functions, is also required to engage and co-ordinate with a wider range of expertise which can affect the schedule of the design team itself. Furthermore, it is incumbent on the design team to 'translate' the strategic and project objectives into their design equivalent which are called ***design objectives*** (See Part B, Chapter 2 for more details). At its specialist airspace 'level', the Terminal Airspace design team also needs to identify **project dependencies** e.g. other (En Route or Terminal) airspace projects being planned or developed

In **External Directive projects**, time scales for implementation, general scope of the project and strategic objectives are usually decided up the 'external' third party providing the 'trigger' for the launch of the project. In this managerial framework – again, without a Project Steering Group – the Operational Manager and Terminal Airspace design team bear a greater managerial responsibility. (The relationship between them is usually decided by internal procedure). Usually, depending on internal arrangements, it is the responsibility of the Operational Manager or the design team to identify the design objectives and scope. The responsible party also needs to ensure that project dependencies are identified, that working arrangements are set up to accommodate the project (e.g. with other airspace projects), and that the pre-defined implementation date is respected.

Terminal Airspace Design Guidelines - Part B

From one perspective, the **ATM Project** managerial frameworks which is 'lightest' in terms of reporting structure (there is no Project Steering Group), could be considered heaviest in terms of the responsibilities falling directly on the Terminal Airspace design team. One of the greatest advantages this type of managerial framework is, however, that it is usually possible for implementation time-scales to be decided only by the Terminal Airspace design team.

1.3 IMPACT OF TYPE DIFFERENCES

1.3.1 IMPACT OVERVIEW

It is not surprising that the differences between managerial frameworks can be substantial in terms of the project planning.

In order to appreciate the impact of these differences, a tabular overview is provided below followed by para. 1.3.2 which introduces the impact of Type differences on Project Planning – thus setting the scene for Chapter 2.

Note 1: Readers' attention is drawn to the fact that some of these differences will become clearer after reading the remainder of the Chapters in Part B.

DIFFERENCES AND SIMILARITIES BETWEEN SAMPLE PROJECT 'TYPES'			
Terminal Airspace Project –	Major Infrastructure project	External Directive projects	ATM Project
(1) ...Initiated by	Policy by (national or regional) government, realised by Project Steering Group	Policy by (regional/municipal) government, or court ruling i.e. 'external' party	ATM operational requirements/ User requirements identified by/submitted to the Terminal Airspace design team
(2) .. Management Structure decided by	Project Steering Group	Operational Manager or Terminal Airspace Design team	Operational Manager or Terminal Airspace Design team
(3) ...Implementation date selected by	Project Steering Group in consultation with Policy makers, usually as a function of scope.	Decided at policy level/court ruling i.e. external party , enforced by Operational Manager (or equivalent), (often) despite the scope.	Decided by Terminal Airspace Design team as a function of Scope and objectives after scope and objectives set
(4) .. Strategic Scope & Objectives selected by	Project Steering Group.	'External' party.	Determined by the Terminal Airspace design team before deciding implementation date
(5) .. design objectives selected by	Terminal Airspace Design Team	Terminal Airspace Design Team	Terminal Airspace Design Team
(6) Dependencies with other projects Identified by	Project Steering Group, Operational Manager (and Terminal Airspace Design Team , at specialist level)	Operational Manager or Terminal Airspace Design Team	Operational Manager or Terminal Airspace Design Team
(7) Reference Scenario agreed by (Part C, Chapter 2)	Terminal Airspace Design Team	Terminal Airspace Design Team	Terminal Airspace Design Team
(8) Safety and Performance Criteria selected by (Part C, Chapter 3)	Terminal Airspace Design Team in accordance with Regulatory Requirements	Terminal Airspace Design Team in accordance with Regulatory- or external requirements	Terminal Airspace Design Team in accordance with Regulatory Requirements

Terminal Airspace Design Guidelines - Part B

Terminal Airspace Project –	Major Infrastructure project	External Directive projects	ATM Project
(9) Assumptions	Time Pressures, external to ATM Other airspace requirements	Requirement for common assumptions across several project teams is common.	can be affected by external requirements but otherwise selected by Terminal Airspace design team
(10) Constraints	Potential for technical enablers being provided (usually because of project profile and ease of access to higher-level management)	Time Requirement for common assumptions can reduce design flexibility Increased co-ordination	Time Pressures, external to ATM Other airspace requirements
(11) Enablers	Greater spread of expertise readily available to Terminal Airspace Design team (from other projects); Greater likelihood of technical enablers being provided usually because of project profile and access to management	Greater spread of expertise readily available to Terminal Airspace Design team (from other projects); Greater likelihood of technical enablers being provided usually because of project profile and access to management	Potential for technical enablers being provided (usually because of project profile and ease of access to higher-level management)

Table 1- I: Comparison of Sample Project Types**1.3.2 IMPACT ON PLANNING**

It has become evident that all Terminal Airspace design projects are undertaken in response to a particular requirement and that the source of a particular requirement largely determines the type of managerial framework for the project. Similarly – and quite predictably – these differences are also reflected in the extent and number of planning steps. Although this is dealt with fully in the next chapter, it is useful to consider what impact this has on planning. By way of introduction, the next diagram shows a sequence of sample planning steps and that the number of steps is dependent upon the managerial ‘type’. In Figure 1-2, planning for-

- ❑ A **Major Infrastructure project** would commence at the rose-coloured dot (with the Project Steering Group) in the form of a **General Requirement** and the Terminal Airspace design team is created to undertake a specialist sub-project and to determine the **design objective** from the **project objective** defined by the Project Steering Group.
- ❑ An **External Directive project** would start at the mauve-coloured dot. In this case, the trigger for the project is handed to the Terminal Airspace design team as a **project objective**.
- ❑ An **ATM Projects** would commence at the green-coloured dot where a project has been triggered by either an ATM or User Requirement (known as an **Operational Requirement**) identified by the Terminal Airspace design team; from which **design objectives** are formulated.

These different levels of objectives are amplified in the next chapter.

Terminal Airspace Design Guidelines - Part B

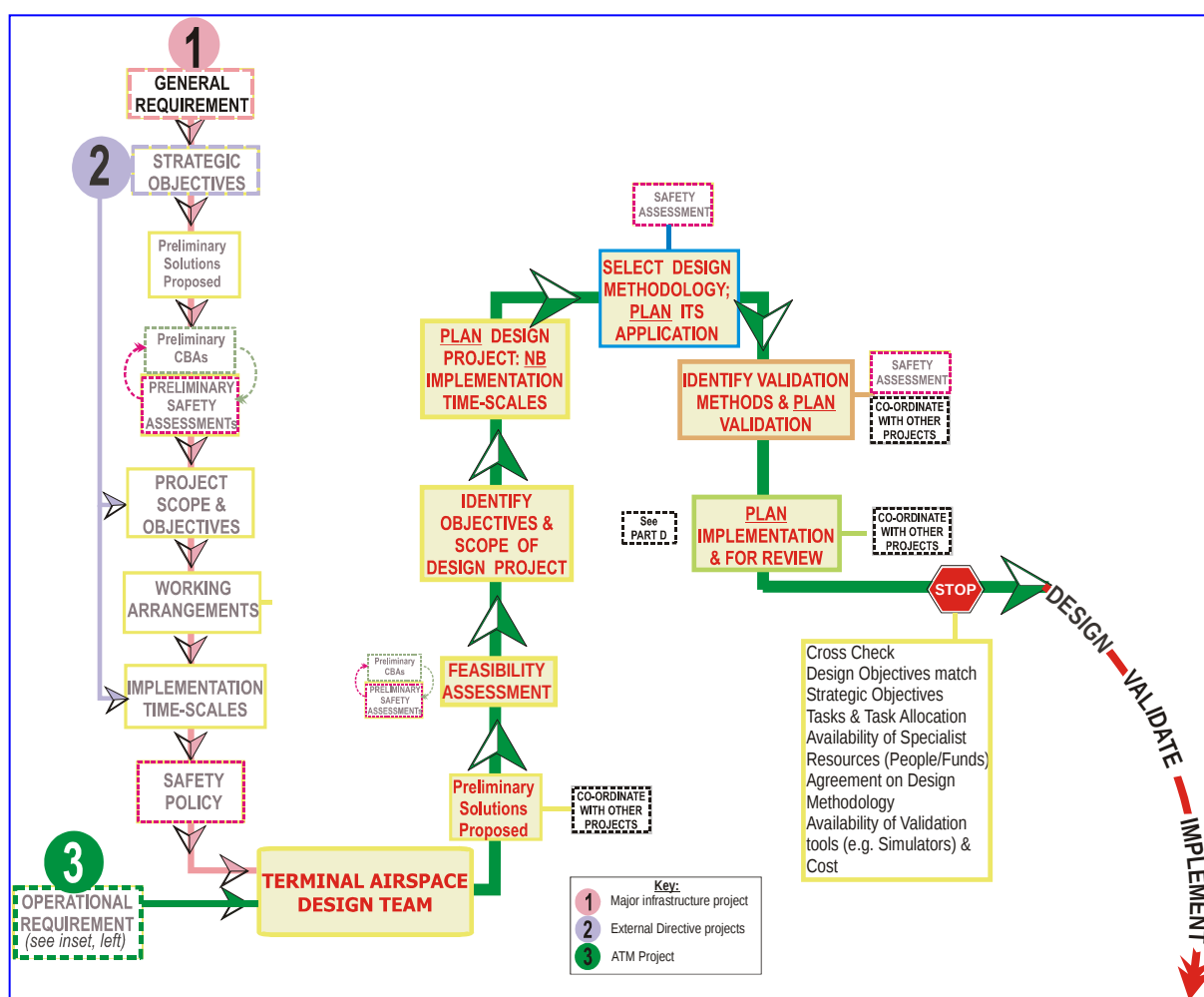


Figure 1 - 2: Different Planning Processes

1.4 SUMMARY

This Chapter has discussed working arrangements in the context of managerial framework 'types' in which Terminal Airspace design projects may be undertaken. Management structures that 'flow' from these managerial frameworks have also been explained and three (sample) 'levels' of management identified – the most significant, in the context of this document, being the Terminal Airspace design team.

Having laid these foundations in this chapter, the next chapter discuss Terminal Airspace design project planning.

CHAPTER 2

– PLANNING STEPS –

Contents

2.1	INTRODUCTION	B-2-2
2.2	SAMPLE PROJECT INITIATION	B-2-3
2.2.1	MAJOR INFRASTRUCTURE PROJECT	B-2-3
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2.2.3	ATM PROJECT.....	B-2-4
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2.4.1	DESIGN OBJECTIVES.....	B-2-6
2.4.2	DESIGN PROJECT SCOPE AND TASK IDENTIFICATION.....	B-2-7
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2.5	SUMMARY	B-2-9

ATTACHMENTS

- B.2-1: Sample Project Schedule
- B.2-2: Sample Task list
- B.2-3: Sample Project Planning

Terminal Airspace Design Guidelines - Part B

2.1 INTRODUCTION

This Chapter builds upon the foundations laid in Chapter 1; it amplifies aspects of project planning by providing a sequence of **sample** planning steps for a single Terminal Airspace design project. These planning steps could be used by a Terminal Airspace design team where an in-house process is not available.

That each of the three project ‘types’ (see previous chapter) are initiated differently, significantly impacts upon why and how the Terminal Airspace design team tackles its tasks. For this reason, this chapter first provides, for each managerial type, a brief (diagram-based) overview of sample project initiation process leading up to the point where a Terminal Airspace design team undertakes the re-/design of a Terminal Airspace. This is followed by a brief overview of setting up a Terminal Airspace design team which then leaves the bulk of this chapter to cover project planning by the Terminal Airspace design team (primarily within an ATM Project managerial framework).

Note 1: The Attachments to this chapter provide an overview of a sample planning process (in steps) which could be used as a the basis for a checklist by the Terminal Airspace design team.

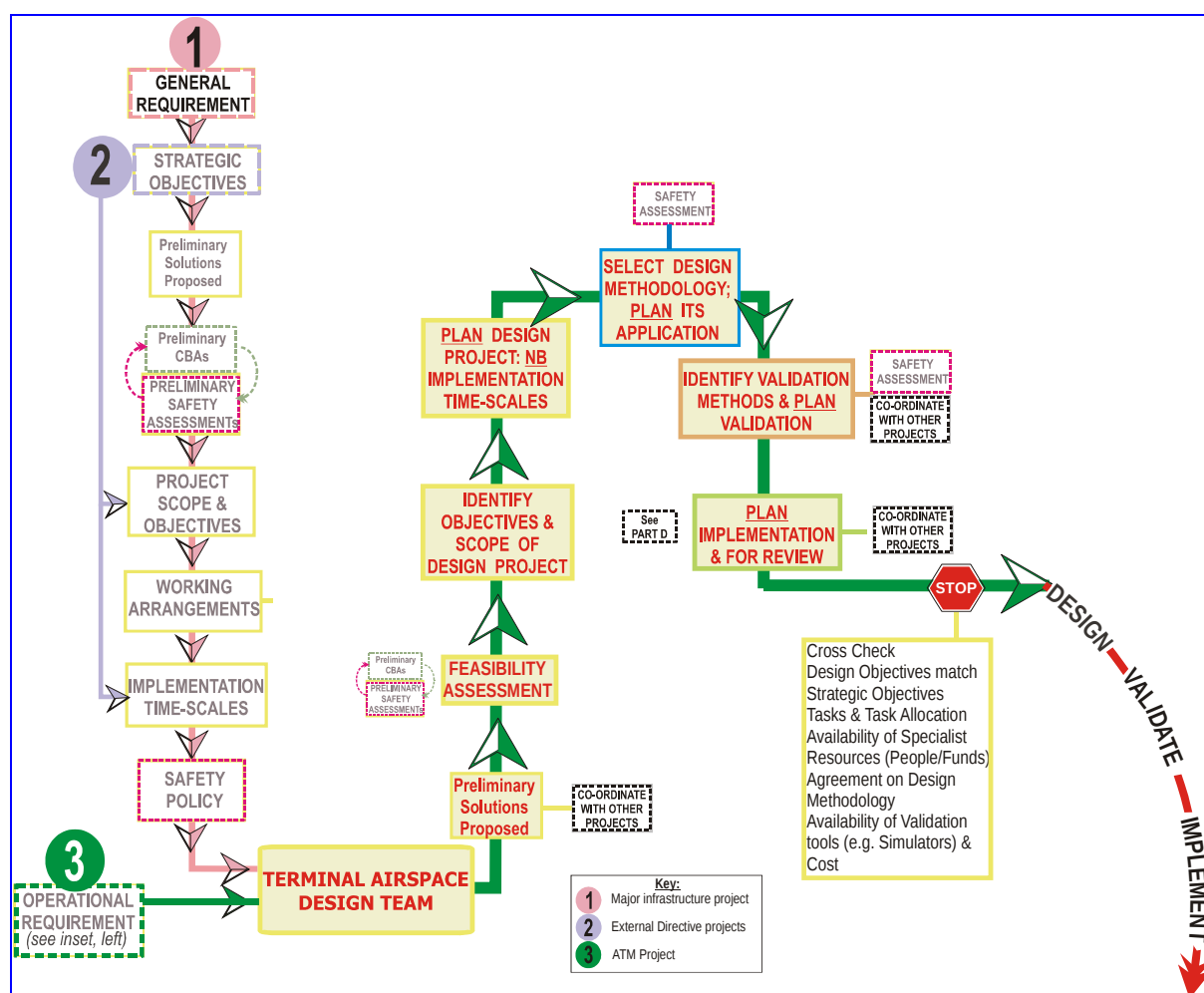


Figure 2 - 1: Overview – Sample Project initiation and Planning Steps

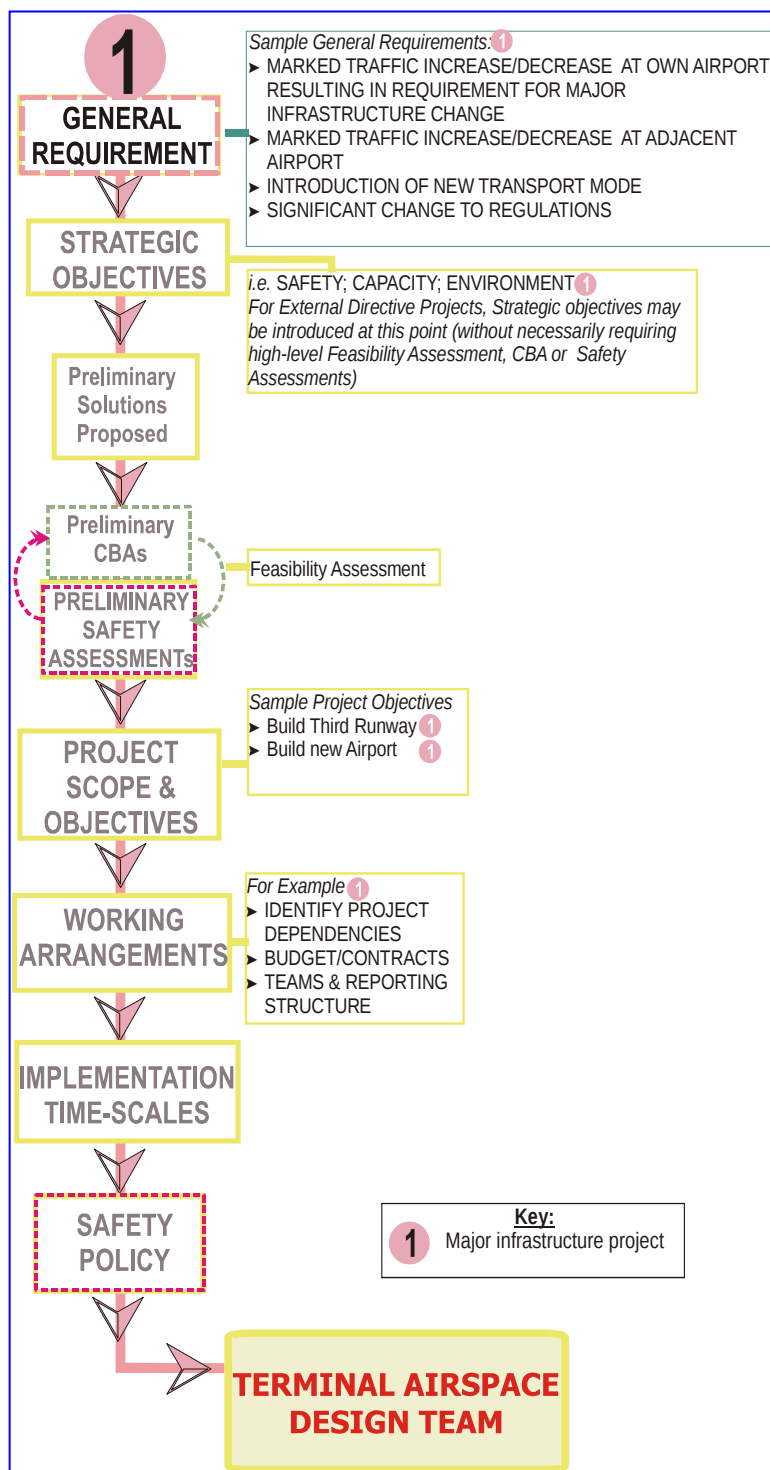
Depending upon the circumstances of a particular project, it is possible for ‘start points’ 1, 2 & 3 (above) to be located elsewhere in the process chain.

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2.2 SAMPLE PROJECT INITIATION

2.2.1 MAJOR INFRASTRUCTURE PROJECT

In this type of managerial framework, the project may be said to commence with **General Requirements** stemming from national policy.



- An example of a (high level) **General Requirement** is to ensure that sufficient capacity exists at Airport X, to accommodate forecast traffic increases.

In context, it is assumed that the Project Steering Group (PSG) is formed at this stage. One of its first tasks is to identify **Strategic Objectives** from the General Requirement.

- An example of a **Strategic Objective** stemming from the General Requirement could be to double the capacity at Airport X.

Note: Strategic Objectives generally relate to Safety, Capacity or Environment. Usually, more than one is selected.

Once strategic objectives are decided, the PSG then seeks to identify how these strategic objectives may be fulfilled. The 'solution' selected may be called the **Project Objective**.

- An example of a **Project Objective** could be to build a new parallel runway 18L/36R at Airport X.

The Terminal Airspace design team would be included in the working arrangements to fulfil the project objectives. It would have to derive/determine **design objectives** compatible with the **project objectives**. (see para. 2.4.1 & 2.4.2)

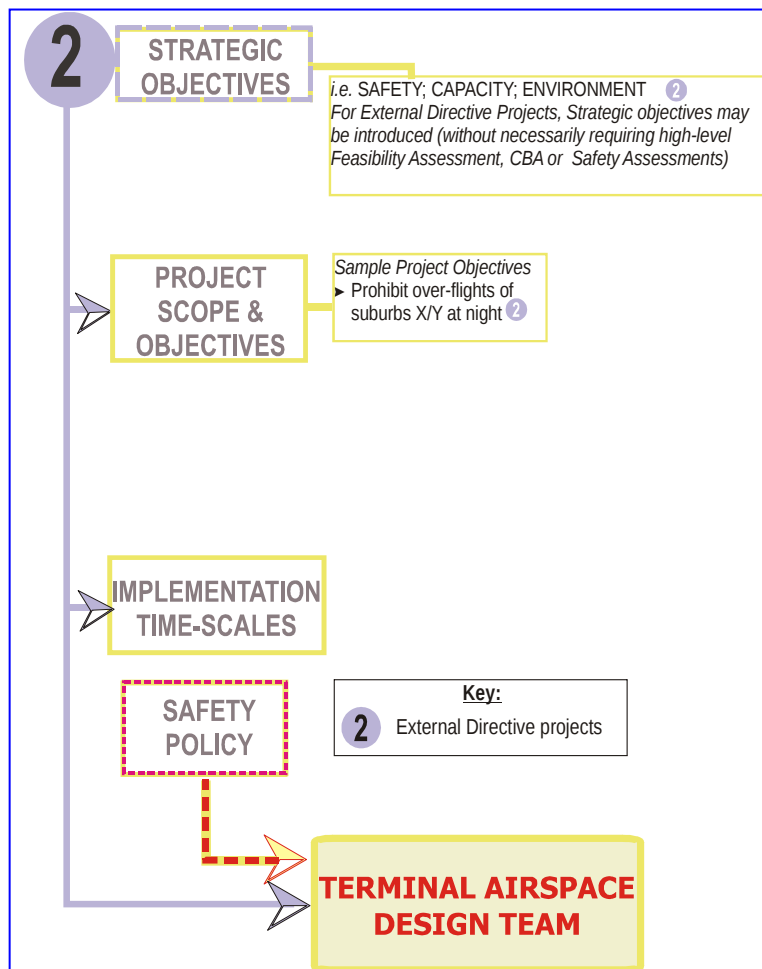
Figure 2 - 2: Sample project initiation for a Major Infrastructure project

Terminal Airspace Design Guidelines - Part B

2.2.2 EXTERNAL DIRECTIVE PROJECT

This type of managerial framework is characterised by the fact that the project is 'started' by parties outside ATM/airspace users. Furthermore, these 'external' parties are usually in a higher authority e.g. within national government or the judiciary. These parties 'provide' the ANSP (and thus the Terminal Airspace design team) with ready-made **strategic** and **project objectives** in the form of a court order or ministerial directive/order.

As suggested previously, these projects tend to be politically charged, demanding quick results in a limited time period and most often, they relate to environmental impact and/or mitigation, especially noise.



□ Examples of different levels of 'received' objectives include –

- Minimise environmental impact (strategic objective);
- Over-flight of suburbs X and Y prohibited between 2300-0530 (project objective).

In such a case, The Terminal Airspace design team would be tasked to fulfil the (very specific and narrow) project objectives. To this end, it would have to derive /determine **design objectives** compatible with the **project objectives** (see para. 2.3).

Figure 2 - 3: Sample project initiation for External Directive project

2.2.3 ATM PROJECT

In contrast to the previous project 'types', ATM-type projects are usually initiated for ATM – related reasons by either the Terminal Airspace design team, operational air traffic controllers, airspace users etc. As such, these projects are initiated because some **operational requirement** has been identified. Examples of an operational requirement include:-

- Reduce the workload of Sector TX between 1000-1700 UTC on week-days.
- Increase the frequency of north-bound departures exiting the Terminal Airspace via point KODAP.

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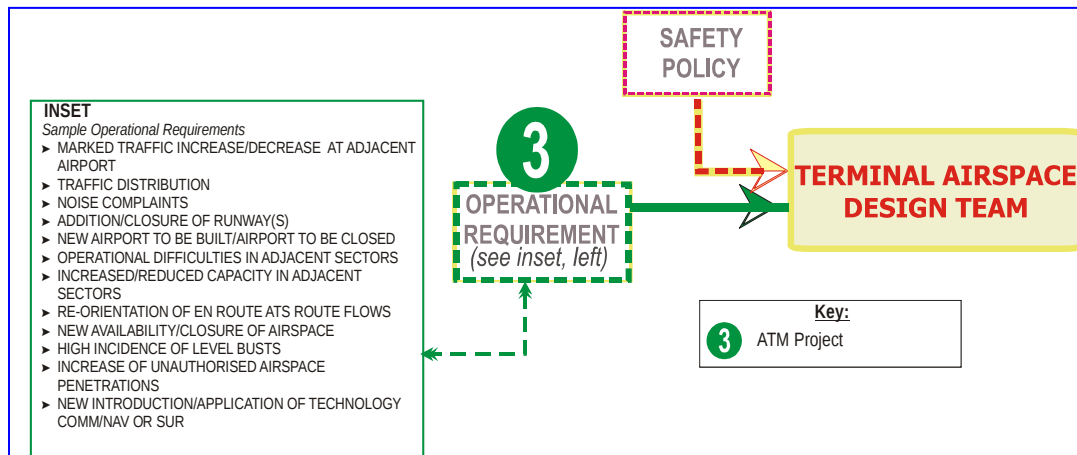


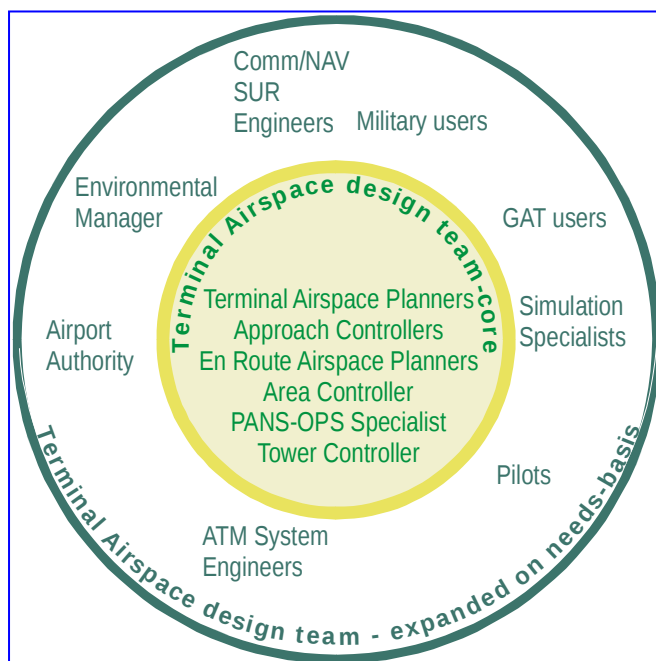
Figure 2 - 4: Sample Project initiation ATM Projects

It is then up to the Terminal Airspace design team to ‘translate’ or derive **design objectives** from these operational requirements by going through the process such as the example provided in para. 2.3.

2.3 FORMING THE TERMINAL AIRSPACE DESIGN TEAM

Irrespective of the managerial framework within which the Terminal Airspace design team operates, the Terminal Airspace design team is ideally made up of specialist airspace planners (where available), operational Approach Controllers, at least one operational Area controller, a Tower controller and a PANS-OPS specialist.

Whilst these members may be viewed as the core of the team, this is not the team's limit. On a needs basis, the team will grow to include additional expertise such as pilots, engineering, simulation and safety specialists. If the decision to include such specialists is not taken when the project is launched, it is advisable to identify which specialists are needed once the objectives and scope have been formulated and tasks identified (see paras.2.4.1 and 2.4.2).



Depending upon the internal arrangements of a particular ANSP, the team may be led by the Operational Manager or a separate **team leader**. A Single focal point for the team is a useful way of ensuring that there is at least one individual whose most important task is to oversee, co-ordinate and ensure coherency of all the work being done. Other tasks of the leader include ensuring that schedules are kept, that communication occurs with relevant (dependent) projects and that the project's development is consistent and coherent with the larger project.

Figure 2 - 5: Terminal Airspace design team

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2.4 SAMPLE TERMINAL AIRSPACE DESIGN PLANNING STEPS

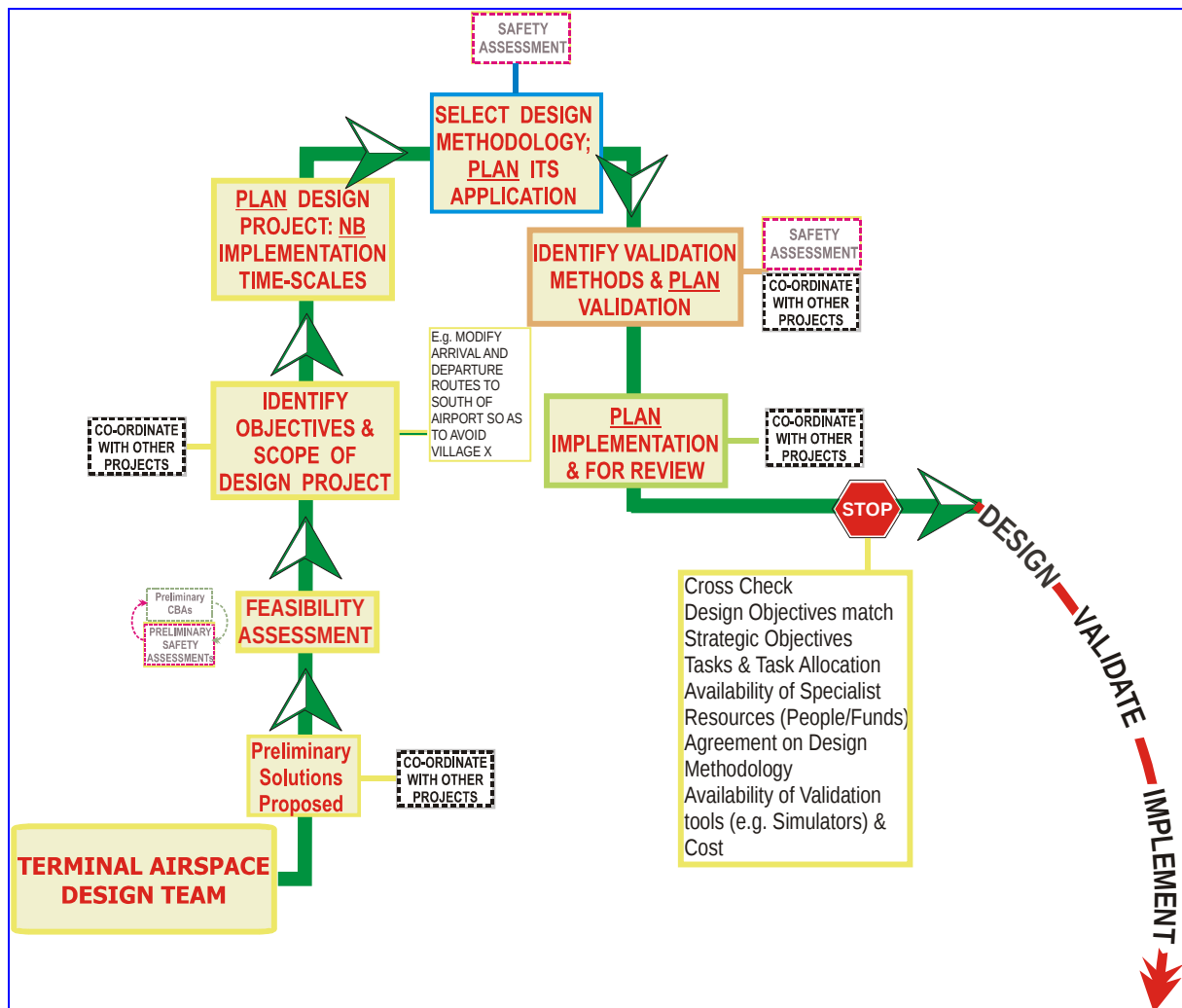


Figure 2 - 6: Sample Project Planning

2.4.1 DESIGN OBJECTIVES

Irrespective of the way in which a project is initiated, one of the first tasks of the Terminal Airspace design team is to determine the project's **design objectives**.

Thus, as a first step, the Terminal Airspace design team identifies ways in which higher goals (be they project and/or strategic objectives) might be fulfilled from a Terminal Airspace design perspective. Not every solution proposed is likely: to be acceptable, solutions must be safe in ATM terms, and a solution's benefit is usually required to outweigh its costs. This ratio between benefit and cost is usually determined by undertaking a **CBA** (Cost Benefit Analysis). Thus **the feasibility** of each solution is **assessed** in terms of safety and cost, and a 'solution' is chosen.

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Usually the solution chosen is one -

- [i] **which meets the objectives of ATS Safety Management**¹ (this includes determining the likelihood of the safety assessment showing that the acceptable level of safety will be met),
- [ii] **which meets the objectives of the Air Traffic Services**² (and compliance with air traffic service Standards, Procedures and guidance material provided for by ICAO and national regulation); and
- [iii] whose **Benefits** out-weighs its **Cost**.

The 'solution' selected by the Terminal Airspace design team may be called the **Design Objective**.

- An example of a **Design Objective** stemming from the Project Objective, could be to design arrival and departure routes to accommodate a new parallel runway 18L/36R, whilst ensuring that risk is not increased, that current safety levels are at least maintained and environmental impact is minimised. (Note the 'echo' of Strategic Objectives contained in these design objectives)

2.4.2 DESIGN PROJECT SCOPE AND TASK IDENTIFICATION

Defining the **Scope** of the Terminal Airspace design project is the next logical step *after* the, **design objectives** have been identified. It 'wraps-up' **what needs to be done** in order to achieve the **design objectives**. If, for example, the design objective cited above is used as a basis for defining the scope, the **scope** from a Terminal Airspace Design Project perspective could include - .

- develop a Terminal Airspace Design Concept i.e. design Routes, Holding Areas, Airspace Volume and ATC Sectorisation;
- decide upon criteria on which the design will be assessed and then qualitatively assess the Terminal Airspace Design Concept and;
- decide upon criteria on which the design will be assessed and then quantitatively assess the Terminal Airspace Design Concept;
- Validate the design using fast- and/or Real-time simulation;
- Undertake a Safety Assessment;
- Design the validated routes in accordance with PANS-OPS criteria;
- Determine controller training requirement and establish training programme;
- Publish and Implement the new Terminal Airspace Structure.

Note: The Scope cannot exist in a vacuum. Not only is it frequently affected by the time-scales for implementation (below) but it also presupposes the existence and application of general principles and a design methodology.

What is evident in the above list is that it also constitutes a core list of **tasks** that will need to be broken down into sub-tasks and scheduled.

Perhaps the most important consideration when deciding the scope is to aim for what can realistically be achieved **in the time available**. Although it is tempting to widen a project's scope in order to cover *all* aspects (even those which are not crucial to meet the objectives), success is more likely if the aims are modest and the work undertaken of high quality.

¹ These are to ensure that a) the established level of safety applicable to the provision of ATS within an airspace or at an aerodrome is met; and b) safety-related enhancements are implemented whenever necessary. (PANS-ATM, Chapter 2)

² these include preventing collisions between aircraft; expediting and maintaining an orderly flow of air traffic; providing advice and information useful for the safe and efficient conduct of flights; (Annex 11, Chapter 2)

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As with the design objectives, the value of properly deciding the **scope** of a project cannot be under-estimated. Not only does the **scope** set the limits of what will be done, but it also constitutes the first –level ‘checklist’ of tasks to be accomplished.

2.4.3 TASK ALLOCATION AND SCHEDULING

In order to effectively produce a successful design, the tasks identified during the **objectives and scope** phase will need to be broken down into more specific tasks, scheduled so that they are undertaken in the correct order and allocated to team members. Notably, not all identified tasks are necessarily the responsibility of the Terminal Airspace design team. In some organisations, for example, there are dedicated Simulation specialists whose job is to prepare and run simulations so as to validate designs or a Safety specialist whose main occupation is the development of safety cases across a variety of disciplines.

2.4.3.1 Task Scheduling as a function of project dependencies

At this specialist level, project dependencies relate to the relationships that exist (of necessity) between a Terminal Airspace design project and other airspace or airport type projects. (These may have no connection with a larger project being managed by a Project Steering Group in the case of a Major Infrastructure project). If, for example, the En Route network planners are developing scenarios for future route-networks, the Terminal Airspace design team needs to ‘link’ into this En Route project (perhaps within the context of the greater project under the helm of the Project Steering Group) so as to ensure that – in the example used – the SIDs/STARs to be developed for the new runway will be coherent with the en route plans and vice versa.

At specialist level, therefore, the Terminal Airspace design team may have to consider two sets of project dependencies which may or may not affect task scheduling of the Terminal Airspace design team. Those dependencies identified at high-level (between the yellow boxes shown in next diagram, would relate to a Major Infrastructure project) and those shown in the large grey-shaded circle in the same diagram, which would be relevant irrespective of the project type.

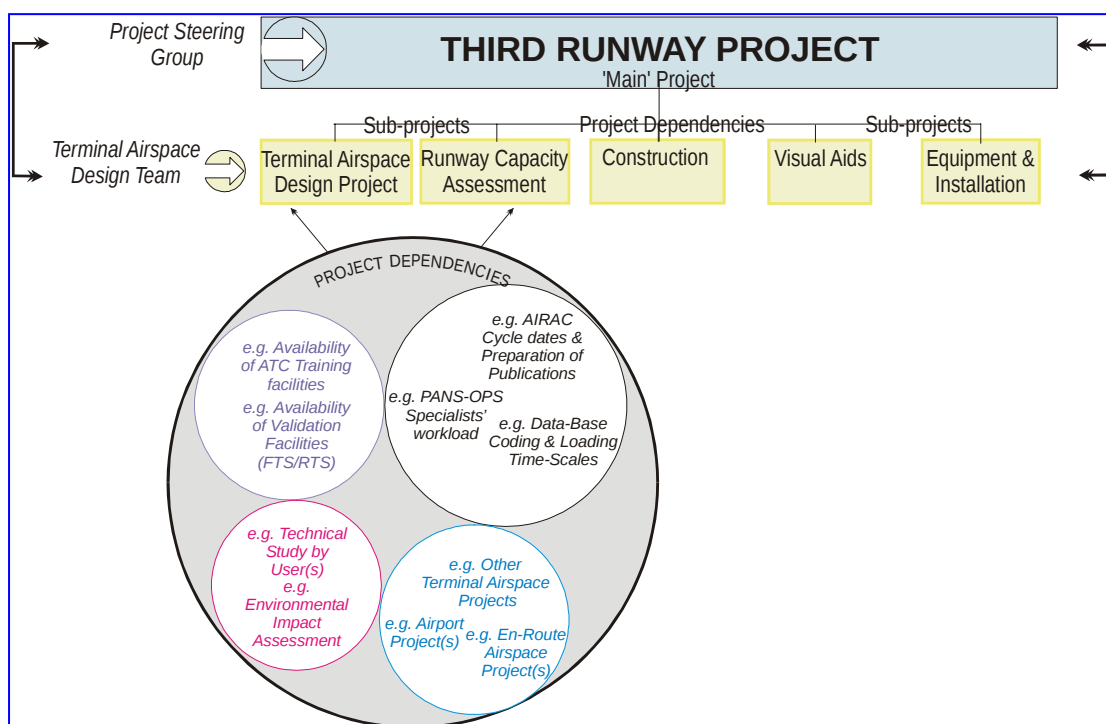


Figure 2 - 7: Examples of dependencies at ‘specialist’ level – inside circle

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Two types of dependencies may be identified:

- ❑ **Necessary overlap and interface between other associated projects:** e.g. an En Route airspace project and a Terminal Airspace design team project can only be successful if there is a 'sharing' of team members.
- ❑ **Scheduling dependencies:** for example, the PANS-OPS office cannot design the SIDs and STARs in accordance with obstacle clearance criteria until the SIDS/STAR concept has been developed and the SIDS/STARs have been validated in a holistic ATM context.

2.4.3.2 Task Scheduling and Implementation

It is extremely important that the Terminal Airspace design team ensures that **planning allows all identified tasks and activities to be completed before implementation.**

- ❑ In those cases where Terminal Airspace design team works within the framework of an ATM Project, the team may be in a position to decide its own implementation time-scales. In this case, care should be taken not to under-estimate the time needed to complete the tasks and to add in extra days (approx. 10%) to allow for error or unforeseen difficulties.
- ❑ Where a Terminal Airspace design project is undertaken within the framework of a Major infrastructure project or initiated by External Directive, the Terminal Airspace design team is required to meet a pre-determined time-scale, chosen by someone else. (In the case of an external directive project, time scales could be very short). In this case, the Terminal Airspace design team should ensure that the work is organised so that the tasks can be completed in the time available. Where timescales are extremely short, this would usually result in more human resources being required to accomplish the tasks.

A sample task list is provided as an attachment to this chapter.

2.5 SUMMARY

This Chapter has discussed the planning steps applicable to a Terminal Airspace design project in the context three managerial framework Types. It has shown that *planning* the work and *doing* the work are critical elements to be accounted for when selecting a date for implementation or when working towards an implementation date.

This Chapter contains three Attachments, one shows a Sample Planning schedule, the second a sample task list for a Terminal Airspace Design project, the third a summary of the Planning Process discussed in this and the previous chapter.

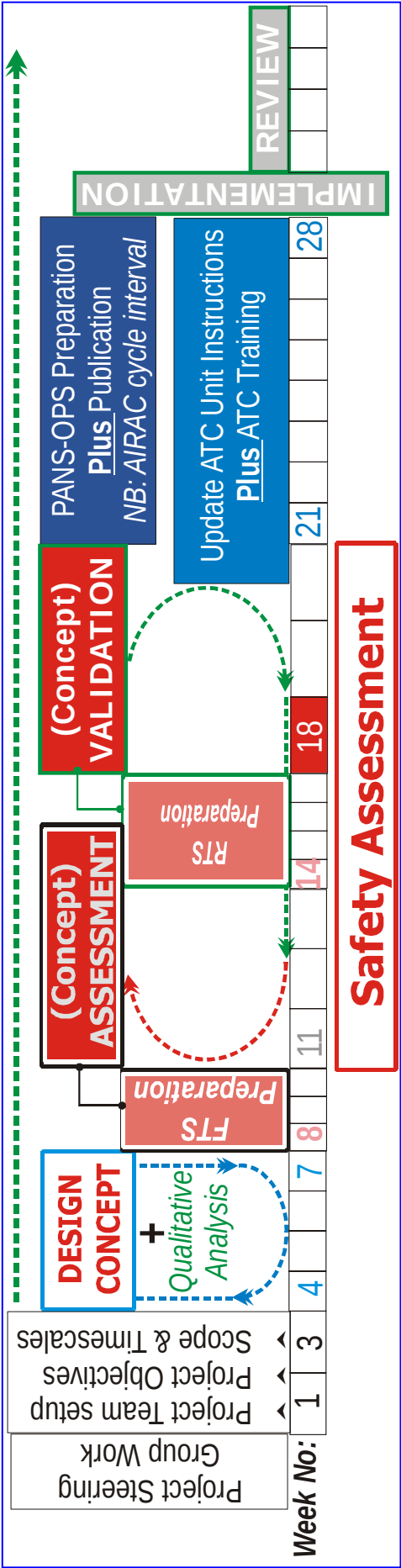
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Terminal Airspace Design Guidelines - Part B

Sample Project Schedule

Attachment B.2-1



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Terminal Airspace Design Guidelines - Part B**Attachment B.2-2****Sample Project Planning Checklist**

TERMINAL AIRSPACE DESIGN PROJECT (ref. Part B)			
PROJECT NAME:	START: [date]	TARGET ↓IMPLEMENTATION↓ [DATE]	
ESTIMATED EFFORT (TOTAL)	END: [DATE]		
BACKGROUND & CONTEXT:			
INTERNAL DESIGN TEAM MEMBERS:	[NAME]	[NAME]	[NAME]
	[NAME]	[NAME]	[NAME]
EXTERNAL TEAM, MEMBERS:	[NAME]	[NAME]	[NAME]
INTERNAL REPORTS TO:	[NAME]	[NAME]	[NAME]

STRATEGIC CONSIDERATIONS

1. OBJECTIVES:

DESIGN CONSIDERATIONS	
1. OBJECTIVES:	2. SCOPE:
3. DEPENDENCIES:	4. RISKS: performance indicators
5. PERFORMANCE INDICATORS:	
Safety:	
Capacity:	
Environmental:	

Terminal Airspace Design Guidelines - Part B

A. WORKING ARRANGEMENTS	
➤ Members of Terminal Airspace Design Team ➤ Leader of Terminal Airspace Design Team, (if applicable) ➤ Operation Manager, (if applicable) ➤ Project Steering Group, (if applicable) ➤ Additional team members (recruit, latest, after Tasks are identified (see below)	
Number of days required to set up working arrangements	
B. POLICY AND REGULATORY MATERIAL	
➤ Safety Policy ➤ Environmental Policy. ➤ Safety Assessment requirements and guidelines ➤ Environmental guidelines ➤ Approved Airspace Design Methodology ➤ Approved Validation methods (that may be used to validate design) ➤ Relevant International material e.g. ICAO SARPs, PANS etc.	
Number of working days required to identify relevant Policy and Regulatory material	
C. PROJECT DEPENDENCIES	
➤ Availability of ▪ ATC Training Facilities ▪ Simulation facilities (once validation method selected) ▪ Specialists to undertake specialist/technical studies e.g. Environmental Impact studies. ➤ Tentatively reserve facilities for ATC Training, Simulation; ➤ Prepare draft calls for tender w.r.t anticipated technical/specialist studies ➤ Content and Schedule of other airspace/airport projects ➤ PANS-OPS specialist (availability) ➤ Tentatively reserve services of PANS-OPS Specialist. ➤ AIRAC cycle dates(affects implementation)	
Number of working days required to identify project dependencies and complete (tentative) preparatory work	

Terminal Airspace Design Guidelines - Part B**D. PROJECT TASKS & RELATED ACTIVITIES**

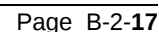
1. Propose design objectives
2. Feasibility Assessment (including Cost Benefit Analysis and Preliminary Safety Assessment)
3. Finalise Design Objectives and Scope
 - a) Decide implementation date as a function of Tasks to be completed; or
 - b) Tailor Scope/Objective to fit into available time.
4. Firm up Calls for tender w.r.t specialist/technical studies
5. Confirm reservation for ATC training facilities and Simulation
6. Cost Benefit analysis and Preliminary Safety Assessment
7. Statement and Critical Review of Reference Scenario
8. Selection of Performance and Safety Criteria
9. Identification of Assumptions, Constraints and Enablers
10. Development of Terminal Airspace design concept, including
 - a) Routes and Holds
 - b) Structures and Sectors
 - c) Qualitative assessment of concept
 - d) Impact assessment of proposed concept (e.g. Environmental impact study)
11. Select Scenario(s) to be Validated
12. Validation of proposed Scenarios and Safety Assessment
 - a) Prepare simulation
 - b) Run simulation
 - c) Data analysis
 - d) Write up final report of findings
13. Complete safety assessment documentation as per Safety Policy
14. Finalise outstanding reports
15. Obtain approval for implementation
16. Prepare for implementation
 - a) PANS-OPS Specialist to design SIDs/STARs as per PANS-OPS Criteria
 - b) AIP and other relevant Publications (NB AIRAC cycle dates)
 - c) ATC Training
 - d) Amend Letters of Agreement (if required)
 - e) Amend local/national ATC Procedures, (if required)
 - f) Amend local/national regulations, (if required)

Number of working days required for each identified Task/Activity

Terminal Airspace Design Guidelines - Part B

E. TASK ALLOCATION			
Task No:	Responsible Person/s	Due date (Draft Report)	Due Date (Final Report)
1			
2			

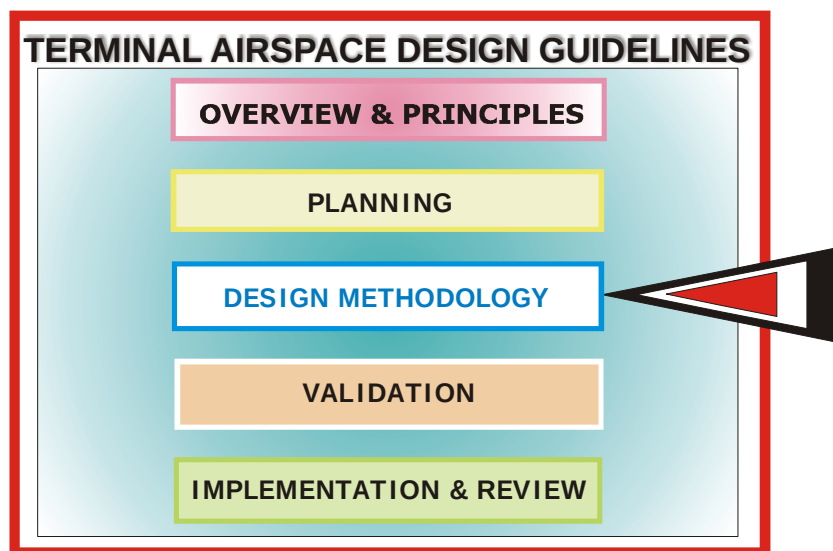
ESTIMATED TOTAL NUMBER OF DAYS (A+B+C+D+E)	
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Terminal Airspace Design Guidelines - Part B

PART C

DESIGN METHODOLOGY



Terminal Airspace Design Guidelines - Part C

INTRODUCTION

Part C supplies the level of guidance required by Terminal Airspace Design Planners. Building upon the foundations created in Parts A and B, Part C contains the *Design Methodology*.

As such, Part C assumes that the **objectives** and **scope** of the Design Project (see Part B, para. 1.3.1) have been agreed.

General

Mindful that it is neither possible nor desirable to create a generic blueprint for the design of Terminal Airspace – because each Terminal Airspace is unique and subject to local considerations – Part C should not be construed as a blueprint. Instead, Part C should be viewed as a store of proven methods and guidelines intended to support Terminal Airspace design planners in their quest to meet their strategic and design objectives. As such, expressions such as *should* and *may* are used intentionally throughout Part C. With the increasing availability of new technologies for use by Terminal Airspace designers, Part C will, more than any other part of this document, be updated progressively over time.

Given the level of detail referred to above, the contents of Part C are covered over several chapters as follows:

- ❑ **CHAPTER 1: DESIGN METHODOLOGY – AN OVERVIEW**
- ❑ **CHAPTER 2: THE REFERENCE SCENARIO**
- ❑ **CHAPTER 3: SAFETY & PERFORMANCE CRITERIA**
- ❑ **CHAPTER 4: ASSUMPTIONS, ENABLERS & CONSTRAINTS**
- ❑ **CHAPTER 5: GUIDELINES - ROUTES AND HOLDS**
- ❑ **CHAPTER 6: GUIDELINES – STRUCTURES AND SECTORS**
- ❑ **CHAPTER 7: CONCEPT EVOLUTION**
- ❑ **CHAPTER 8: DESIGN METHODOLOGY – CHECKLISTS**

Terminal Airspace Design Guidelines - Part C

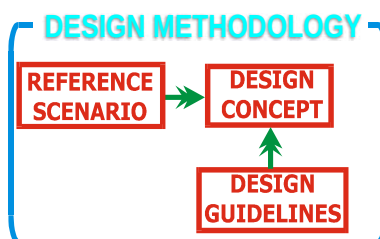
Safety Provisions

The attention of airspace designers is drawn to the following ICAO and EUROCONTROL provisions concerning safety in the context of airspace design and planning. These document references include but are not limited to -

- ATS Safety Management (ICAO Annex 11 Chapter 2);
- Safety Assessments as per (ICAO PANS-ATM Chapter 2);
- Guidance to ATM Safety Regulators (ESARR 3);
- Risk Assessment and Mitigation in ATM (ESARR 4).

Style Notes

1. Because the Design Methodology contained in Part C is detailed, each Chapter begins with its own abridged Table of Contents and a Design Methodology 'Locator Box' (below).



2. When considered helpful, Comment Boxes have been inserted at various places in Part C. These have been given a distinctive in appearance (below), and provide answers to general questions that are frequently asked. For example:

Comment: *What extraneous factors should be considered in selection of a 'futuristic' Traffic sample?*
Various factors, not easily visible within a given traffic sample, may influence traffic patterns of the future. Examples of these include ...

3. Exceptionally, more specific comments mainly dealing with RNAV, weather phenomena and the Environment are provided, particularly in Chapters 5 and 6. For convenience, these are preceded by distinctive symbols:

	RNAV
	VFR Operations or VFR Routes
	Weather
	Environment

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CHAPTER 1

- DESIGN METHODOLOGY: AN OVERVIEW –



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ATTACHMENTS

C.1-1: Document References of Relevance to Terminal Airspace Design.

Terminal Airspace Design Guidelines - Part C

1.1 INTRODUCTION

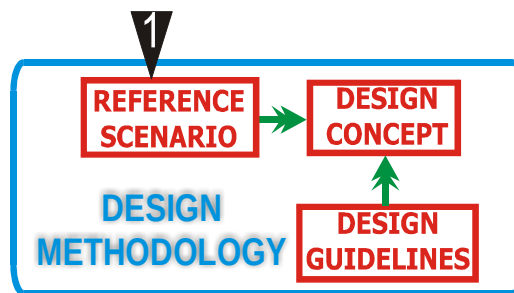
This chapter provides an overview of the *Design Methodology* which consists of the **Reference Scenario**, the **Design Concept** and **Design Guidelines**. It also explains the context of the *Design Methodology* in a Terminal Airspace design project, its potential applications and basic assumptions underlying the design process.

1.1.1 REFERENCE SCENARIO (CHAPTER 2)

The *Reference Scenario* and a *Critical Review* of this reference marks the starting point of the design methodology. Whilst its relevance might not be apparent, its importance is three-fold:

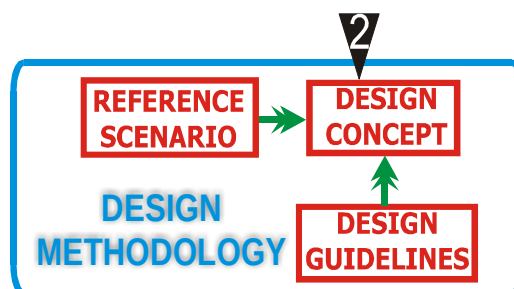
- ❑ it is an efficient way of refining the *design objectives* given that a design project is usually undertaken as a means of improving upon the existing design; and
- ❑ it provides a benchmark against which the *design concept* can be compared; and
- ❑ it prevents design 'weaknesses' identified in the *Reference Scenario* in the *Design Concept*, being repeated.

For the above reasons, the Reference Scenario is where the *Design Methodology* commences.



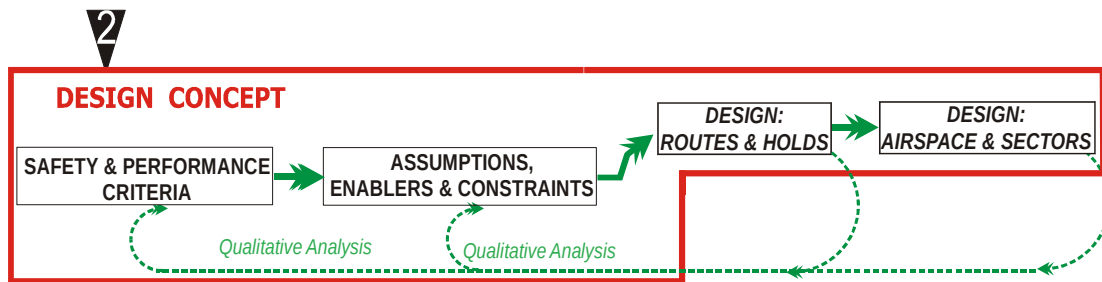
1.1.2 DESIGN CONCEPT (CHAPTERS 3 & 4)

The *Design Concept* marks the second major step of the *Design Methodology* but the **starting point of the design process**.



The *Design Concept* is not limited to designing routes, holds, the airspace and sectorisation but also includes all the preparatory work involved in the design process. For this reason, the *Design Concept* is made up of several components, which are usually undertaken in the (left-to-right) order illustrated below.

Terminal Airspace Design Guidelines - Part C

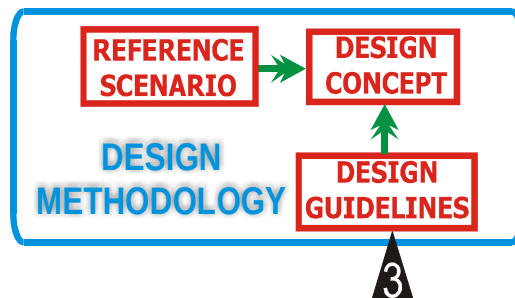


Several remarks may be made about the above illustration:

- ❑ The reverse arrows and expression *Qualitative Analysis*. These serve to show that when the design stage is reached, a continuous cross-checking process is required to ensure that safety and performance criteria are being met and that the assumptions, constraints and enablers are consistent with the design.
- ❑ The expression *Qualitative Analysis* is significant in that it implies that expert judgement is required in order to make a meaningful analysis.
- ❑ Safety and Performance Criteria as well as Assumptions, Enablers and Constraints are *constants* to the entire Terminal Airspace modification process. They are carried through to the Assessment and Validation phases of the project (see below).

1.1.3 DESIGN GUIDELINES (CHAPTERS 5-7)

Last – but not least – the *Design Guidelines* provide the third component of the *Design Methodology*. They explain **how** to design the different parts of a Terminal Airspace i.e. routes, holds, the airspace and ATC sectorisation.



As with the *design concept*, the design guidelines are also made up of several components, undertaken in a specific order. Usually, this order is

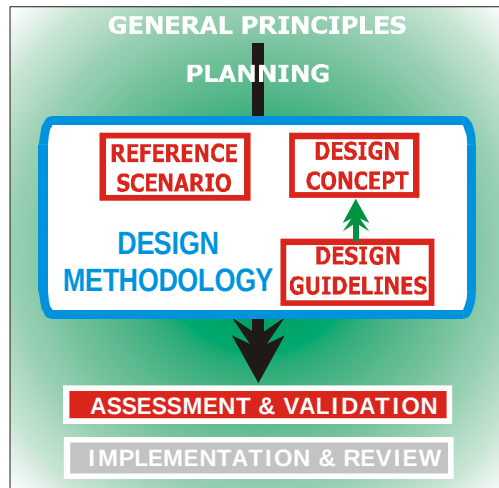
- ❑ routes and holds are designed **first**;
- ❑ the Terminal airspace structure is designed **second**;
- ❑ ATC sectors are designed **third**.

However, throughout the design process, early design of each component may be adapted or altered in light of evolving considerations of the other components i.e. a continuous process of qualitative analysis and adaptation unless a coherent and effective end result is achieved.

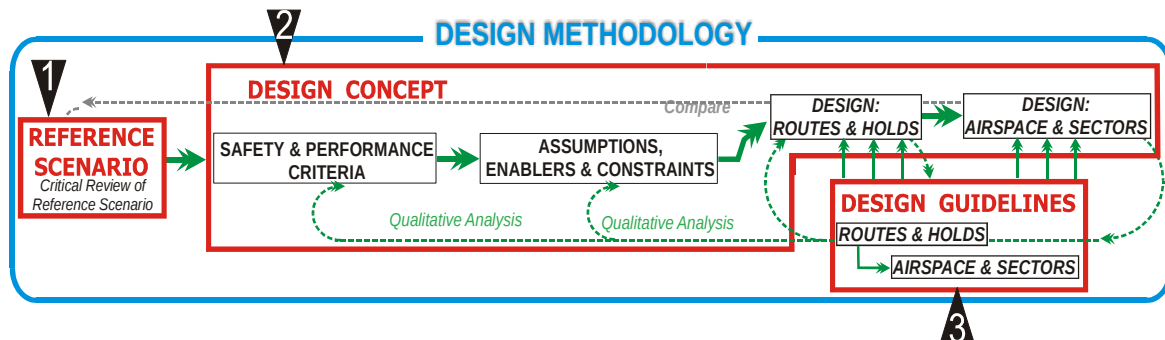
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1.2 DESIGN METHODOLOGY IN CONTEXT

In the overall Terminal Airspace Design process, the *Design Methodology* underpins the airspace design and is placed after planning (where the operational requirements and objectives are identified) and before assessment and validation takes place.



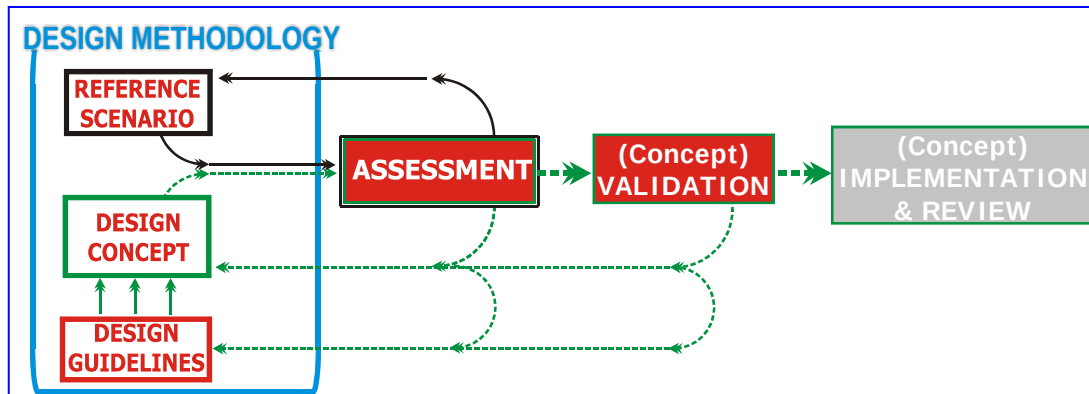
As far as the designer is concerned, the *Design Methodology* starts with the *Reference Scenario* and is followed by the *Design Concept*. This concept would be based on a set of *Design Guidelines* (which may be of a national nature or those contained in this document).



Because this document provides *guidance* as to how a Terminal Airspace should be *designed*, however, the *Design Guidelines* are identified as a separate 'component' of the *Design Methodology*. In reality, however, the *design concept* would be based on the other elements of the design concept and a set of *design guidelines*.

In the context of *actual* Terminal Airspace design, it may be said that the *Reference Scenario* and *Design Concept* are the main products of the *Design Methodology*. Once established, these two components are then assessed (as discussed in Part D), and once a *Design Concept* is selected – because it has reached a suitable stage of maturity – the *Design Concept* is validated and implemented (and the *Reference Scenario* put to one side). Notably, the assessment involves *comparisons* with the *Reference Scenario*, and consistency checks with the design concept - hence the reverse arrows below.

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Although it is not possible to claim that each of the four steps should all be completed in order to ensure successful design, **what can be stated with certainty is that a design process starts at a conceptual level and that expert judgement is integral to each of the four steps.**

Comment

*It is fair comment that the creation of the design concept and its qualitative analysis are relatively inexpensive when compared to later stages identified as Assessment and Validation (usually undertaken by Fast- or real-time simulation). This is one – but certainly not the main – reason why it is advisable to subject the design concept to rigorous qualitative analysis **before** moving to the Assessment and Validation phase. From a practical perspective, some airspace studies have shown that high calibre qualitative analyses make it possible to skip the Assessment and move directly to validation using, for example, a real-time simulation (normally, these are for relatively simple airspace developments). In similar circumstances, high-quality fast-time simulations can serve both the quantitative analysis and validation phase – which may allow for by-passing validation by real-time simulation and proceeding directly to implementation.*

*It is commonly believed that results from real-time simulation are better than those provided by fast-time simulation (and that the same is true of fast-time simulation as regards airspace modelling or creation of the design concept). This is not necessarily true: the value of **any** validation steps could be questioned if poor assumptions are made and/or poor formulation occurs.*

1.2.1 POTENTIAL APPLICATION OF THE DESIGN METHODOLOGY

Four situations may be envisaged when seeking to employ the Design Methodology.

- (i) Re-design/modification of an existing Terminal Airspace in response to a particular problem or with a view to a future development;
- (ii) the creation – for the first time – of a new Terminal Airspace at an existing airport;
- (iii) the design of a Terminal Airspace for an airport which has yet to be built, where the runway orientation for the airport is known;
- (iv) the design of a Terminal Airspace for an airport which has yet to be built and the runway orientation will be selected from a pre-defined set as a function of the preferred Terminal Airspace design amongst other factors.

Whilst the first option (i) is by far the most common and the incidence of options (iii) and (iv) quite rare, option (ii) is rapidly gaining prominence due to an increasing tendency for low-cost airlines to locate their centre of operations at (previously) 'quiet' regional airports.

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Of particular interest, as regards options (ii) to (iv), is the fact that no *Reference* (Terminal Airspace) *Scenario* exists and as such, it is not 'available' for comparison with the Design Concept. In the absence of a *Reference Scenario*, another benchmark is required and the *Design Guidelines* together with designer experience can provide adequate benchmarks.

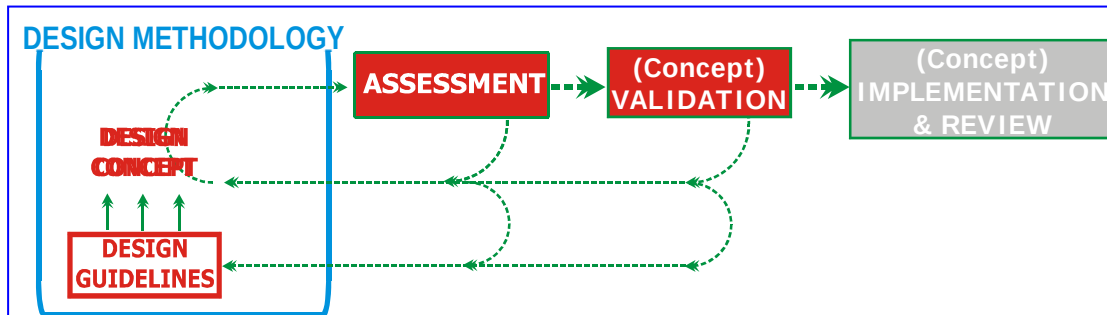


Figure 1- 1: Design Methodology without Reference Scenario

1.3 UNDERLYING ASSUMPTIONS

1.3.1 METHOD

Although this chapter – and indeed, this document – lays considerable emphasis on the importance of following a *method* when designing a Terminal Airspace, it is necessary to state that successful design is not guaranteed if the *methodology* is followed in *form* but not in *substance*. Adherence to a process and working one's way through a checklist is not enough: the planning methodology used in the process needs to be underpinned by a clear **set of objectives** (see Part B para. 1.3.1) as well as a **realistic** view of Terminal Airspace operations both present and future. Thus, for example, if the **design objective** of the design project is to find a way to reduce track mileage on a certain STAR, the solution might be to design a STAR for use by aircraft that are P-RNAV certified. This said, the STAR should only be designed **if** the aircraft for whose use it is intended are likely to be P-RNAV certified.

As obvious as the above example might seem, an **unrealistic** approach to design is one of the frequent criticisms levelled at designers and planners. Flawless though the design of a particular route or procedure may be, if it cannot be used (because, for example, the assumptions on which it is based are unrealistic) the design cannot be successful because it will fail to meet the operational needs. This suggests, therefore, that aside from knowing the **objectives** of the design project, one of the first 'rules' of Terminal Airspace Design concerns a requirement for the project to be based upon a **realistic assumptions, realistic constraints and realistic enablers**. This 'rule' applies equally to the *Reference Scenario* as it does to all phases of the project i.e. design, assessment and validation processes.

1.3.2 COLLABORATION

Whilst all of the Principles described in Chapter 2 of Part A are considered part of the foundation of the Terminal Airspace design process, it is considered opportune to emphasize that user requirements and environmental interests should be accounted for in the design phase. Collaboration is an on-going an extensive process: it applies whether fixing the **Reference Scenario, Assumptions, Enablers and Constraints** or undertaking the design. In all cases, input from airspace users, environmental specialists *and* various branches of the air traffic services (i.e. collaborative effort) should be invited.

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Importantly, collaboration is not limited to a process within a particular State. In the case of a Terminal Airspace located close to an international border – and especially where *two* Terminal Airspaces are located in close proximity to the common internal border, this collaboration should be extended into the international domain. Input from the adjacent State(s) is also desirable – particularly when designing routes, holds, creating the airspace structure and sectorisation. Indeed, future traffic demands could conceivably require two independent Terminal Airspaces on either side of a border to be transformed into a common cross-border Terminal Airspace.

Comment:

Present day air traffic management is characterised by specialisation in different fields. For this reason, a broad range of specialists should be included in the Terminal Airspace Design team. This means that the design team should include ATC experts as well as Users, PANS-OPS specialists and Environmental representatives. Failure to collaborate effectively with the support of other specialists, adjacent States or to obtain the input of other interested parties could result in the wrong assumptions being fixed or constraints and enablers not being identified correctly. Of necessity, such errors weaken the design and may lead to subsequent rejection.

1.3.3 STRIKING THE BALANCE

General Principles and the principle of collaboration considered, it becomes evident that the designers are frequently required to strike the balance between the diverse and competing interests. Despite this reality, it is opportune to point out that the quest for collaboration should not extend to compromising safety. Whilst safety objectives can be achieved in a variety of ways (which can be viewed as a ‘compromise’ of sorts), safety itself should not be compromised. Thus in the triangle made up of Safety, Capacity and Environmental interests, Safety is not negotiable.

1.4 SUMMARY

The *Design Methodology* described in this chapter is the anchor point of the Terminal Airspace design project and is aimed at responding to the operational requirements and design objectives described in Part B.

Made up of the **Reference Scenario**, the **Design Concept** and **Design Guidelines**, the efficiency of the Design Methodology depends upon following a well planned step-by-step process undertaken in collaboration with interested parties with a view to ensuring the safety of operations within the airspace being designed.

To the above ends, qualitative analysis is of particular importance to the entire *Design Methodology* at each part of the process.

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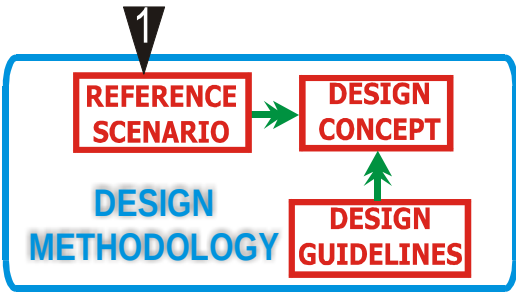
Terminal Airspace Design Guidelines - Part C**Attachment C.1-1****Document References of Relevance to Terminal Airspace Design**

Part C				
Chapter	Subject		Document Reference	
3	Safety Assessment	How to undertake -	Doc. 9689	
		Need For-	Annex 11	Chapter2
		Need For-	Doc. 4444	Chapter 2
		Need for & How to undertake -	ESARR 3 & 4	
4	Enablers, Constraints	Environmental Protection	Annex 16	
		RNP - Manual of	Doc. 9613	
		LoA - Common Format	EAPM	Section 6
		Radar Surveillance ... Major Terminal Airspace	E-Ref. 1 (below)	Chapter 5
5	Arrival/Departure Routes	Design Criteria – Conventional/RNAV	Doc. 8168	Vol. II
		Design Criteria – RNAV	E-Ref. 2 (below)	
		Helicopter Operations	Doc. 9426	Part II, Section 4
		IFR/VFR - Mixed Operations	Doc. 9426	Part II, Section 4
		Instrument Flight Procedures Construction	Doc. 9368	
		Lateral Limits	Annex 4	
		Level Restrictions - (~Vertical Limits)	Annex 4	
		Mixed IFR/VFR Operations	Doc. 9426	Part II, Section 4
		Publication	Annex 4	
		Publication	Annex 15	
		SID/STAR - Establishment of	Doc. 9426	Part I, Section 2
		SID/STAR- Identification of	Annex 11	Appendix 3
		Significant Points - Establishment & Identification	Annex 11	Appendix 2
		Waypoint Naming Convention	E-Ref. 3 (below)	
	<i>Routes - Other</i>	<i>ATS Routes (RNAV) - Establishment of</i>	<i>Annex 11</i>	<i>Attachment B</i>
		<i>En Route ATS Route Design Guidelines</i>	<i>EAPM</i>	<i>Section 4</i>
	Holding	Design Criteria - Conventional/RNAV	Doc. 8168	Vol II
		Design Criteria - RNAV	E-Ref. 3 (below)	
		Holding - Establishment of	Doc. 9426	Part I, Section 2
		Template	Doc. 9371	
6	Terminal Airspace	General Terminal Airspace Information	Doc. 9426	Part I, Section 2
		Publication	Annex 15	Chapter 3
		Vertical/Lateral Limits	Annex 11	Chapter 2
	<i>Airspace - Other</i>	<i>Airspace Restrictions & Reservations</i>	<i>EAPM</i>	<i>Section 3</i>
		<i>General Airspace Guidelines</i>	<i>EAPM</i>	<i>Section 1</i>
		<i>En Route Design Guidelines</i>	<i>EAPM</i>	<i>Section 4</i>
	Sectorisation	Capacity Estimation	Doc. 9426	Part II, Section 1
		Capacity Estimation	Doc. 4444	Chapter 3
		Co-ordination	E-Ref.3	
		Co-ordination	Doc. 4444	Chapter 10
		General Information	Doc. 9426	Part II, Section 3
	<i>Sectorisation - Other</i>	<i>En Route Sectorisation Guidelines</i>	<i>EAPM</i>	<i>Section 4</i>
E-Ref.1	EUROCONTROL STANDARD DOCUMENT FOR RADAR SURVEILLANCE IN EN-ROUTE AIRSPACE AND MAJOR TERMINAL AIRSPACE [Edition 1, MARCH 1997]			
E-Ref.2	EUROCONTROL: GUIDANCE MATERIAL FOR DESIGN OF TERMINAL PROCEDURES (DME/DME, BARO-VNAV & RNP-RNAV) [Edition 3, JANUARY 2003]			
E-Ref. 3	Common Format, Cross-Border, Inter-Centre Letter of Agreement Document [ASM.ET1.ST015 DEL01/02]:			

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CHAPTER 2

- THE REFERENCE SCENARIO -



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2.1 INTRODUCTION

This chapter presents the *Reference Scenario* which constitutes the first step of the *Design Methodology*.

As stated in the previous chapter, the relevance of the *Reference Scenario* and a *Critical Review* is four-fold:

- ❑ it provides a benchmark against which the *design concept* can be compared¹; and
- ❑ it is an efficient way of refining the *design objectives* and ensuring that operational requirements are being addressed (see Part B) given that a design project is usually undertaken as a means of improving upon the existing design; and
- ❑ it may help to refine the scope of the existing project; and
- ❑ it prevents design 'weaknesses' identified in the *Reference Scenario* being repeated.

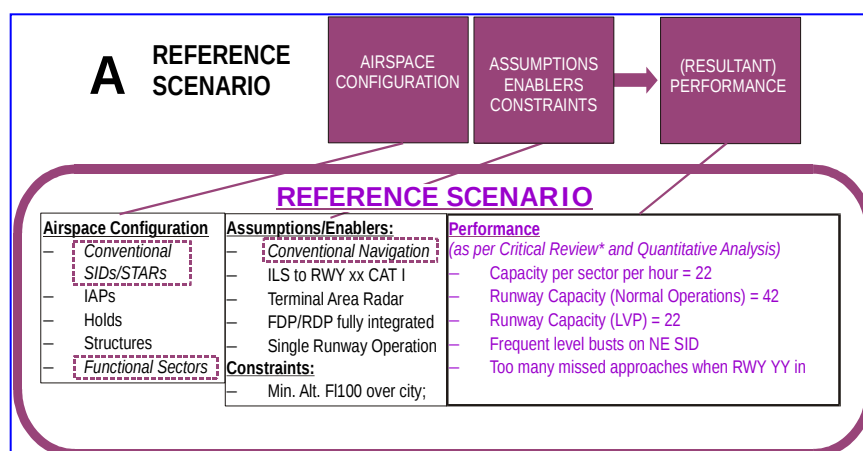
Although the process of describing current Terminal Airspace operations is sometimes considered a tiresome exercise, one of its additional advantages is that it provides the opportunity to discover (and correct inconsistencies) related to the existing design. Examples of these discoveries may include –

- ❑ published SIDs/STARs – that are no longer used;
- ❑ out-dated instrument approach procedures;
- ❑ publication errors in the AIP;
- ❑ abandoned navigation aids.

2.2 WHAT IS THE REFERENCE SCENARIO?

In general terms, the *Reference Scenario* is a description of the **current** Terminal Airspace operations. As such, the Reference Scenario describes the **current layout of routes and instrument approach procedures as well as holding patterns, airspace structures, ATC sectorisation and how the traffic is managed within the airspace and in relation to surrounding airspace**.

Given that the (main) purpose of the Reference Scenario is to provide a benchmark against which the new/modified design is compared, the assumptions, enablers and constraints which formed the basis of the Reference Scenario should also be identified.



¹ The relevance of this is that a comparative assessment is the most usual way in which safety is assessed in those instances where 'absolute' measurement is not required. (See Part C, Chapter 3).

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Nevertheless, there are cases when the **current** Terminal Airspace is not used as the *Reference Scenario*. This occurs when, for example, previously validated modifications to any aspect of the Terminal Airspace (i.e. routes, or holds or structure or sectorisation) are to be implemented in the short-term i.e. before the implementation of the current project.

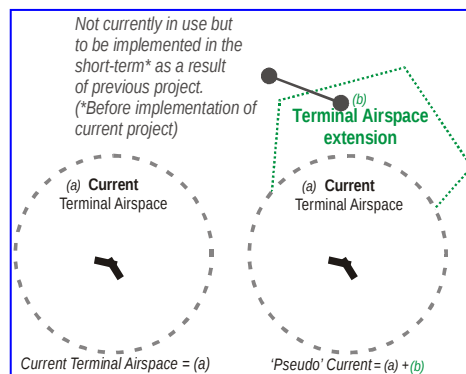


Figure 2- 1: Reference and 'Pseudo' Reference

Figure 2- 1 illustrates the 'Pseudo' current using an example of a change to airspace dimensions. The yet-to-be-implemented change (i.e. (b)) would thus be used as a 'Pseudo' Reference against which new changes are measured. This 'Pseudo' Reference could equally be based upon a new route or routing structure, holding patterns or the sectorisation.

2.3 CREATING THE REFERENCE SCENARIO

At this stage of the *Design Methodology*, creation of the Reference Scenario is mainly a paper exercise. Even so, the detail and quality of the information contained in the Reference Scenario should be such that someone unfamiliar with the Terminal Airspace and its operating practices is able to form a comprehensive 'picture' of the airspace.

The Reference Scenario is created from various sources. Ideally, all these sources should be used so as to build the most complete picture as to the current or 'pseudo' current Terminal Airspace operations.

Below, an abridged list is provided showing selected items needed in the statement of the *Reference Scenario*. A comprehensive Checklist and the sample questions is provided in Chapter 8, **Attachment C-8-1**:

<u>Information</u>	<u>How obtained</u>
☐ Predominant Runway-in-use at airport(s) within the existing Terminal airspace.	Statistical analysis of existing data over the last few years.
☐ Current Traffic Demand and its geographic and time distribution.	Traffic samples can be obtained from the CFMU and/or local ATC centre ⁽¹⁾ .
☐ Analysis of the Traffic sample e.g. IFR/VFR mix; Fleet Mix; Aircraft performance mix, etc.	Traffic sample. obtained above.
☐ Routes (IFR & VFR), instrument approach procedures and Holding patterns/areas.	AIP and traffic sample;
☐ Radar Vectoring patterns	Operational controllers
☐ Airspace dimensions	AIP and Operational controllers

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- ❑ Sectorisation (Terminal Airspace, adjacent Terminal Airspace and Lower ACC sectors) Operational Controllers and ATC System specialists
- ❑ Traffic Management i.e. Co-ordination agreements between sectors and Local ATC Instructions and Letters of Agreement.
- ❑ Existing constraints (e.g. terrain) PANS-OPS specialists / environmental specialists; policy makers.
- ❑ Existing ATM/CNS enablers (e.g. 5 DMEs in Terminal Airspace) Operational controllers/Engineers

Note (1): Part C, Chapter 4 explains how to select and analyse Assumptions. One of the most important assumptions is the Traffic Sample.

2.4 CRITICAL REVIEW OF THE REFERENCE SCENARIO

Once the Reference (or Pseudo Reference) Scenario has been described, it should be critically reviewed. This critical review is a qualitative exercise which involves operational experts closely scrutinising the existing Terminal Airspace operations i.e. each element of the airspace organisation and how effectively and safely it works with a view to identifying operational problem areas. This is the stage at which existing constraints are identified, and the required mitigation and enablers (see Part C, Chapter 4).

Undertaking the critical review is a relatively straight-forward exercise – although it can be difficult for the design team to examine (what may be their previous efforts) in a critical light. As can be seen by the Reference Scenario and Critical Review Checklist in Chapter 8 **Attachment C.8-1 and C.8-2**, the Critical Review is concerned with establishing *What is wrong*, or *What factors limit* the Reference Scenario. On the positive side, aspects that work well should be identified (so that the benefits are not lost).

If, for example, the SIDs are being critically reviewed, the design team may agree that for most of the year, the existing SIDs meet the operational requirements in that they appear to respond to the actual aircraft performance of the current fleet mix. This said, however, controllers may notice that most heavy aircraft bound for the Far-East are unable to make the level restrictions on one of the SIDs when the temperature are high during the summer months. During the critical review process, this situation is identified – and may indeed be used to refine the design objectives discussed in Part B.

2.5 REFINING DESIGN OBJECTIVE(S)

One of the 'outputs' of the *Critical Review* process is that current design weaknesses or flaws in the current operation may be 'added' to list of design objectives or used to refine the design objectives. In the example used above, the possibility of designing a discrete SID for use during the summer months by heavy aircraft has arisen and as such, it may be appropriate opportune to add this to the design objectives.

2.6 COMPARING SCENARIOS

Although the Reference (or 'Psuedo' Reference) Scenario serves, at a later stage, as the yard-stick against which the success of the new or modified design is measured, it may be considered logically inconsistent to seek comparisons between the Reference Scenario and new Scenarios based upon different assumptions or enablers (or constraints). The diagram below presents this apparent dilemma.

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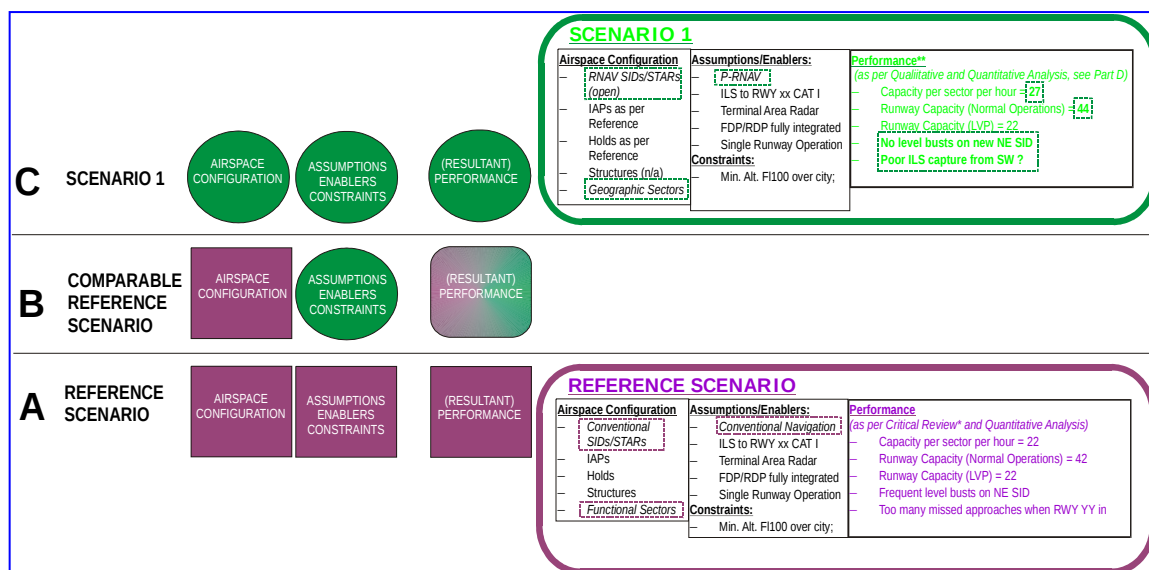


Figure 2- 2: Scenario Comparison

In the above diagram -

A= the Reference Scenario with its particular Assumptions, Enablers and Constraints and its resultant Performance.

C= the new Scenario 1, with, for example, a new set of SIDs/STARs based on a different assumptions (e.g. Navigation means = P-RNAV) and its resultant Performance.

In comparing the Performance of Terminal Airspace C (Scenario 1) with that produced by A (Reference Scenario), it could be argued that A and C are not comparable because the assumptions are different (e.g. navigation) and that the changes made to the SIDs and STARs are therefore substantial. Furthermore, a different sectorisation method has been used. Logically, this argument is correct, and if followed through one would need A to be based on C's assumptions to obtain performance B and that B should then be compared to C so that the comparison is meaningful.

If this approach were followed, it could be argued that the Reference is no longer the Reference once it is based on different assumptions. e.g. assume the 'true' Reference has one runway, and a new assumption is the addition of a parallel runway.

For this – amongst other – reasons, airspace designers seek to compare the performance output of the 'new' scenarios, in order to establish whether the new scenario(s) meets strategic and/or design objectives.

2.7 SUMMARY

The establishment of the *Reference Scenario* is the first step of the *Design Methodology* and is undertaken prior to embarking upon the *Design Concept*. The *Reference Scenario* usually reflects the current Terminal Airspace, though in some instances, use may be made of a 'Pseudo' current Reference Scenario.

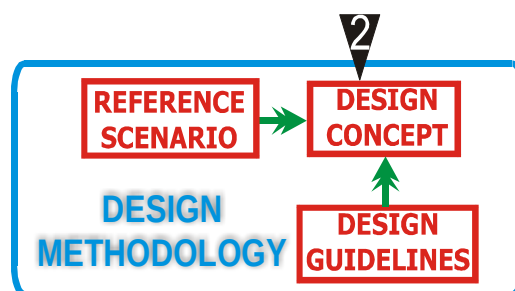
As a means of establishing a useful benchmark for comparison with the *Design Concept*, in order to refine the *design objectives* and as a mechanism of identifying existing design weaknesses, the *Reference Scenario* is subjected to qualitative analysis known as a *Critical Review*.

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CHAPTER 3

- SAFETY & PERFORMANCE CRITERIA -



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Figure 3 - 1: Evaluating Safety.....C-3-4

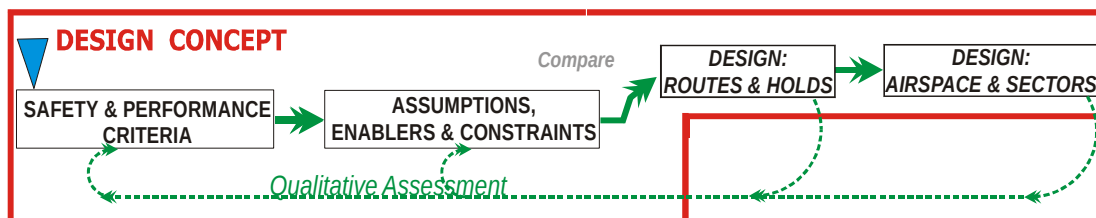
Figure 3 - 2: Assessment & Evaluation.....C-3-5

Figure 3 - 3: ESARR Safety Case Approach.....C-3-6

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3.1 INTRODUCTION

This chapter discusses *Safety and Performance Criteria* whose formulation constitutes the first phase of the *design concept*.



Safety and performance criteria are important because they provide a yardstick against which the safety and performance of the proposed design can be measured. Identified during initial project planning, these criteria may be translated into project and/or design objectives (see Part B) which accompany the project throughout its life-cycle. These ‘benchmarks’ remain constant throughout the development of the Terminal Airspace design project though the extent to which they can be successfully ‘measured’ may be affected by the project phase. For example, it may not be possible during the concept design phase to measure whether a capacity performance target is met, though this can be determined during the validation phase using the appropriate tool. In order for a proposed and implemented design change to be considered successful in safety and performance terms, the selected criteria need to be satisfied.

Although safety and performance criteria have always been important, their significance has increased since the introduction of mandatory ICAO and European requirements for States to undertake a safety assessment when making changes to their airspace design – See Part A, Chapter 2, General Principles.

Since entering into force of ICAO and EUROCONTROL¹ provisions in 2001 and 2003 respectively, expressions such as ‘safety case’, ‘safety argument’, ‘safety assessment’ and ‘safety criteria’ have become common-place. Sometimes, these terms are not necessarily used in a consistent manner and this has generated some confusion e.g. the expressions ‘safety argument’ and ‘safety case’ are sometimes used interchangeably. An awareness of this has influenced the layout of this chapter:

- ❑ Attempts have been made to align safety-related terms with their ICAO and ESARR equivalents. However, as this has not been entirely successful (because a one-on-one correlation between ICAO and ESARR terminology is not necessarily provided for), a section of this chapter has been devoted to several ‘key’ terms/concepts so that they can be recognised and understood irrespective of the nomenclature used.
- ❑ ‘Safety Criteria’ are not discussed in isolation but rather described within the greater context of safety case development. The latter is a generally accepted way of undertaking safety assessments.

Despite the above, attention is drawn to the fact that the aims of this document do not include providing guidance for the undertaking of safety assessments. It is therefore **stressed that the Terminal Airspace design team bears the responsibility for complying with the safety policy prescribed by the National Regulator, and that none of the material contained in this chapter should be construed as relieving the Terminal Airspace design team of such obligations.**

¹ See Part C, Chapter 1, Attachment C.1-1 for reference material related to Safety.

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3.2 CONCEPTS**3.2.1 QUALITATIVE AND QUANTITATIVE ASSESSMENT**

The need to assess the safety or other performance of a Terminal Airspace design is one reason for establishing safety and performance criteria. **Assessment** is an ongoing process: **qualitative assessment** which begins at conceptualisation and continues through implementation also provides the foundation for **quantitative assessment**.

Two types of assessment have been distinguished: **qualitative** and **quantitative** assessment.

- **Qualitative assessment** is achieved by expert judgement being used to assess the design using ICAO standards, recommended practices and procedures as a benchmark. Qualitative assessment relies upon expert (air traffic control/operational) judgement and effectively forms the basis for the design concept (and the Critical Review of the Reference Scenario and the identification of Assumptions, Constraints and Enablers). Qualitative Assessment is an on-going process: as well as providing the basis for the design concept, this expert judgement is also used to qualitatively assess *all* phases of the design methodology, and it is integral to quantitative assessment and to safety measurement – even when the emphasis appears to be on measurement against an absolute threshold. That qualitative assessment forms the backbone of the various validation methodologies will become evident in Part D, and it is used in implementation planning (Part E).
- In contrast, **Quantitative assessment** is concerned with ‘quantified’ results produced in the form of numerical data. e.g. capacity increased by 20%.

It is perhaps because quantitative assessment appears to provide ‘tangible’ values that these results are perceived as being preferable to those of a qualitative nature. But this perception is inaccurate – for at least two reasons:

- [i] Qualitative assessment made by expert ATC judgement is the primary way in which ICAO SARPs and procedures are safe-guarded during the design process; and
- [ii] if total reliance is placed upon quantitative results without qualitatively assessing what they mean (i.e. using expert judgement to interpret the results), the value of the quantitative assessment is likely to be less.
- [iii] Quantitative assessments are inadequate in effectively depicting and quantifying the complex and highly variable nature of airspace and air traffic operations. This is because quantitative safety assessment models tend to simplify many operational elements in order to be manageable. This results in limiting the number of elements to those having the greatest potential for effect – and this can return incorrect results. For this reason, quantitative assessment needs to be balanced by qualitative assessment i.e. operational judgment and experience for the complex interactions, conditions, dependencies and mitigations for which quantitative assessment cannot provide a meaningful measure.

What will become evident in the next section is that both qualitative and quantitative assessment are essential to the process of safety evaluation.

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3.2.2 EVALUATING SAFETY

ICAO Annex 11 and PANS-ATM includes requirements for a Safety Assessment to be undertaken when making certain modifications to the Air Traffic Management System. Significantly, ICAO has detailed those instances in which a Safety Assessment is required and an excerpt from the relevant ICAO material has been included in Part A of this document at Chapter 2. Because airspace designers must ensure and demonstrate that an airspace design is safe² (i.e. provide evidence of safety through a safety assessment process), this section provides a broad overview of how safety can be evaluated.

Two methods are commonly used to evaluate safety: one is **comparative (or relative)**, the other **absolute**. The use of one method does not exclude the other and most frequently, they are combined.

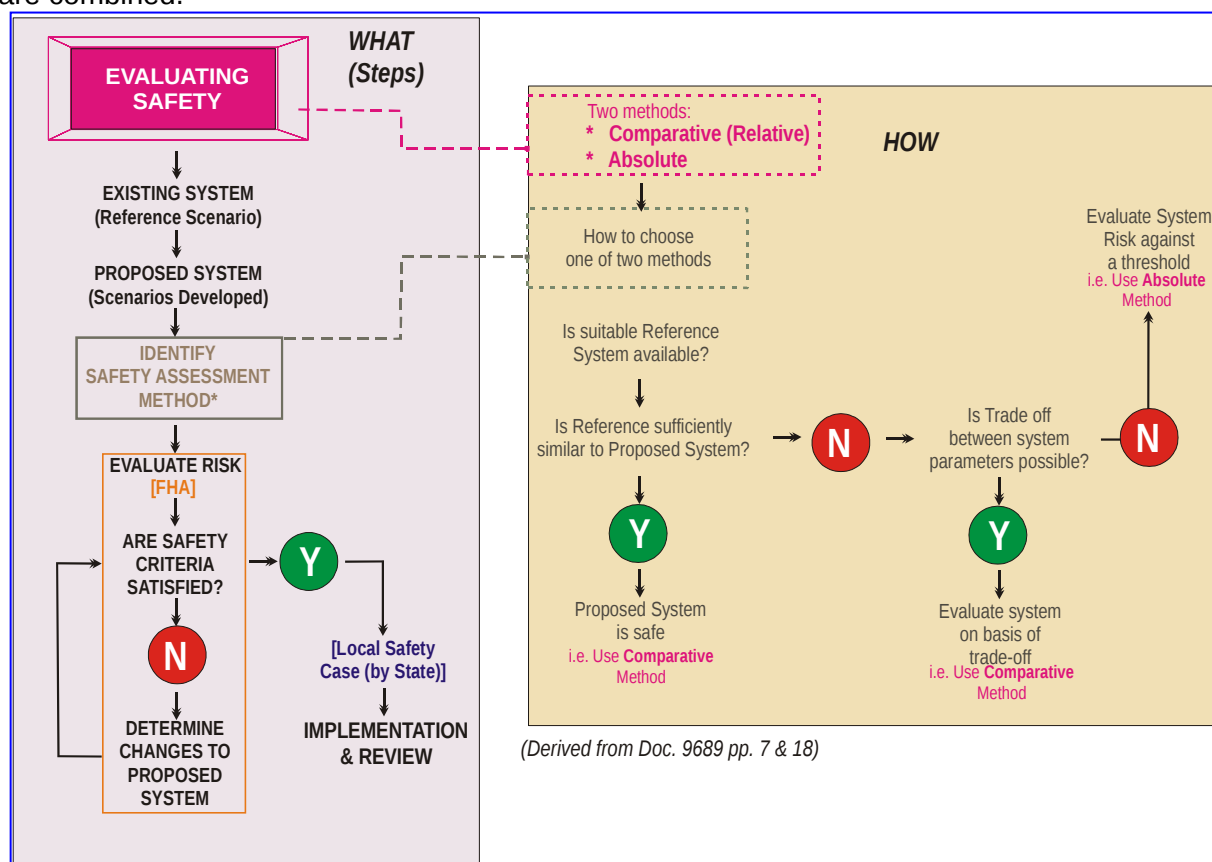


Figure 3 - 1: Evaluating Safety

Most airspace designers are familiar with the **comparative (or relative) method** because it is the most and frequently used. When safety is evaluated using this method, the safety of the proposed Terminal Airspace design is compared in relation to an existing design (called a Reference Scenario – see Part C, Chapter 2). Use of this method could therefore show an *increase/decrease or maintenance of safety* of a proposed design which has been compared to a Reference Scenario.

In contrast the **absolute method** involves evaluating safety against an 'absolute' threshold. An example of such an absolute threshold could be: *that the risk of collision is not to exceed 5 fatal accidents per 1 000 000 000 flight hours*. (This would more commonly be expressed

² See Part A Chapter 2, First Principle.

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as a requirement to meet a target level of safety (TLS) of 5×10^{-9}). A collision risk analysis using a collision risk model is the usual way in which a determination is made as to whether a TLS is being met – See Part D, Chapter 8.

Notably, **safety criteria** are set whichever method is used. Differently put, a benchmark is created whether the **absolute** or **comparative** method is used. The benchmark, however, is different dependent upon the method used. Whatever the method and/or safety criteria used, a safety evaluation can only be rigorous if **qualitative assessment** forms the backbone of the evaluation process.

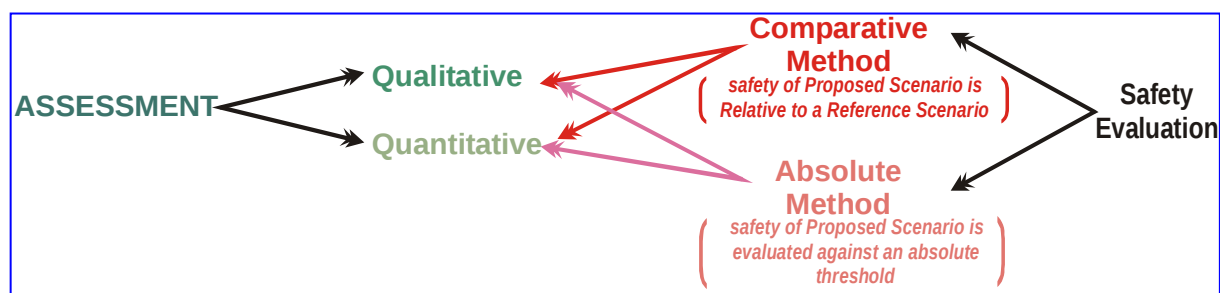


Figure 3 - 2: Assessment & Evaluation

It should be noted that the safety of an airspace design is not *only* dependent upon the correct application of design criteria when designing routes, holding areas, and airspace structures designed in accordance with the design rules and procedures contained, *inter alia*, in ICAO Annex 11 and Doc. 8168 (especially Vol. II). Safety factors are considered before and during this design phase, by, for example –

- ❑ developing a feasible airspace design concept (see Part C, Chapter 5 and 6) prior to the application of the PANS-OPS design criteria; and
- ❑ ensuring the accuracy of critical aircraft and operational assumptions which are used to form the basis of the PANS-OPS design;

In the 'greater' context, the design is also required to satisfy the safety objectives which are included, but not limited to the generic ATC objectives and whether these are met is most often determined by **qualitative assessment**. Thus whilst Annex 11 and Doc. 8168 provide rules relating to airspace dimensions and obstacle clearance criteria respectively, qualitative assessment criteria are included, but not limited to, PANS-ATM and various ICAO Annexes.

Comment:

How does the designer know when safety should be evaluated using the absolute method? Typically, the absolute method is to be used when required by ICAO. This usually involves instances when the change envisaged is radical and untried elsewhere (see Ref.1). For example:

- reduction of the vertical separation minima (RVSM)
- determination of new spacing between parallel ATS routes for which lateral navigation accuracy is specified with a view to applying the separation minima in PANS-ATM Chapter 5, as a basis for route spacing in Terminal Airspace; (see Ref 2)

It is opportune to add that because most Terminal airspace re-designs rely, for the most part, on existing ICAO provisions and do not involve radical changes such as those introduced with the RVSM example, the comparative/relative method is likely to remain the most frequently used (subject to certain conditions). In order to gain a greater appreciation of these two methods, readers are strongly encouraged to refer to the introductory chapters of ICAO Doc. 9689 and requirements of ESARR 4.

Ref.1: Manual on Airspace Planning Methodology for the Determination of Separation Minima, Ch. 6.

Ref. 2: Annex 11, Attachment B, paras. 1.1 & 3.1 in particular.

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3.3 THE SAFETY CASE APPROACH

The Member States of ECAC are required to comply with ESARR/4. Whilst ESARR/4 is regulatory in nature, guidance documents have been provided to ECAC States which explain how to undertake a safety assessment. One such document is entitled Air Navigation System **Safety Assessment Methodology (SAM³)**.

ESARR/4 and SAM are characterised by a **holistic approach**, a **risk based approach** and **system approach** to safety assessment.

Significantly a...” *Safety Assessment should be holistic: it should consider all the implications of new systems within the widest context and at all stages in the life-cycle.*” This includes (investigating) “*The complete chain of events in which the system may be involved in accident and incident causation: the potential consequences of system failures (hazards), their possible consequences on aircraft operations and their possible causes (deficiency of system elements and external events)*”. This suggests that such assessments are also made with other elements of the airspace operation e.g. aircraft, systems, procedures etc.

Therefore, the pre-implementation process involves the development of a safety case comprising a reasoned safety argument based on a Functional Hazard Assessment (FHA) and Preliminary System Safety Assessment (PSSA). After implementation, the safety case is revised as well as a System Safety Assessment (SSA). – See diagram below.

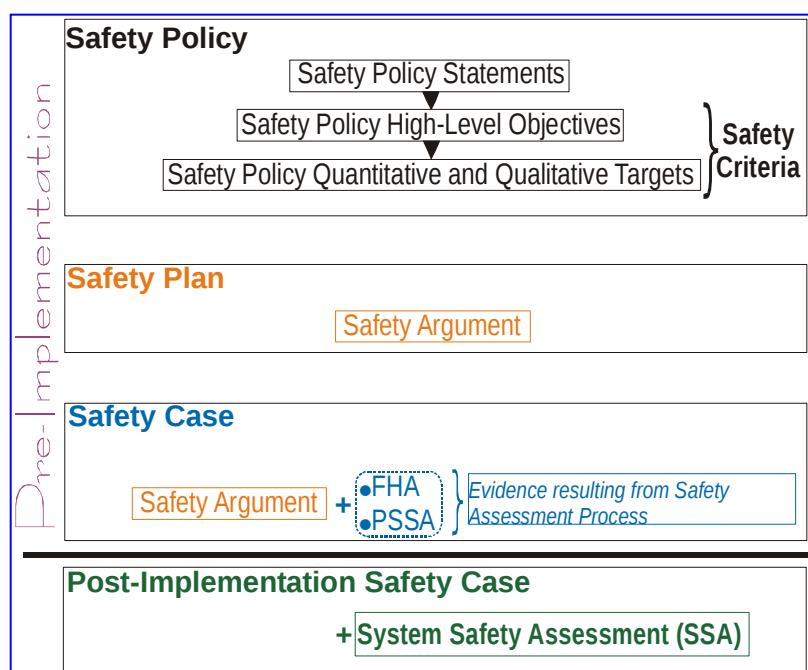


Figure 3 - 3: ESARR Safety Case Approach

3.4 OTHER PERFORMANCE CRITERIA

Performance criteria relate to the way in which the success of a Terminal Airspace design is measured. Whilst ‘safe’ performance may be viewed as the ‘first’ measurement of success, it is not enough for a Terminal Airspace to be safe if it does not deliver the performance expected in terms of capacity and environmental mitigation amongst others.

³ Air Navigation System **Safety Assessment Methodology**, EUROCONTROL, 17 April 2000 (SAF.ET1.ST03.1000-MAN-01-00),

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As with the *safety criteria*, **Performance criteria** are closely linked to the Design Objectives described in Part B (and, of necessity, the generic set of ATC Objectives described by ICAO in Annex 11). The *Performance criteria* to be selected become evident when answering the question “*What determines the success of the Terminal Airspace design?*” Differently put, *How can one confirm that the objectives have been met?*

The following are examples of performance criteria:

- ❑ an airport capacity increase of 20% is demonstrated; and
- ❑ no increase in noise pollution is experienced by the residents of Suburb Y between 22:00 and 05:00 UTC;
- ❑ track mileage flown by arriving aircraft is not extended by more than 5%;

Having decided upon the performance criteria (usually embodied in the strategic and design objectives – see Part B), it is necessary for the Terminal Airspace design team to select the appropriate tool so as to correctly measure these criteria. These are discussed in Part D.

3.4.1 EVALUATING CAPACITY AND ENVIRONMENTAL IMPACT

Although the **comparative** and **absolute methods** are commonly used in a safety context (above), other performance criteria can also be evaluated using in either a comparative or absolute manner. This can be demonstrated using the examples cited in para. 3.4:

1a. an airport capacity increase of 20% is demonstrated; and	Comparative
2a. no increase in noise pollution is experienced by the residents of Suburb Y between 22:00 and 05:00 UTC;	
3a. track mileage flown by arriving aircraft is not extended by more than 5%;	
<i>examples of Absolute measurement being required, are illustrated by changing the wording of the above criteria to new wording below.</i>	
1b.airport capacity = 129 movements p.hour	Absolute
2b. noise emitted by each ACFT does not exceed 65dB at the noise monitoring point.	
3b. track mileage flown by arriving aircraft does not exceed 32 NM from Terminal Airspace Entry point.	

Naturally, normal ATC simulators such as fast- or real-time may not be suitable for measurements relative to noise (e.g. 2a or 2b, above) and noise modelling tools would be required. It should be noted that developments are underway to combine fast time simulation with noise modelling software.

3.5 SAFETY, PERFORMANCE AND PROJECT PLANNING

Because a project's strategic objectives are closely linked to safety and performance criteria, it is useful to connect the information contained in this chapter with information presented in Part B – Planning. To this end, use is made of a fictitious example:

Strategic Objectives: *Increase existing **capacity**; reduce **environmental** impact over Suburb Y; meet the Target Level of **Safety**.*

Design Objectives: *Create new Terminal arrival and departure routes to accommodate a new parallel runway.*

(ICAO ATC Objectives: *Prevention of collision; maintaining a safe and orderly flow of air traffic i.e. creating a design that will be conducive to these objectives)*⁴.

⁴ inserted for completeness.

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Safety Criteria: the route spacing of 8NM between parallel Terminal Routes is required to meet a target level of safety of 5×10^{-9} .

Performance criteria: The Terminal Airspace design will be considered a success if, for example:

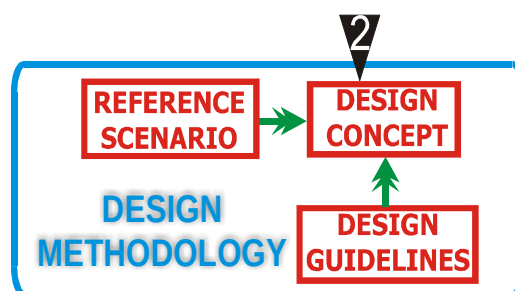
- **(quantitative)** Approach West Sector demonstrates a capacity increase of 20% demonstrated; and
- **(quantitative)** no increase in noise pollution is experienced by the residence of Suburb Y between 22:00 and 05:00 UTC;
- **(quantitative)** track mileage flown by arriving aircraft is not extended by more than 5%;
- **(qualitative)** A crossing SID and STAR have been designed in accordance with PANS-OPS criteria complete with profiles. Inadvertently, the profile of both the SID and STAR requires aircraft to be at FL70 at the crossing point. This error would be detected during the qualitative assessment (which is almost an on-going subconscious process for most designers). As such, this error would be identified and the profiles redesigned so that the SID and STAR profiles are separated by at least 1000 feet at the crossing point.

3.6 SUMMARY

This chapter has sought to explain safety criteria in the greater context of the safety case approach to safety assessment. To this end, explanations have been provided on some basic concepts, how safety can be evaluated and an outline of the safety case approach has also been provided.

CHAPTER 4

- ASSUMPTIONS, CONSTRAINTS & ENABLERS -



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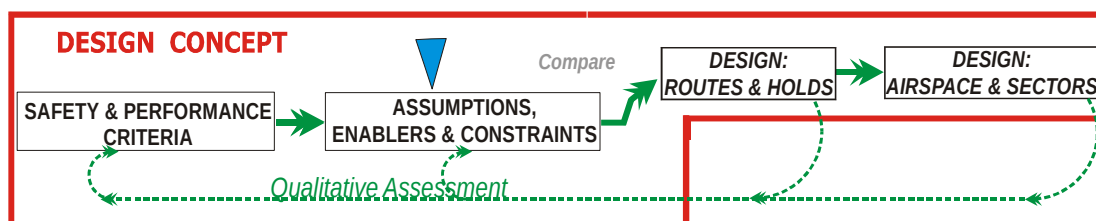
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4.1 INTRODUCTION

This chapter discusses *Assumptions, Enablers and Constraints* which constitute the second phase of the *design concept*.



As stated in Chapter 2, *Assumptions, Enablers and Constraints* are *constants* to the entire Terminal Airspace design process. They are carried through to the Assessment and Validation phases of the project (see Part D)

As suggested in previous chapters, the **performance criteria, assumptions, enablers and constraints** are established *before* the Terminal Airspace is designed conceptually or any other design phase is undertaken. Moreover, it is important to note that **assumptions, constraints and enablers underpin all phases of the design process and therefore remain constant throughout the design process** (unless one of the aims of a Scenario (see Part D) is to test an assumption (or enabler, or constraint)). This requirement for consistency is illustrated below.

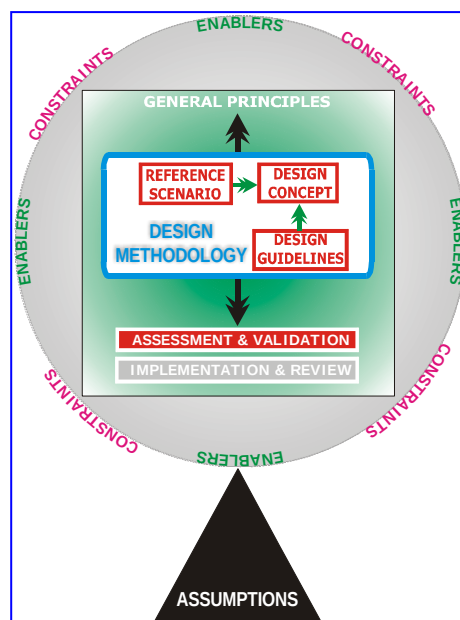


Figure 4 - 1: Consistency

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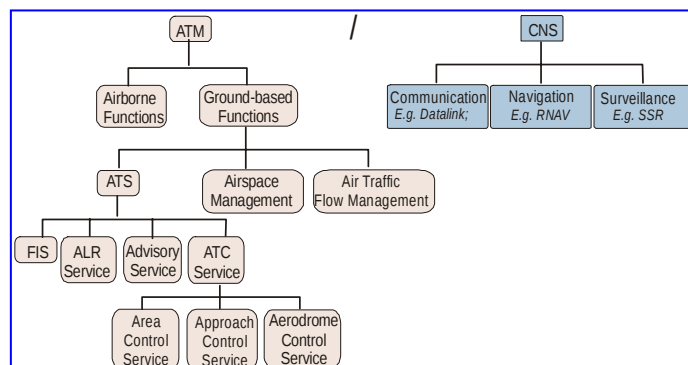


Figure 4 - 2: ATM/CNS¹

4.2 WHAT ARE ASSUMPTIONS, CONSTRAINTS AND ENABLERS?

4.2.1 ASSUMPTIONS

Assumptions refer to elements of ATM/CNS which are assumed to be ‘true’ for purposes of the design. ATM/CNS covers a wide variety of fields which often requires most designers to consider factors beyond the limits of their own expertise. Assumptions may also have to be made concerning factors beyond direct ATM/CNS e.g. certain weather phenomena.

Whilst some assumptions are based upon factors/elements which can be relied upon with reasonable certainty within the time-scales of the design project, other assumptions are likely to be no more than an ‘educated guess’ [because obtaining *firm* knowledge is not possible within the timescales]. It is better to undertake the design process without any uncertainties, but there is sometimes no option but to include them so as not to stop or delay the overall design project.

The incorrect identification of assumptions can be the undoing of a Terminal Airspace design. It is therefore better to err on the side of caution when selecting assumptions. This can be illustrated by way of an example:

Example: Suppose that it is not possible to establish whether a ATS route will be available for traffic from X to Y, and that the absence/presence of the new route is the key to reducing the workload in a particular sector. In this case, it would be better **not** include the new ATS route as an assumption in the traffic sample. This said, however, it may be worthwhile to have a two-phase design plan where the first excludes the new ATS route and the second includes the ATS route, so that the true value of the new route can be quantified.

The identification and selection of assumptions is likely to provide the greatest challenge to the designer in the case of *futuristic* design projects e.g. creating a Terminal Airspace model for the year 2025 for a new airport site with eight parallel runways. As most designers can vouch, the closer the implementation date the easier the assumptions are to select. In the case of futuristic projects, the designer may be left no choice but to use educated guesswork – and ensuring that the final report properly reflects this.

4.2.1.1 Traffic Assumptions

Assumptions made concerning the **traffic demand** in the Terminal Airspace and those made concerning the **predominant and secondary runway(s) in use** are of crucial importance to the design of a Terminal Airspace. **Traffic demand** and **runway(s) in use** are important because the notion of Terminal Airspace includes the ‘resultant’ airspace created to protect

¹ Derived from International Civil Aviation Vocabulary, ICAO Doc. 9713 (2001), Part 1

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IFR flight paths to and from the runway(s) in use. For this reason, it is imperative that the designer:

- ❑ properly analyses the **traffic demand**; and
- ❑ the **predominant and secondary runway(s) in use**, their mode of operation and any conditions attached thereto are established.

In context, **traffic demand** refers to a traffic sample which the design team considers representative of the traffic servicing the airport(s) within the Terminal Airspace. Thus the **representative traffic sample** chosen by the design team is the '**assumption**' and it is this assumption that requires thorough analysis prior to commencing the design process. (How the traffic sample is selected is discussed in para. 4.3.1).

Whilst traffic demand inevitably refers to a traffic sample, a traffic sample may need to be created to cater for *futuristic* Terminal Airspace design projects e.g. a concept design for the year 2025. In such a case future market analyses are undertaken and a traffic sample created for airspace design purposes. (see para. 4.3.1.1).

4.2.1.2 Runway in use

Similarly, identifying the **predominant and secondary runway(s) in use** requires assumptions to be made as to which runway orientation is used for the greater part of the day (e.g. RWY20 is used 70% of the time as opposed to RWY02). (How to determine the predominant and secondary runway is discussed in para. 4.3.2)

This important relationship between runway in use and traffic flows explains why the addition of a new runway within a Terminal Airspace invariably results in the need for some modifications being made to the Terminal Airspace design.

4.2.2 CONSTRAINTS

Constraints stand in contrast to assumptions in that they suggest the absence of certain elements of ATM/CNS or limitations created by extraneous factors. Typical constraints include high terrain, adverse weather patterns, the requirement to satisfy environmental needs (which dictate, for example, the noise-preferential runway to be used at night time) or the absence of rapid-exit-taxiways which may limit the landing rate and therefore influence route placement. In general terms, constraints can be said to have a negative impact upon the ATC operational requirements of a Terminal Airspace design. At best, it may be possible to mitigate the constraints using enablers. At worst, constraints have to be accepted because there is no alternative 'solution'.

4.2.3 ENABLERS

Enablers refer to any aspects of ATM/CNS that may be used to mitigate the constraints identified and/or any factors which may be relied upon to 'enable' ATC operations in the airspace designed. Importantly, the identification of enablers may take the form of functional requirements (which are then 'translated' into technical requirements) which require follow up work on the part of the ANSP and may be outside the scope of the design project – see Figure 4 - 3 and Table 4 - 1

4.2.4 SIMILARITIES AND DIFFERENCES

Whilst (design) **assumptions** can be viewed as 'uncertainties' which have been elevated to 'facts' to be used as a basis for the design, the role of **enablers** is to mitigate against **constraints** which have been identified. An example can be used to illustrate this difference: Suppose that a designer wishes to design RNAV routes up to the final approach fix in a Terminal Airspace. Because Terminal RNAV Routes with waypoints having a level restriction below MSA or MRVA may only be designed for use by aircraft which are certified for P-

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RNAV operations, an assumption can be created that aircraft operating within the Terminal Airspace are appropriately certified. [Note: this sort of assumption should only be made if the design team is sure that aircraft are appropriately certified]. In seeking to design the route based upon this assumption, the designer identifies a **constraint** viz. that the navigation infrastructure is inadequate and therefore does not allow the design of a necessary STAR route. This constraint could be **mitigated** against by the installation of a new DME pair in the Terminal Airspace and the **enabler** would be an enhancement of the navigation infrastructure – see Table 4 - 1. As shown in the diagram below, the means by which the enabler is achieved/provided (functional and technical requirement) usually falls outside the scope of the design team's work. In view of the costs which enablers sometimes incur, a Cost Benefit Analysis (CBA) may be required to determine whether the benefits provided by the enablers outweigh the costs. If this is not the case, it may be necessary to identify alternative mitigation. – See Part B.

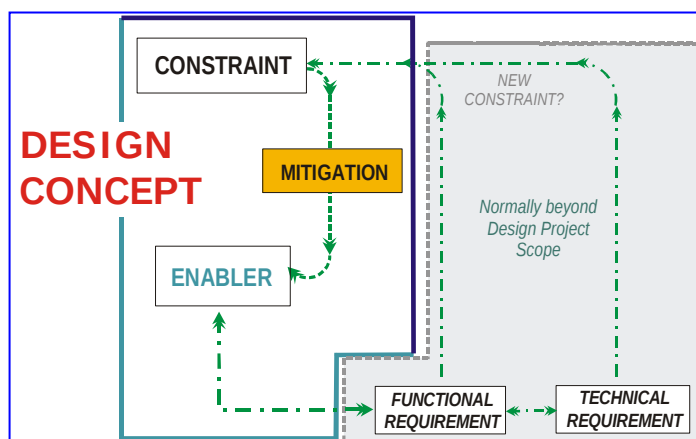


Figure 4 - 3: Constraints – Mitigation - Enablers

CONSTRAINTS	MITIGATION	ENABLERS
High Terrain on final approach RWY X	Increase ILS angle by 1°?	Specification change for ILS
Multiple airports within close proximity with poor co-ordination agreement	Letter of Agreement	EUROCONTROL DOC The Cross-Border Common Format Letter of Agreement
Aircraft Performance Mix limits capacity	Design different SIDs for high and low performance aircraft.	Airspace Design
Aircraft Navigation Performance Mix limits capacity by increasing ATC workload	ATC system modification to allow FDPS/RDPS to show aircraft navigation capability	Software Application Change
Inadequate Navigation infrastructure	New DME at Location A	Enhance NAV infrastructure
High mix of IFR-VFR movements limits capacity	SEGREGATED VFR/IFR ROUTES	Airspace Design
Fixed-wing/Rotor craft mix increases approach workload and complexity	Separated routes based on aircraft category	Airspace design
TSA which adversely affects traffic patterns	Airspace sharing arrangements	Flexible Use of Airspace Concept and EUROCONTROL DOC The Cross-Border Common Format Letter of Agreement
Poor Radar Coverage prevents route placement in part of the Terminal Airspace	Improve Surveillance capability	Enhance Radar infrastructure
Poor Radio Coverage adversely affects route placement in part of the Terminal Airspace	Improve Radio Coverage	Enhance communications infrastructure
Severe weather disrupts traffic, especially at peak times	Create 'contingency' routes for poor weather operations; re-locate holding patterns	Airspace design
No flights permitted over Village X	Diverge departure routes as soon as possible after take-off	Airspace design
Flights over City Y not permitted below 10,000 feet	Continuous Descent Approach	Airspace design and Level constraints in procedures

Table 4 - 1: Constraints, Mitigation and Enablers

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4.3 SELECTING ASSUMPTIONS, CONSTRAINTS AND ENABLERS

In order to identify and select assumptions, constraints and enablers, a comprehensive inventory of ATM/CNS elements is needed as well as expert input from, for example, meteorologists and pilots. Although it is possible for a Terminal Airspace design team to formulate the ATM/CNS parts of the inventory based upon their expert knowledge of local conditions, an inventory ATM/CNS completed in this manner is likely to be incomplete. This is because discrepancies frequently exist between what designers *believe* and what *exists* (see *Example* below). For this reason, it is necessary to determine from the outset what elements of ATM/CNS exist and are published in state-originated documents such as the Aeronautical Information Publication (AIP) and what factors can reasonably be assumed.

To these ends, thorough data collection of ATM/CNS elements is needed. If undertaken correctly, this data collection will reveal what can be assumed (assumptions), what is not available or inhibiting the design (constraints) and what is required to make the design workable (enabler). Importantly, assumptions, constraints and enablers should be linked to a certain date (i.e. 'date stamped') so that the design team may quickly identify the (time) period ascribed to a assumptions (or constraints/enablers) should it become necessary at later stage.

In order to illustrate the differences which can exist between perception (on which assumptions are frequently based) and reality of local conditions referred to above, the following examples are provided.

Example: A Terminal Airspace contains four DME stations. A fifth, located in an adjoining State, is assumed to be within the range of most aircraft departing from RWY23 at the only airport within the Terminal Airspace. Based on this belief the designers include the availability of this 'cross-border' DME in their assumptions when designing a SID (intended to be flown by P-RNAV equipped aircraft) from RWY 23. What the designers have not realised, however, is that the co-ordinates of this fifth DME are not WGS84 compliant (which is pre-requisite for SIDs designed for use by P-RNAV equipped aircraft). (Data collection obtained from an official source such as the AIP of the neighbouring State would reveal this shortfall.) Thus the 'assumptions' has turned out to be a constraint requiring mitigation.

Example: Having tested various sectorisation options, designers decided upon a combined functional/geographic sectorisation option because (a) it was the most efficient and (b) it did not require extra working positions and allowed them to make use of the existing three. When seeking to implement these new sectors, however, they were informed by ATC system specialists that the current ATC system was incapable of functional sectorisation and that it was no longer possible to modify the system software. (In this instance, the input of an ATC systems expert during the design phase would have prevented this option being chosen).

4.3.1 CHOOSING A TRAFFIC SAMPLE

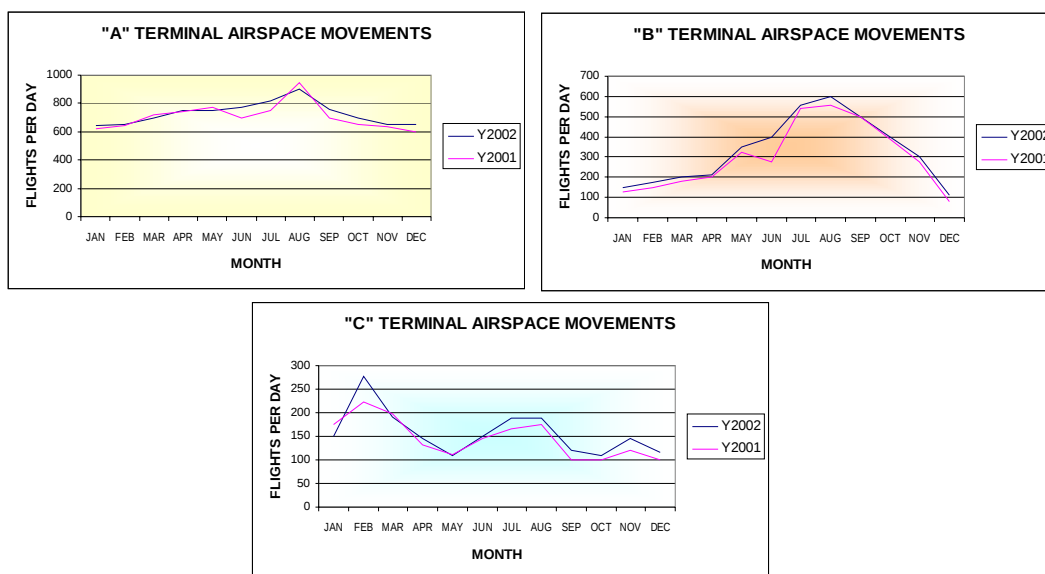
As stated previously, **traffic demand** refers to a traffic sample which is considered representative of the traffic servicing the airport(s) within the Terminal Airspace. This **representative traffic sample** is an '**assumption**' which needs to be selected with care. Selection of a traffic sample that is most representative of the traffic within a Terminal Airspace is best achieved by combining statistical analysis with ATC experience and by looking beyond the information available. Two elements of the traffic sample are to be distinguished, which for convenience, will be described as *Traffic Distribution over Time* and *Geographic Distribution of traffic*. An appreciation of both elements is crucial to choosing a *representative* traffic sample.

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4.3.1.1 Traffic distribution over Time

As regards *Time*, a feasible starting point is a snapshot analysis of the number of movements through the Terminal Airspace *by month* so as to determine the regularity of the resultant graph².

Using the sample graphs below (of three fictitious Terminal Airspaces) the following information can be drawn: Where Terminal “A” has a graph that is characteristic of large Terminal Airspaces in the core area, Terminal “B” is typically representative of summer holiday resorts and Terminal “C” typical of winter holiday (ski) resorts.



Graph 4 - 1: Distribution of Traffic over Time

Whilst in the case of Terminal “A” it is obvious that *one day’s traffic* (the traffic sample) should be selected from one of the busier months, airspace design planners for Terminals “B” and “C” may wonder whether selecting one day during the busiest month truly constitutes a *representative* traffic sample. Because two busy months of the year may not be ‘representative’, airspace designers from these two Terminal Airspaces would do well to select *two* traffic samples i.e. one day from the busy months and one day from the quieter period.

The advantages reasons for this are two fold:

- ❑ to enhance the potential to apply the Flexible Use of Airspace concept (see Part A, Chapter 2 and Sections 1 and 3 of the EUROCONTROL Manual for Airspace Planning).
- ❑ if the geographic spread of the traffic is significantly different during the ‘quiet’ and ‘busy’ months, it may be necessary to create two sets of Terminal Routes;

² It is also useful to ascertain the ‘busiest day’ of the year determined annually by EUROCONTROL.

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Comment: *Is it viable to create two (or more) sets of Terminal Routes to accommodate significant changes in traffic density and/or distribution? Opinions diverge as to how significant changes in the operating environment should be accommodated. Whilst one view holds that an ‘unstable’ or ‘changeable’ airspace structure is to be avoided, the opposing view contends that it is not only possible but desirable to use airspace in a flexible manner. Whatever the philosophy followed, designers should ensure that the design fully supports safe and orderly air traffic management.*

4.3.1.2 Geographic distribution of traffic

Having selected a one-day traffic sample from a *Time* perspective (i.e. one that is representative of periods of high and low activity), it is necessary to determine the geographic distribution of this traffic with a view to identifying the predominant and secondary traffic flow(s). To this end, the traffic sample needs to be analysed using, for example, a spreadsheet. Because traffic data files contain information on each flight, flights can be sorted in several ways, e.g. –

- ❑ **Terminal Area entry “point”** (in the case of arrivals) and **Terminal area exit point** (for departures).
- ❑ **origin** (in the case of arrivals) and **destination** in the case of departures;

Comment: *Once sorted, a graphic representation of the geographic distribution of traffic by entry/exit point can be depicted as per Figure 4-4.*

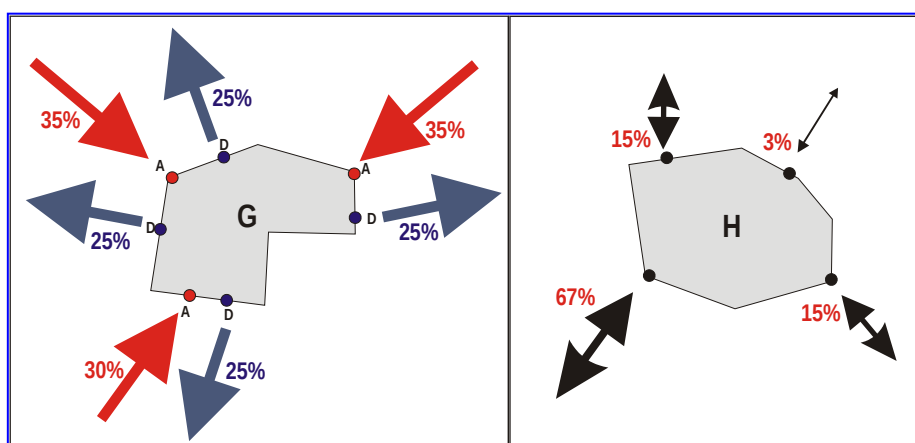


Figure 4 - 4: Geographic Traffic Distribution

(Of the two samples, Terminal Airspaces, “G” is typical of the core area of Europe and “H” of the geographic periphery of Europe. Because of the marked predominance of traffic distribution to the south/south-west of Terminal Airspace ‘H’, this model could fit the northern geographic periphery of Europe. Inversely, were the major traffic flow to/from the North, the model would probably fit that of the southern geographic periphery of Europe. The same can be said of dominant east or west flows).

Sorting the geographic traffic distribution by **origin and destination** so as to identify the raw demand³ is only necessary when (i) doubt exists that the current En-Route ATS route network is not sufficiently refined thus making it lightly that some aircraft are not on the most direct route or, (ii) in the case of futuristic design projects for new airports where part of the exercise is trying to develop an entire airspace organisation on a clean sheet. The diagrammatic representation of raw demand is not nearly as clean as that of entry/exit point.

³ this is usually the same as market demand.

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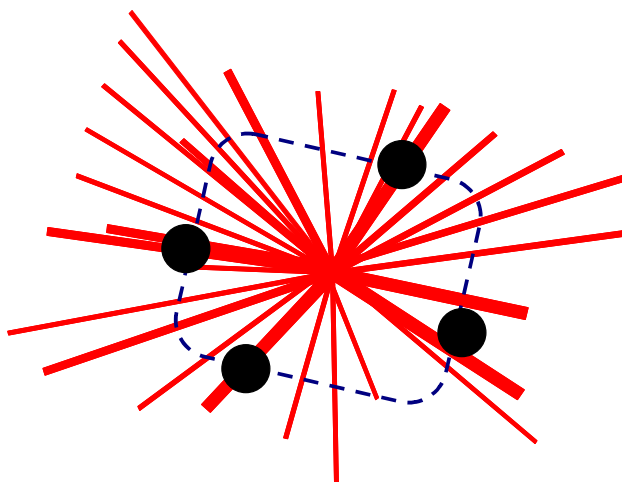


Figure 4 - 5: Geographic Distribution – Raw Demand

Given that the thicker lines in the above diagram represent routes of heavier (raw) demand, it is possible to ascertain – by comparing the location of existing Terminal entry/exit point [black circles above] in relation to these lines – whether these points have been placed effectively.

In those instances where En Route airspace designers alter their route network within the greater EUR ARN so as to minimise the differences between the raw demand ‘tracks’ and actual traffic routings, it is not necessary for Terminal Airspace design planners to undertake the ‘raw demand’ exercise – providing that En-Route or Terminal Airspace design is undertaken collaboratively⁴ as a matter of course.

The significance of the proper identification of the predominant traffic flow(s) becomes evident when undertaking the route design process described in Part C Chapter 5. This is because the designer should strive to meet all the Guidelines of route design as regards the major traffic flows. Thus where a ‘conflict’ arises between the interests of a major flow and minor flow, the interests of the major flow should prevail.

Comment:

Why should the traffic sample be analysed when ATC knows the traffic distribution? Many designers are surprised to discover errors in the way they perceive their major/minor traffic flows. This is particularly true when dealing with traffic samples based on forecast traffic where it may be incorrectly assumed that traffic increases will be proportionate to each entry/exit point.

4.3.1.3 Using Forecast Traffic Samples

Forecasting air traffic provides its own challenges: the more futuristic the forecast, the greater the likelihood of error creeping into some of the assumptions. Complex by definition, traffic forecasts attempt to determine whether and to what extent the traffic will change (increase or decrease) by examining the triggers that may bring about these changes. Whilst some triggering events can be forecast with reasonable accuracy, others cannot be easily foreseen.

Examples of ‘triggering events’ which can be determined with relative certainty include –

⁴ Terminal airspace and En Route experts work together on airspace design projects be these projects ‘En Route’ or Terminal Airspace, by definition.

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- ❑ GDP trends and their effect on the individual's propensity to fly;
- ❑ Timescales for the introduction of another transport mode between two city pairs (e.g. the high speed train between Brussels and Paris) which could significantly reduce the number of flights between the two points;

Note: Whilst determining the timescales for the introduction of a new transport mode may be relatively simple, the same cannot necessarily be said when it comes to determining the effect of the alternative transport mode. In the case of high-speed trains, the total travel time gained/lost by the HST when compared to air travel is a significant factor.

Examples of 'triggering events' which are more difficult to predict include –

- ❑ political developments across Europe in 1989/1990 (which, for example, started a new tourist trend between Russia and northern Greece);
- ❑ the 1991 Gulf war (which affected traffic density)
- ❑ the wars in South-East Europe in the early 1990s (which affected the geographic distribution of traffic as a consequence of closing large tracts of airspace in the area.)

In closing, it is opportune to add that undertaking a 'raw demand' analysis such as depicted in Figure 4 – 5, is also useful for such futuristic projects.

4.3.2 DETERMINING THE PREDOMINANT & SECONDARY RUNWAY(S) IN USE

By and large, the **predominant and secondary runway(s) in use** are usually easier to identify (e.g. either because environmental requirements or weather phenomena dictate runway use). The importance of identifying which runway(s) is used more than another will be seen in the following Chapter, the predominant Terminal Routes invariably take precedence over minor routes.

Whilst '**predominant runway in use**' is a relative term (as is 'major traffic flow'), a predominant runway is one that is used most of the time. Usually stated as a percentage e.g. 80% (which equals 292 days a year), it may be said that RWY20 is used 80% of the time, and RWY02 20% of the time. At multiple-runway airports, this 'predominance' may be distributed among several runways e.g. e.g. RWY20 is used 80% of the time by arriving aircraft, and RWY 18 is used 90% of the time by departing aircraft.

4.3.3 CONSTRAINTS, MITIGATION AND ENABLERS

As stated in Part C, Chapter 3, the Critical Review provides an occasion to identify constraints in the Reference Scenario, and possible mitigation measures and associated enablers. This said, however, constraints are also identified once the conceptual design phase starts (see next Chapter, Chapter 5).

Whilst Table 4-1 depicts *enablers* as being the means whereby constraints can be overcome, enablers are also what make it possible to realise design objectives. In either case, the viability and correct identification of enablers is to be most effectively found in a partnership between technical/engineering expertise (e.g. PANS-OPS specialist), air traffic controllers and pilots.

Because of the increasing use of RNAV in ECAC terminal airspace (and therefore the increasing 'visibility' of navigation), **Attachment C.4-1** provides an overview of Navigation as an enabler in the context of RNAV.

Similarly, because of the importance of the ATC system to the design, **Attachment C.4-2** is provided, entitled *Understanding the ATC System: Constraint or Enabler*.

Guidelines on *how* to plan the design of routes, holds and airspace sectors are discussed in Chapters 5 & 6.

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Chapter 8 at **Attachment C.8-4** provides a checklist which designers may find useful for the identification of assumptions, constraints and enablers. Although some of the items on the sheet do not always appear to be directly related to issues of Terminal Airspace design issues, many of them capture the factors which may influence the design plan.

4.4 WHEN TO IDENTIFY ASSUMPTIONS, CONSTRAINTS & ENABLERS

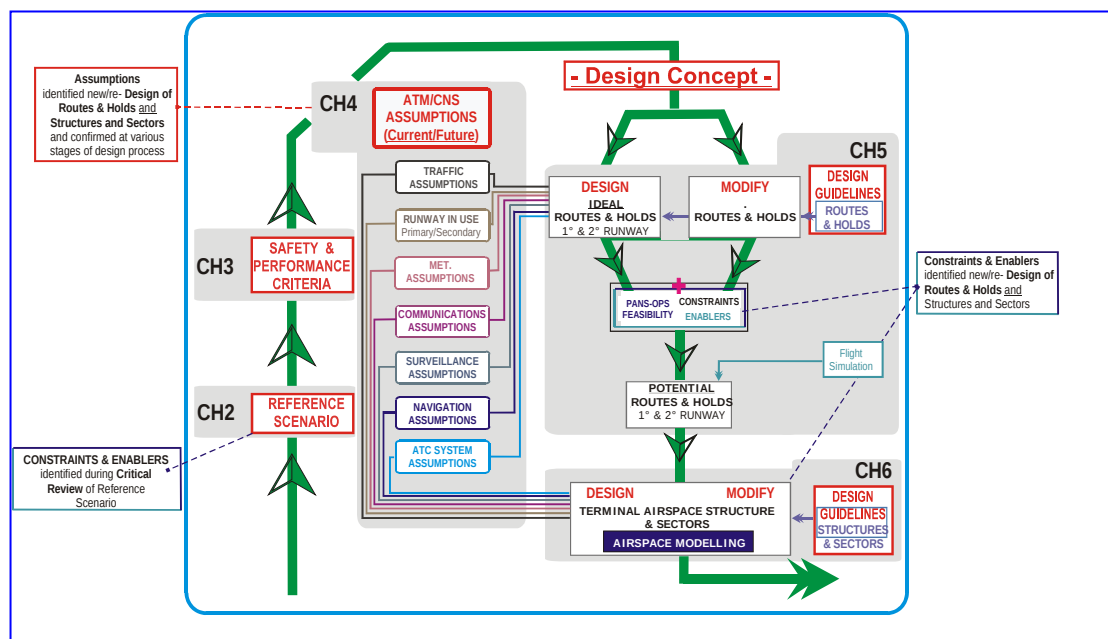


Figure 4 - 6: Phases for Identifying Assumptions, Constraints & Enablers

As shown in the above diagram, Assumptions, Enablers and Constraints are identified at different stages of the design process. Constraints and Enablers enter the design process during the critical review of the Reference Scenario where the constraints and enablers refer to the Reference Scenario. The Assumptions are identified prior to commencing the conceptual design –and these are verified at different stages of the process. During the design process i.e. the conceptual design of Routes, Holds, Structures and Sectors, constraints, mitigation and enablers are identified. In some cases, a Cost-Benefit analysis may be required (see para. 4.2.4).

4.5 SUMMARY

The importance of correctly identifying *assumptions*, *constraints* and *enablers* cannot be over-stated for it is on these elements that the design concept of the Terminal Airspace rests. Most importantly, these assumptions, constraints and enablers should be *realistic*.

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Attachments C.4-1

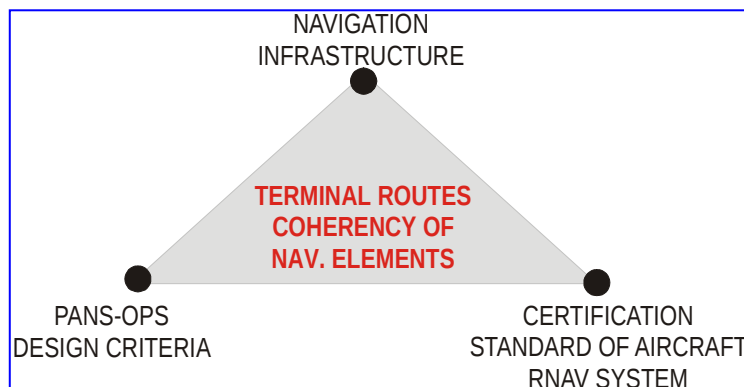
Area Navigation as an Enabler.

Whilst communication, surveillance and navigation are all vital elements to be considered in the design of a Terminal Airspace, the importance of navigation into the design equation has increased through the application of area navigation (RNAV) in Terminal Airspace.

In its *Definitions*, PANS-ATM describes Area Navigation (**RNAV**) as *A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. (Attention is drawn to the fact that this definition describes a **navigation method** and not RNAV system capabilities or certification).*

In order to design RNAV Terminal Routes (e.g. SIDs/STARs for use by RNAV-equipped aircraft in Terminal Airspace), coherency is required between

- ❑ the availability of a navigation infrastructure that supports the standard of RNAV to be employed. (Nav aids can be ground- or space-based or self-contained on-board the aircraft); and
- ❑ Design of the procedure in accordance with PANS-OPS design criteria stipulations of the PANS-OPS Design Criteria used; and
- ❑ the aircraft's onboard **RNAV system** being certified (or the navigation function included in a flight management **system** (FMS)) being certified to the RNAV standard required by the Terminal area procedure and/or SID/STAR (and the flight crew having the appropriate operational approval);



In ECAC, two RNAV standards exist:

- ❑ Basic RNAV (B-RNAV) which was introduced into the upper airspace of ECAC in 1998; and
- ❑ Precision RNAV (P-RNAV) for use in Terminal Airspace.

Note: With effect from ± 2010, RNP RNAV is likely to be the applied in Terminal Airspace.

For both B-RNAV and P-RNAV, this coherency referred to previously between the navigation infrastructure, PANS-OPS design criteria and the certification standard of the aircraft's RNAV system is required. Thus different obstacle clearance criteria (PANS-OPS) apply for B-RNAV compared to P-RNAV, different certification standards exist for B-RNAV and P-RNAV, and the navigation sensors (which relate to the navigation infrastructure) that can be used for B-RNAV and P-RNAV are not necessarily the same (though similar).

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The main differences between any RNAV type and another concerns:

□ RNAV Systems Description

(E.g. a database needed; positioning sensors to be used etc)

- Airworthiness Certification Objectives:

Described in terms of accuracy, Integrity & Continuity of service

- Functional Criteria:

(Required; Recommended)

- (Area of application: where it can be used...and how)

The differences for RNAV System Descriptions are identified in the following table:

	B-RNAV	P-RNAV	RNP _(x) RNAV*
Accuracy	5 NM Lateral	1 NM Lateral	(x) NM Lateral and Longitudinal
Integrity	Low	Medium	High
Continuity of Function	-	Loss = Remote	Loss = Extremely Remote

* According to MASPS DO236-B

The increasing level of sophistication of the RNAV System (B-RNAV < P-RNAV < RNP(x) RNAV) results in a proportional increase on the Requirements for respectively the RNAV Systems, Accuracy/Integrity/Continuity and Required Functionalities.

The main differences in what is required and what is recommended for Functional Criteria between any RNAV type and another are identified in the following table:

	B-RNAV	P-RNAV	RNP (x) RNAV*
Required	4 Way point storage (manual data entry; Display of distance/bearing to Way-point)	NAV Data Base; Data Integrity; leg types (e.g. TF; CF; FA)	NAV Data Base; Integrity (RNP alerting); leg types (e.g. RF; FRT)// Off-set
Recommended		// Off-set	

* According to MASPS DO236-B

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Where and how different RNAV types can be used i.e. the Area of Application is described in the following tables:

	B-RNAV	P-RNAV	RNP* (x) RNAV
Area of Application	• ENR • Above MSA/MRVA	• ENR • TERMINAL AIRSPACE up to Final App WPT • Below MSA/MRVA	• ENR • TERMINAL AIRSPACE depends on Functional Requirements

* According to MASPS DO236-A

Depending on the RNP accuracy the following distinction can be made:

RNP ₁ RNAV	RNP ₃ RNAV	Functionalities specified by JAA (EASE) determine area of application
ENR TA up to FA WPT Below MSA/MRVA	ENR TA inside FA WPT Below MSA/MRVA	

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Terminal Airspace Design Guidelines - Part C**Attachment C.4-2****Understanding the ATC System: Constraint or Enabler**

This Attachment provides a high-level description of the basic principles of an ATC system. It is presented with a view to increasing awareness of the role played by the ATC system in the Terminal Airspace Design concept. With this objective in mind, a general description of the ATC system is provided first, and then a selection made of certain components because of their relevance to Terminal Airspace design.

Designers' attention is drawn to the fact that the need to understand the technical capabilities and limitations of the ATC system should not be under-estimated. The same can be said of the requirement to ensure that a proposed Terminal Airspace design can be supported by the ATC system. As a basic rule, it may be stated that the more complex the design of a Terminal Airspace, the greater the demands made on the technical capabilities of the ATC system.

□ **GENERAL TECHNICAL DESCRIPTION OF THE ATC SYSTEM**

In simple terms, it may be stated that the basic aim of the technical ATC system is to get the data related to a flight to relevant controllers in a timely and complete manner.

In a technical ATC system, the main data carrier is called a flight plan. It is often referred to as a System Flight Plan or a Current Flight Plan and FPL, SFPL or CPL are commonly used abbreviations.

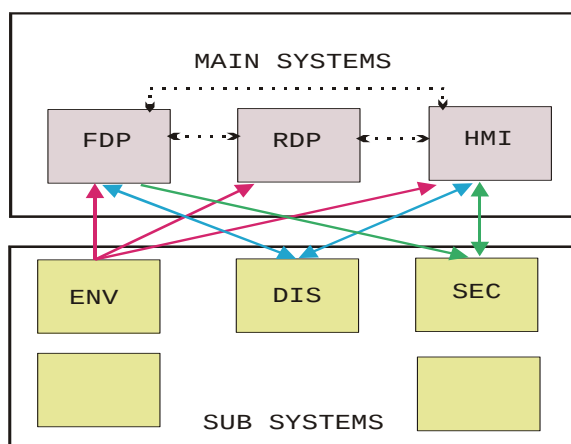
In general terms, it can be stated that the technical ATC system generally consists of three main components:

- Flight Data Processing (FDP)
- Radar Data Processing (RDP)
- Display System or Human Machine Interface (HMI)

From a Terminal Airspace Design perspective, the following sub-components of the system are also relevant:

- Environment Data Processing (ENV)
- Flight Plan Distribution (DIS)
- (Flexible) Sectorisation (SEC)

The following diagram provides an overview of the relations between main components and sub-components of the technical ATC system.



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□ DESCRIPTION OF SPECIFIC COMPONENTS OF THE ATC SYSTEM**➤ Environment Data Processing (ENV)**

Environment Data Processing refers to the management of Route-points, Routes and Sector shapes etc. This is called static Environment data. In order to determine the feasibility of implementing a design, the designer should ensure that the design can be incorporated in the Environment data. (This is especially important with complex Terminal Airspace designs). In order to whether the design concept can be incorporated into the Environment data, the following questions could be asked::

1. Does the system support independent layering of sectors?
2. Is it possible to create new route-points or points in the system?
3. Is it possible to group/un-group sectors in the operational environment?

The relevance of question 1 is that if a system can not do this it is probably not possible to implement complex sector structures.

The relevance of question 2 is more related to the implementation process of a particular design. In some systems considerable effort is required in creating new structures (e.g. changes need to be made in the code). Considerations well beyond the design project scope may result in constraints on the design process (e.g. system availability, system safety considerations, ownership issues with the system provider etc.).

The relevance of question 3 is that if the answer is negative it may become necessary to simplify the design as much as possible because all operations need to be performed in the same operational configuration.

It is important to note that all three 'main' ATC system components FDP, RDP and HMI are 'clients' of an ENV function. The consistency of the ENV data for the main components is a safety issue. Verification of this consistency is required to ensure the safety of the design before implementation. A design should **not** be the solution to an insufficient technical ATC system.

➤ Flight Plan Distribution (DIS)

Flight Plan Distribution refers to the most basic aim of the technical ATC system i.e. to get the data related to a flight to relevant controllers in a timely and complete manner. It is obvious that a more complex design results in a more stringent requirement to ensure that the controllers get flight plan information when it is required.

The Distribution Function may not have a direct effect on the design as such but it is prudent to ensure that the technical system provides this service. If it does not, the designer may work with wrong assumptions on the level of technical support that is provided to the controller that operates in the TMA. In addition it is advisable to establish the quality of the distribution function. For example, it is possible that the function is available but does not adapt after a sectorisation change or a runway change. Again, this could result in a flawed assumption being made regarding the level of technical support to the controller.

In general the FDP and HMI are clients of the DIS function. In systems where the Code Callsign Correlation function is part of the RDP system, the RDP may be a client as well, but these are all considerations for the technical infrastructure and not for the design as such.

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➤ (Flexible) Sectorisation (SEC)

(Flexible) Sectorisation refers to a system's capability to adjust the sector configuration in the operational environment (i.e. in the OPS room) by combining or de-combining sectors in accordance with capacity demands in real-time.

If a technical ATC system does not have this capability there is a direct impact on the design. The designer will be restricted to one final design and will not be able to propose different sectorisation approaches that provide solutions for different capacity demands.

□ SUMMARY

The rationale from a designer's point of view is that management of airspace starts with the design of airspace based on operational requirements which may stem from safety, capacity and Environment objectives. From this perspective, the technical ATC system is an enabler which supports the optimum design and airspace use.

If the technical ATC system cannot support the design, two courses of action are available to the designer:

1. Limit the possibilities for the design and limit airspace use (i.e. Constraint); or
2. Add requirements on the technical ATC system (i.e. identify Enabler(s))

In general, the second option requires additional investment. It is usually subject to processes outside the scope of any design project.

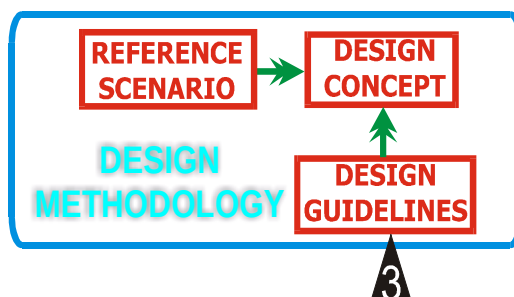
In closing, the readers attention is drawn to the fact that not all ATC Systems necessarily 'fit' into the pro forma described in this attachment and that many ATC systems include additional elements such as STCA (Short Term Conflict Alert), MSAW (Minimum Safe Altitude Warning) and Trajectory Prediction Tools.

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CHAPTER 5

- DESIGN GUIDELINES: ROUTES & HOLDS -



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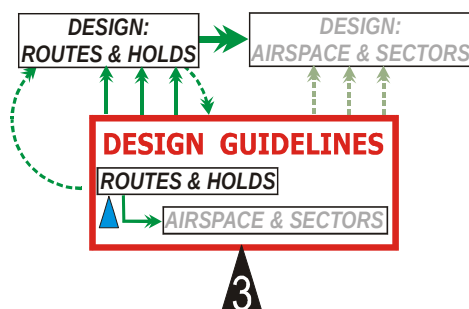
ATTACHMENTS

C.5-1: RNAV Routes & Holds

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5.1 INTRODUCTION

This chapter presents Design Guidelines for *Routes and Holding Patterns*. They are intended to support creation of the *design concept* for Routes and Holds for a specific Terminal Airspace. This concept would be based on certain assumptions. Given the phased approach described in Chapter 4, constraints and enablers would be identified in a phased manner as per para. 5.4.1. Furthermore, the design would be qualitatively assessed against the selected safety and performance criteria as well as the Reference Scenario, if appropriate.



5.2 ROUTES AND HOLDING AREAS

Whilst the generic ICAO definition of ATS Route is broad, (see grey shaded area in Figure 5-1, below), ATS routes within Terminal Airspace are usually arrival and departure routes. These arrival and departure routes may be -

- ❑ **designated**, as is the case with IFR departure and arrival routes which are usually published as SIDs/STARs (based upon RNAV or conventional navigation means), designated VFR routes (promulgated, for example, by visual reporting points) or VFR corridors; and/or
- ❑ those which are **not designated**, as is the case with tactical routeing 'created' by ATC in the form of Radar Vectors or instructions to proceed "direct to" an RNAV way-point.

Since B-RNAV became mandatory in the upper airspace of the member states of ECAC, RNAV has been increasingly used as a basis for the design of **RNAV-based instrument approach or departure procedures**. Usually, the RNAV-based instrument approach procedure does not include the final approach and/or missed approach segment. In many cases, the tracks depicting these procedures are designed to replicate radar vectoring patterns because these procedures are used as a substitute for radar vectoring by ATC. These are depicted in Figure 5-1 in the blue-red box beneath the SIDs/STARs and discussed in para. 5.2.1.

Note: Whilst instrument approach procedures based upon conventional navigation are sometimes used as a substitute for Radar Vectoring, this is less common.

Note: For more general information on RNAV Routes, see Attachment C.5-1.

Although Radar Vectoring has been used by ATC for traffic separation and sequencing for several decades, the increased use RNAV in Terminal Airspace has resulted in ATC being able to provide tactical instructions to a way-point. Unlike Radar Vectors, instructions to a way point result in aircraft flying a particular track (as opposed to heading). Whilst Radar Vectors and instructions to proceed direct to a way-point are not considered to be ATS Routes (in the traditional sense), they have been included in Figure 5-1 because Terminal Airspace designers are required to consider *all* routes when designing an airspace, whether these are 'created' in a strategic or tactical manner.

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In light of this variety, the generic expression **Terminal (Arrival/Departure) Routes** is used to describe the sub-set of ATS Routes comprised of arrival and departure routes, SIDs/STARs and RNAV-based instrument approach or departure procedures i.e. those contained inside the red-line in Figure 5- 1. Naturally, the designer is also required to consider tactical routes shown in the green box in this figure.

Note: When used specifically, expressions such as ATS Routes, Arrival or Departure routes, SIDs/STARs and Instrument Approach Procedure (or parts thereof) are to be ascribed their ICAO meaning.

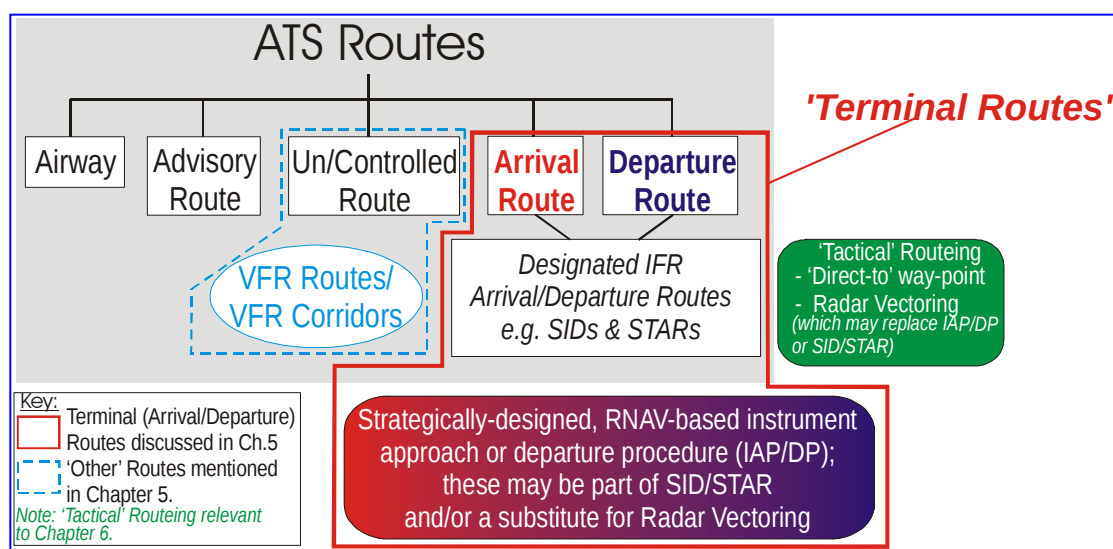


Figure 5- 1: ATS Routes & Terminal Routes

5.2.1 STARS & INSTRUMENT APPROACH PROCEDURES IN AN RNAV ENVIRONMENT

STARs and instrument approach procedures are defined in ICAO Doc. 8168 and explanatory material is provided by ICAO in the *ATS Planning Manual*, Doc. 9426. The identification of STARs (and SIDs) is provided for in Annex 11, Appendix 3.

Over the years, States interpretation of this material has resulted in two quite distinct 'models' of STARs in ECAC Terminal Airspaces. Whilst in the first the STARs provides the connection between the En Route ATS Route system and the Terminal Airspace, in the second, STARs commence closer to the landing runway. Thus in the first case, the STAR begins in the En Route system and ends (usually) inside the Terminal Airspace, often at a holding fix, whilst in the second, the STARs tends to begin at – approximately – the Terminal Airspace boundary (or the Approach Control Unit area of responsibility).

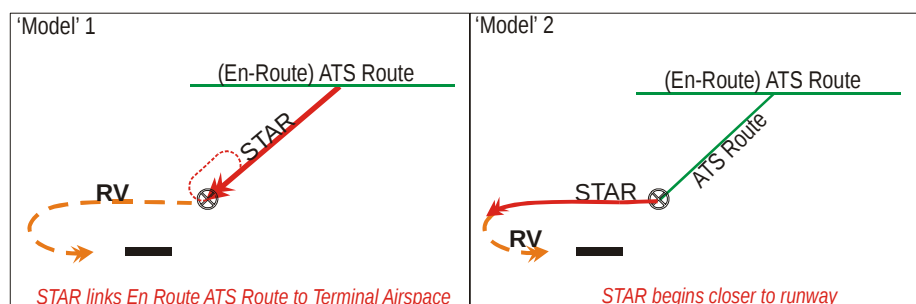


Figure 5- 2: STARs

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The introduction of B-RNAV the ECAC en route airspace in 1998 made it inevitable that RNAV application would be extended into Terminal Airspace. Indeed, RNAV is being used in Terminal airspace, not only as the basis for the design of STARs but also to design RNAV-based instrument approach procedures.

As far as 'Model' 1 is concerned, the introduction of RNAV as the basis for Terminal Route design envisages replacing or replicating Radar Vectoring patterns with RNAV-based instrument approach procedures (or RNAV STARs, in some cases).

□ **Open and Closed STARs**

Although neither 'Open' STARs and "Closed' Stars are ICAO expressions, they are commonly used in the design of RNAV-based STAR or RNAV-Based instrument approach procedures used increasingly in Europe and North America. Whilst the *Open Star* provides and publishes track guidance (usually) to the down wind position from which the aircraft is tactically guided by ATC to intercept the final approach track, *Closed STARs* provide track guidance to the final approach track whereupon the aircraft usually intercepts the ILS. In theory, the *Closed STAR* suggests that the aircraft can navigate itself along the published route onto the final approach track, without being dependent on ATC for navigational guidance.

Significantly, however, Closed STARs can be designed and published in a manner that anticipates alternative routing to be given by ATC on a tactical basis. Whilst tactical routing instructions to 'close' an Open STAR are necessary to align the aircraft with the final approach track, 'tactical' way points may be included in a Closed STAR so as to permit ATC to alter the routing of an aircraft e.g. to provide a short cut. (These tactical instructions may be given in the form of instructions 'direct to a way-point' or Radar Vectors).

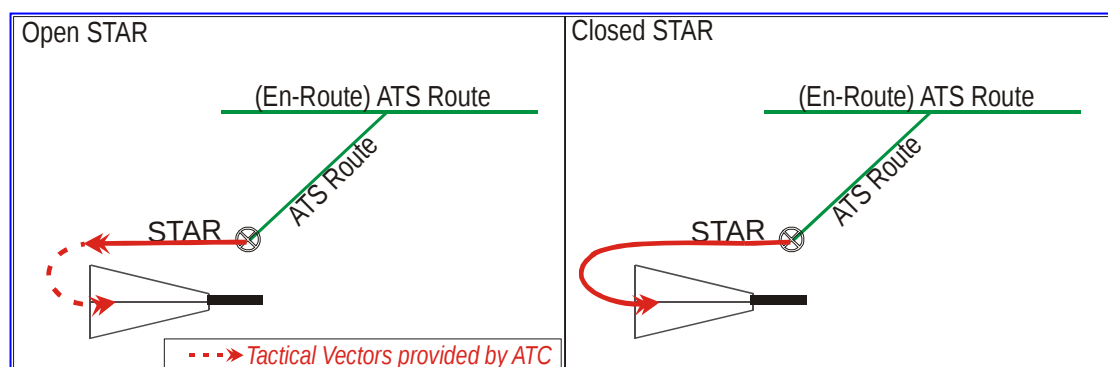


Figure 5- 3: Open & Closed STARs

Note: Neither of these diagrams should be construed as a preference for either *Closed* or *Open* STARs. The implications of radio communication failure (RCF) are different depending on whether STARs are open or closed. As such, RCF would have to be considered.

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5.3 STRIKING THE BALANCE

Figure 5- 4, whilst oriented towards *Routes and Holding Areas* repeats the theme of a similar diagram in Part A of this document. It has been inserted to draw designers' attention to the fact that the design of terminal routes and Holds is rapidly becoming a major challenge in Terminal Airspace increasingly constrained by national boundaries, environmental needs and competing user requirements.

Seldom are these competing interests as evident as when seeking to relocate or design new terminal routes and holds at the most suitable place for Air Traffic Management purposes. Frequently, the most appropriate placement of a route for ATC does not necessarily meet the requirements of an adjacent Terminal Airspace and/or environmental or user needs. Thus a trade off is required.

Mindful that sustaining capacity is already a challenge in some ECAC Terminal Airspaces, it is impossible to over-state the need for a collaborative approach between adjacent Terminal Airspaces and between users, ATC and Airport Operators and/or other environmental interest groups when designing terminal routes. (See Part A, Chapter 2, General Principles). Thus before embarking upon the design of terminal routes and Holding Areas, Terminal Airspace designers require clear directions as to whether, and to what extent, Environmental and User requirements are to be taken into account and when this consultation should occur.

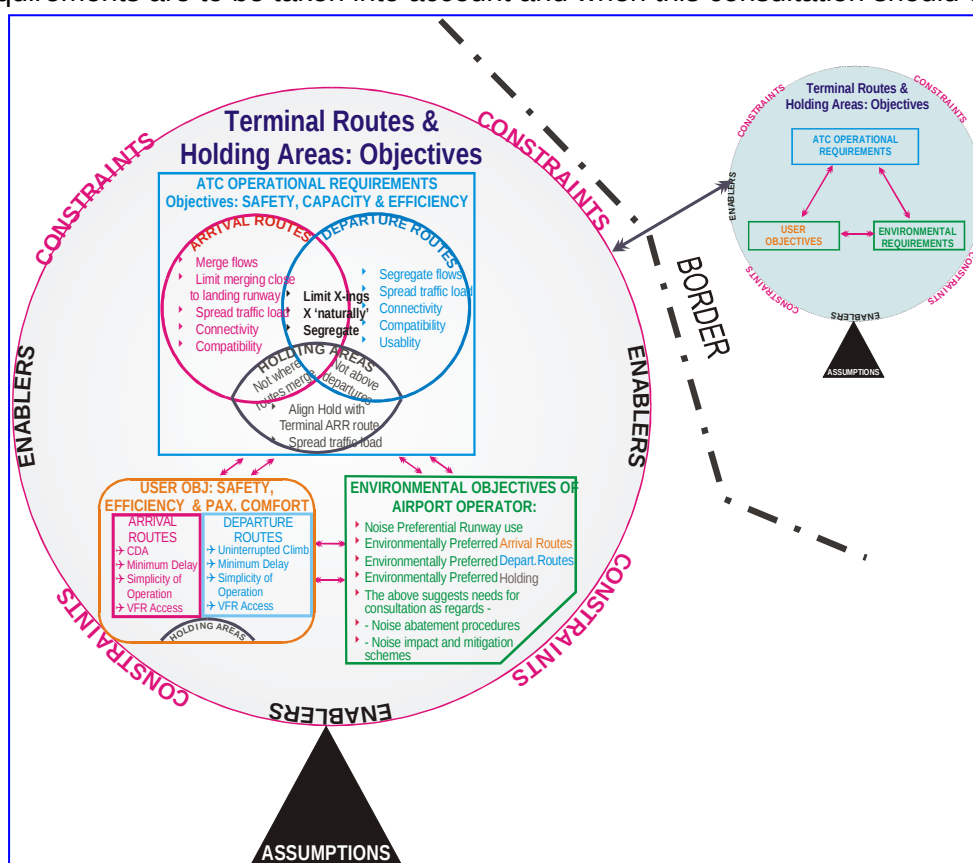


Figure 5- 4: Competing Interests – Striking the Balance

As will become evident in the Guidelines which follow, it is often necessary to affect a trade-off when there is a 'competing interest' between the Routes themselves, and/or between the best placement for the holding patterns. The more complex the airspace design, the greater the likelihood of more 'purely operational' trade-offs. This is discussed in Chapter 7.

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In view of the above, it is stressed again that a collaborative approach to design is required. Once the routes and holds have been created and are available for use – as agreed collaboratively between all parties – they should be used in accordance with the conditions agreed by all parties.



Mandatory Consultation Process: *In some countries where a mandatory consultation process exists, Terminal Airspace development can be discontinued because of a failure to comply with this consultation process.*

5.4 GUIDELINES

In this section, Design Guidelines for terminal routes and Holding Areas are described with a view to creating a conceptual design based on certain *assumptions, enablers and constraints*.

Guidelines related to terminal routes are preceded by an “**R**” and those to concerning Holding Areas, by an “**H**”. They are not prioritised.

Whilst, for the most part, the Guidelines for the Design of terminal routes and Holding Areas concentrate upon IFR flights, many of the notions contained in these design guidelines apply equally to terminal routes promulgated for use by VFR flights. This said however, special mention is made of route planning for VFR use where appropriate.

These Design Guidelines are based on three assumptions:

Assumption 1: An air traffic control service is provided and Radar Surveillance is available within the Terminal Airspace;

Assumption 2: Within the context of needing to strike a balance between competing interests referred to in para. 5.3 (above), these Design Guidelines aim primarily for efficient design of Routes and Holds with a view to enhancing safety and maximising ATM capacity.

Assumption 3: Strategic and Design Objectives as well as assumptions have been identified by the design team.



Within the context of Striking the Balance (para. 5.3) and Assumption 2 (above), policy may dictate that the optimisation of Terminal Route design is weighted in favour of environmental mitigation. In such instances, designers may be required to design 'longer' routes and/or, minimise the likelihood of tactical routeing by radar vectors over noise-sensitive areas.

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5.4.1 PHASED DESIGN APPROACH

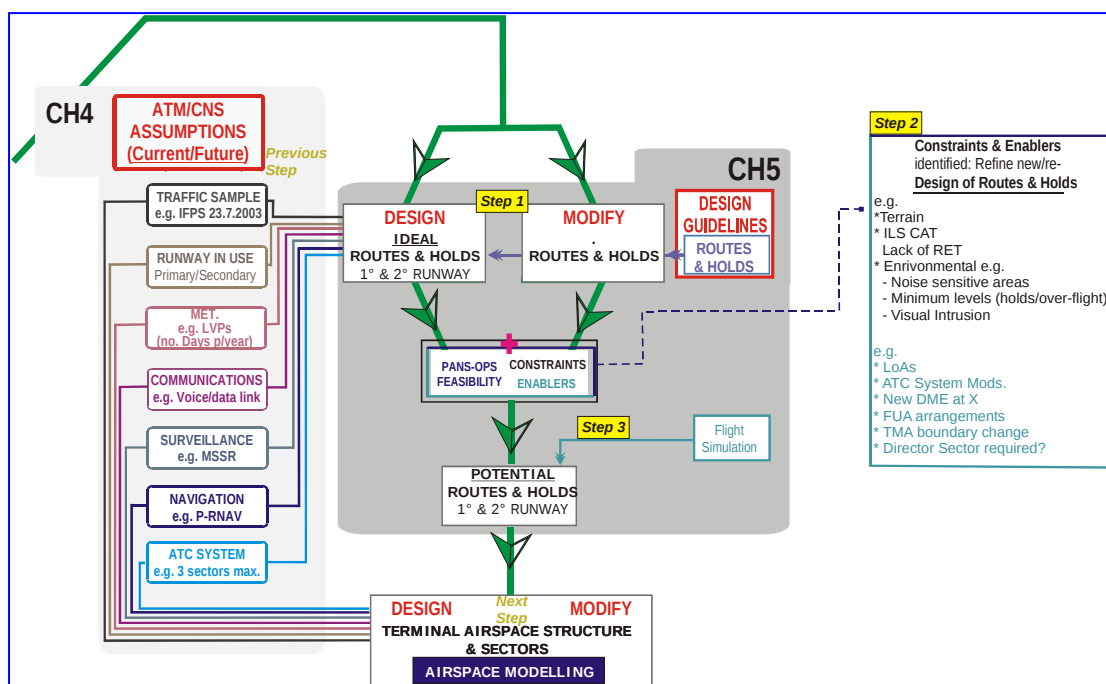


Figure 5- 5: Phased Approach

Figure 5- 5, above, suggests a **phased approach** to the design of routes and identification of constraints and enablers.

- **Step 1:** using assumptions only, create a conceptual design either of ('ideal') routes and holds or modify existing routes/holds; then
- **Step 2:** refine the output of Step 1 by 'adding-in' PANS-OPS feasibility. Constraints and enablers are identified at this stage and the routes modified accordingly.
- **Step 3:** may be used if it is necessary to establish the flyability of the terminal routes.

Note 1: Usually, holding patterns are designed along routes and the routes are therefore designed first. Where required, however, it may become necessary to identify the airspace available for holding and design the relevant terminal routes as a function the placement of the holding areas.

Note 2: Throughout the design process, a qualitative analysis should be undertaken – see Part C, Chapter 3 and iterations of the Routes after the design of the Holds are required to stream-line the conceptual design of Routes and Holds.

Note 3: Designers' attention is drawn to the importance of the ATC System as an enabler (or constraint) in the context of designing Routes and Holds. See Chapter 4, **Attachment C.4-2**

Comment: When should designers design an ideal system of routes and holds as opposed to modifying the existing system? In most instances, a major change to the operating conditions of the Terminal Airspace would be a good time to attempt a clean start by designing an ideal route/hold system. Such major changes may include (i) the addition/closure of a runway at a major airport; (ii) the creation/closure of an airport within a Terminal Airspace; (iii) addition/removal of Terminal Area Radar; (iv) addition/removal of critical navigation or landing aids; (v) significant change to traffic distribution (e.g. as brought about by political events). Above and beyond this, some designers find it a useful exercise to periodically design an ideal system and use it as a benchmark against which to measure the actual design.

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5.4.2 TERMINAL ROUTES

✈ R1. TERMINAL ROUTES SHOULD BE SEGREGATED AS MUCH AS POSSIBLE

R1 FULL DESCRIPTION: TO THE EXTENT POSSIBLE FROM AN ATM OPERATIONAL PERSPECTIVE, TERMINAL ROUTES SHOULD BE SEGREGATED FROM EACH OTHER BOTH Laterally AND VERTICALLY SO AS TO ENHANCE SAFETY AND TO MINIMISE THE CONSTRAINING EFFECT OF THESE ROUTES UPON EACH OTHER.

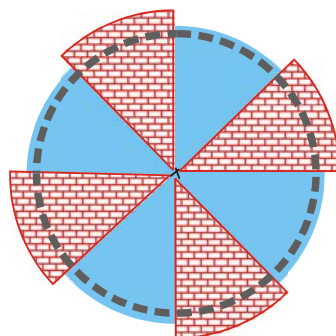


Figure 5- 6: Segregate Arrivals from Departures

This Guideline contains three elements, all of which aim to ensure that Terminal (arrival and departure) routes are kept apart as much as possible. Whilst Guideline R1.1 and R1.2 are alternative ways of resolving the SID/STAR interaction (though R1.1 is preferred, see below) Guideline R1.3 is an add-on which may be viewed as complementary to R1.1 and R1.2. These three Guidelines are described in shaded text below with illustrations.

□ R1.1: TO THE EXTENT POSSIBLE, TERMINAL ARRIVAL AND DEPARTURE ROUTES SHOULD BE LATERALLY SEGREGATED FROM EACH OTHER;

This Guideline means that the entry and exit points of a Terminal Airspace should be different. The illustration provided at Figure 5-7 demonstrates this Guideline; A denotes the entry point (arrivals) and D the exit point (departures).



Can the type of route shown in Figure 5-7 be designed for B-RNAV certified aircraft? Given that B-RNAV certification has no requirement for a database (the RNAV system is only required to accept manual entry of four way points) and that the turn anticipation is in the region of 22NM, B-RNAV. terminal routes requiring precise turns such as shown in Figure 2-3 cannot be designed for aircraft having only B-RNAV certification. (see Attachment C.4-1 of Chapter 4)

Can the type of route shown in Figure 5-7 be designed using P-RNAV? Yes. The requirement for a database is one of the fundamental differences between B-RNAV and P-RNAV. This said, whilst P-RNAV certified aircraft are capable of more precise turns, consistent track keeping is not guaranteed. For this, RNP RNAV with its Radius to Fix capability is required. (see Attachment C.5-1, this Chapter).

Does RNAV change how close the down-wind can be designed to the landing runway? It does not... The minimum distance between the downwind and the landing runway is a function of aircraft performance e.g. the slower the aircraft the closer the downwind can be placed. This said, inertia of (particularly) large aircraft on the turn makes it impracticable to place the downwind closer than 5NM. (Placing the down-wind closer than this increases the risk of aircraft overshooting the final approach track when turning to final.

Space Permitting, it is recommended that terminal routes are not designed through areas of known and/or frequent turbulent weather phenomena.

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To the extent possible, designated VFR routes should be segregated from IFR arrival and departure routes. To this end, visual reporting points (see para. 2.2) should be carefully selected.

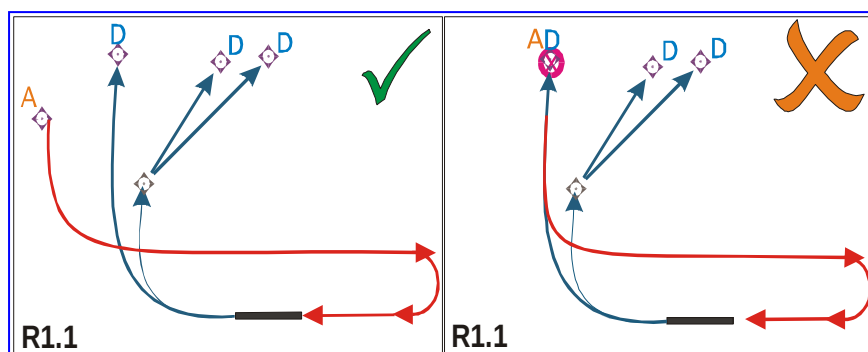


Figure 5- 7: Application R1.1

- ❑ **R1.2:** TO THE EXTENT POSSIBLE, TERMINAL ARRIVAL AND DEPARTURE ROUTES SHOULD BE VERTICALLY SEGREGATED FROM EACH OTHER AS A FUNCTION OF AIRCRAFT PERFORMANCE: WHERE ARRIVAL AND DEPARTURE ROUTES ARE REQUIRED TO CROSS EACH OTHER, THE CROSSING POINT SHOULD BE CHOSEN SO THAT THE 'OPTIMUM' VERTICAL PROFILES OF CLIMBING AND DESCENDING HAVE A MINIMUM CONSTRAINING EFFECT ON EACH OTHER.

Fulfilment of this Guideline requires an understanding and appreciation of aircraft performance. Given that the General Principles elaborated in Part A, Chapter 2 encourage a collaborative approach to Terminal Airspace design, aircraft performance information could be obtained from pilots on the design team. (Of special interest would be optimum aircraft performance i.e. not constrained by ATC or environmental requirements).

The aircraft performance in question concerns primarily the aircraft's speed and rate of climb and descent in a temperature band common to the operating environment. Given that a Terminal Airspace usually caters to a wide range of different aircraft (this can be determined from the traffic sample – see Part C, Chapter 4), account will need to be taken of this performance range. Designers should be aware that the same aircraft type may operate quite differently with different payloads or during different seasons. Seeing as some Terminal Airspaces are subjected to seasonal traffic peaks (See Part C, Chapter 4), the overall design plan should strive, as far as practicable, design routes in a manner that satisfies those (seasonal) peaks. However, the final result is likely to be a compromise.

Used together, Figure 5- 7, Figure 5- 8, and Graph 5- 1 can serve to illustrate the application of this Guideline. The left hand sketch of Figure 5- 8 shows that the departing aircraft has flown ± 7 NM from take-off when the arrival is ± 30 NM from touchdown. By referring to Graph 5- 1, this crossing can be considered feasible because a departure at ± 7 NM after take-off is likely to be at approximately 3500 feet AMSL (and accelerating to 250kts, for example) when arriving aircraft at ± 30 NM from touchdown are likely to be between 7500 and 10,000 feet (dependent on the Rate of Descent). Thus the minimal vertical distance likely to exist between arriving aircraft and departing aircraft on 'optimum profiles' at this crossing point is 4000 feet.

Using the right hand sketch in Figure 5-8 together with Graph 5- 1, a different situation emerges, between the two arrival slopes and two departure gradients at 7% and 10% respectively. At the point marked CP, the right hand sketch of Figure 5- 8 shows that the departing aircraft has flown ± 22 NM from take-off when it crosses the arrival which is ± 32 NM from touchdown. This is an unsuitable crossing because departures at ± 22 NM after takeoff on a 7% or 10% gradient are likely to be between 7600 feet and 11,000 feet respectively when the arriving aircraft at ± 32 NM from touch down are likely to be 7930 feet and 10,225 feet respectively. Given that it is desirable to ensure that the optimum profiles facilitate

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'naturally' the minimum vertical separation minima of 1000 feet, this crossing point is unsatisfactory.

The above does not suggest that aircraft climb performance is the only factor to be considered in determining the vertical distance between the aircraft at the crossing point. Neither should it suggest that 1000 feet is the *minimum* vertical separation to be applied at all crossing points. On the contrary, designers and planners should take various other factors into account in the determination of the vertical distance between the aircraft at the crossing point. These include :

- ❑ History of level busts: where applicable. (Mitigation might include publishing level restrictions which ensure 2000 feet between the climbing and departing aircraft at the crossing point);
- ❑ Nuisance ACAS alerts: an appreciation of how ACAS Traffic and Resolution Advisories may be triggered by route geometry. (For information on ACAS 'hotspots' and ACAS safety information, see ACAS [Safety Bulletin 1¹](#) of July 2002;
- ❑ Low Transition Altitude: Experience has shown that requiring climbing aircraft to stop their climb at or in the vicinity of a low Transition Altitude may increase the likelihood of level busts. The same may be true of arriving aircraft as regards the Transition level.

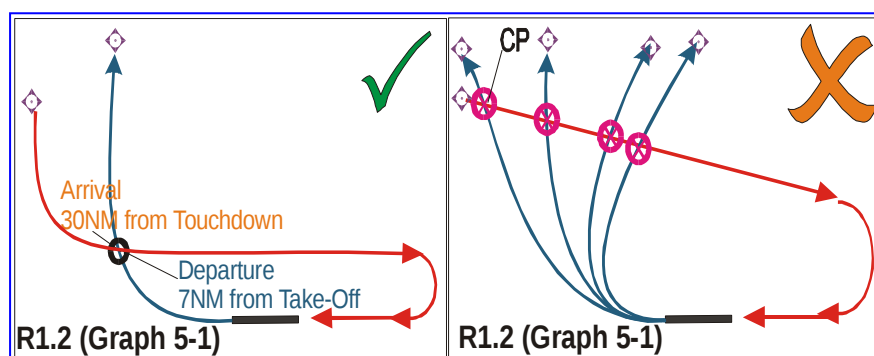


Figure 5- 8: Application R1.2 (&R1.1)



RNAV is all about point-to-point navigation; why is it necessary to design the downwind leg of RNAV STARs close to the runway (as per R1.2/Figure 5- 8)? R1.2 concerns finding the most suitable crossing point between an arrival and departure route so as to restrict, to the minimum, the vertical profile of the crossing aircraft. The application of RNAV does not change the desirability of applying R1.2. Although users sometimes react adversely to the realisation that RNAV has not served to reduce track mileage in this instance, they usually react positively to the freer aircraft profiles.

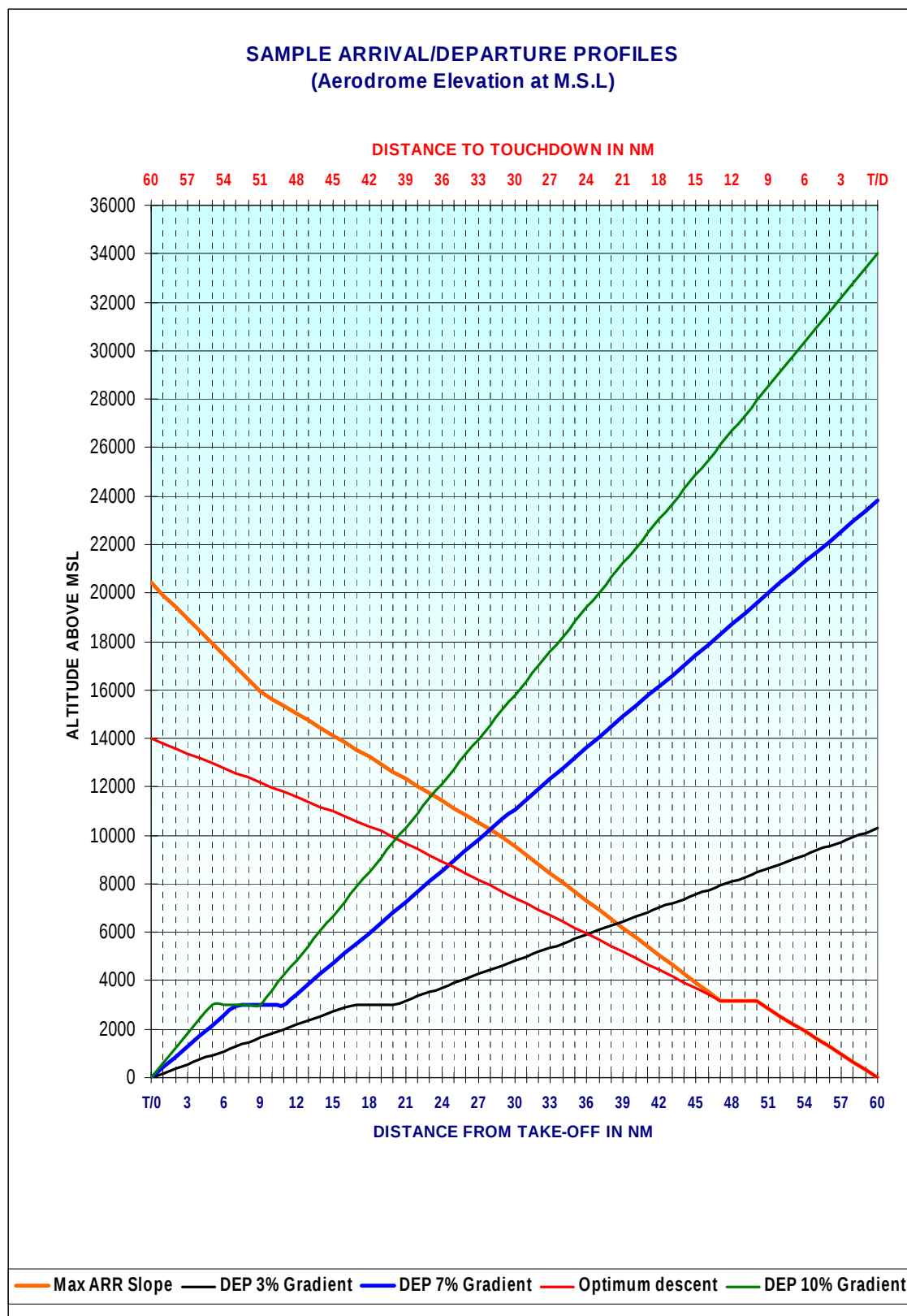


What are the alternatives to designing a downwind as per R1.2/Figure 5- 8? This question arises where the downwind as shown not be designed either because of noise sensitive areas close to the airport or where the richness of terrain makes such design impossible.

Fortunately, alternatives do exist especially if a robust & detailed equivalent of Graph 5- 1 is custom made for a Terminal Airspace. If this graph is developed with the assistance of pilots, it should provide a greater spread of descent/climb profiles which may provide alternative which include –

- RE-locating the SID/STAR crossing points whilst respecting R1.2, if possible (e.g the SID could continue on runway heading for a greater distance);
- raising the climb/descent level restrictions at the crossing point shown in Figure 5- 8;
- permitting only 'quieter' aircraft to fly on the SID/STAR shown in Figure 5- 8 (these aircraft would be identified as a combined function of Graph 5- 1 and data collected from noise monitoring points in the vicinity of the airport)

¹ <http://www.eurocontrol.int/acas/LatestNews.html>

Terminal Airspace Design Guidelines - Part C**Graph 5- 1: SAMPLE CLIMB/DESCENT PROFILES**

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- ❑ **R1.3:** TO THE EXTENT POSSIBLE, TERMINAL [DEPARTURE] ROUTES SHOULD BE Laterally SEGREGATED AS SOON AS POSSIBLE AFTER DEPARTURE, SUBJECT TO GUIDELINES R1.1 AND R1.2

This Guideline may be considered the converse of Guideline R3 (which requires arrival routes to be merged progressively as they approach the entry point of a Terminal Airspace).

Whilst this Guideline seeks to laterally segregate Terminal Departure Routes as soon as possible after departure, it should only be used within the limits of Guideline R1.2 (see commentary which follows Figure 5- 8, above).

The differences between the designs shown in the two right-hand diagrams in Figure 5- 9 (overleaf) concerns the arrangement of the departure routes. Whereas the departure routes fan-out in the top-right sketch, the departure tracks in the bottom right hand sketch are parallel after the first turn and likely to be spaced by a distance exceeding the Radar Separation minima. This configuration would probably make it easier to manage a relatively complex crossing of the downwind.



If 3NM is the Radar separation used in a Terminal Airspace, will the aircraft operating on parallel RNAV terminal routes spaced at 5NM be 'procedurally' separated? No. In order for aircraft to be procedurally separated in such instances, the parallel RNAV terminal routes should be spaced at a distance detailed in ICAO Annex 11 Attachment B.

If 3NM is the Radar separation used in a Terminal Airspace, is it possible to design parallel RNAV terminal routes at 5NM? Yes – but the aircraft operating on the centrelines of these routes are **not 'automatically' separated and it is incumbent upon the Radar Controller to ensure that the 3NM Radar Separation is not infringed.** This technique of route design is sometimes used in high-density Terminal Airspace; the publication of such parallel RNAV terminal routes reduces the amount of Radar Vectoring that the controller has to do, though the Radar monitoring workload may be high.



Aircraft performance and RNAV permitting, would be possible to build an altitude restriction into the right-turn departure tracks so that they can be 'hopped over' the arrival downwind track? Extreme caution should be exercised if an operational requirement is identified for a SID to climb above a STAR, as opposed to the failsafe option of the departure being constrained below an arrival route. This is because the existing PANS-ATM criteria related to the Area of Conflict (see PANS-ATM Chapter 5), are not generally considered useful in ECAC Terminal Airspace. (This is because the PANS-ATM provisions do not provide distances from the crossing point which are considered practicable for ECAC Terminal Airspace operations, most of which are conducted in a Radar environment. Furthermore, PANS-OPS obstacle clearance criteria cannot be used to determine track separation.



When the traffic mix is populated by a high-number of low performance aircraft, it may be useful to design separate Terminal Departure or Arrival Routes to accommodate these aircraft. This can be particularly advantageous as regards noise. Examples include the design of SIDs with 'early turnouts' for less noisy aircraft, or the design of Terminal (Arrival) Routes for 'lower' performance aircraft (which may also simplify sequencing for ATC).



Whenever possible, VFR (departure) routes should be designed so as to clear the initial departure area used by IFR routes, as soon as possible

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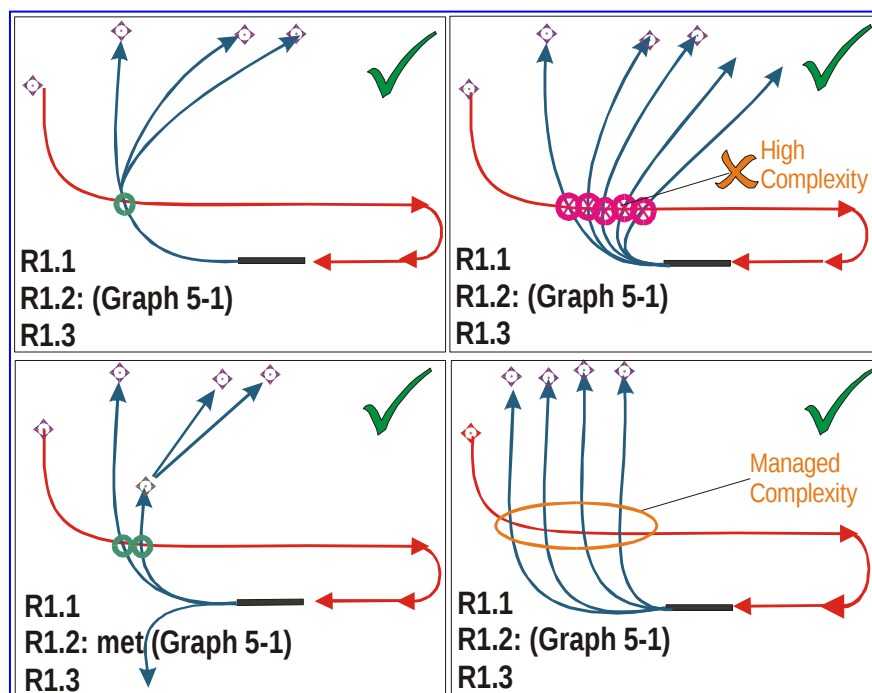


Figure 5- 9: Guidelines R1.1 – R1.3 combined

- **R1.4** TO THE EXTENT POSSIBLE, MISSED APPROACH TRACKS SHOULD BE SEGREGATED FROM EACH OTHER AND FROM THE INITIAL DEPARTURE TRACK OF TERMINAL DEPARTURE ROUTES SO AS TO EXTRACT THE MAXIMUM BENEFITS OF OPERATING INDEPENDENT RUNWAYS AND/OR CONVERGING RUNWAYS.

Requirements for the design of departure and missed approach procedures from parallel (or near parallel) runways are detailed in PANS-ATM (Doc. 4444) and PANS-OPS (Doc. 8168), together with guidance on operations in dependent, independent and segregated mode. See also the ICAO SOIR Manual, Doc. 9643, 1st Edition 2004.

✈ R2. TERMINAL ROUTES TO BE CONNECTED AND COMPATIBLE

R2 FULL DESCRIPTION: TO THE EXTENT POSSIBLE, TERMINAL ROUTES SHOULD BE CONSISTENTLY CONNECTED WITH THE EN ROUTE ATS ROUTE NETWORK AND BE COMPATIBLE WITH TERMINAL ROUTES IN ADJACENT (TERMINAL) AIRSPACES., IRRESPECTIVE OF THE RUNWAY IN USE.

Closely related to Guidelines R1.1, this guideline establishes that Terminal Routes be integrated into the greater Route Network of ATS routes. Furthermore, it requires that these points of connection remain constant irrespective of the runway in use. This Guideline contains three elements: viz. **consistent connection** with the En route ATS route network irrespective of the runway(s) in use, **compatibility** with other terminal routes in other Terminal Airspaces irrespective of the runway in use, and a requirement to minimise the complexity of the terminal route structure when **changing the runway(s) in use**.

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- ❑ **R2.1: TO THE EXTENT POSSIBLE, TERMINAL ROUTES SHOULD CONSISTENTLY BE CONNECTED WITH THE EN ROUTE ATS ROUTE NETWORK IRRESPECTIVE OF RUNWAY IN USE.**

The points at which the en route ATS routes and terminal routes connect should – for both arriving and departing flights - remain constant.

Significantly, this Guideline does not imply that precedence should be given to the En Route ATS Route Network i.e. there is no 'automatic' requirement for terminal routes to 'fit in' with the existing ATS route network (see Part C, Chapter 7, especially Stage 4 and 5 Terminal Airspaces).

Consistent with the General Principle of collaboration (Part A, Chapter 2), adjustments to both the En route ATS route network and terminal routes should be accommodated so as to obtain the best overall result as regards the design and strategic objectives.

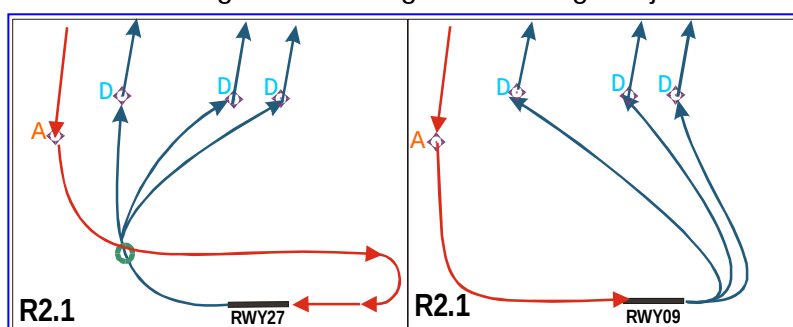


Figure 5-10: Consistent Connectivity, R2.1

Indeed, the entry and exit points of large Terminal Airspaces (e.g. London and Paris) often influence significantly the placement of ATS Routes in the En Route ATS Route Network. The converse is true of smaller Terminal Airspaces, where the placement of terminal routes is driven by the requirements of the EUR ARN.

- ❑ **R2.2: TO THE EXTENT POSSIBLE, IRRESPECTIVE OF RUNWAY IN USE, TERMINAL ROUTES SHOULD BE COMPATIBLE WITH ROUTES IN ADJACENT TERMINAL AIRSPACES (WHETHER THE TERMINAL AIRSPACE IS REMOTE OR IMMEDIATELY ADJACENT).**

This Guideline seeks to ensure the same consistency between terminal routes of adjacent Terminal Airspaces as is required in R2.1. Significantly, this Guideline draws attention to the fact that this compatibility be sought even with terminal routes in more 'remote' Terminal Airspace – even those located in a different sovereign airspace

- ❑ **R2.3: TO THE EXTENT POSSIBLE, CHANGE TO THE RUNWAY IN USE SHOULD CREATE MINIMUM OPERATIONAL COMPLEXITY TO THE TERMINAL ROUTES STRUCTURE.**

Whilst this Guideline effectively repeats the ideas embodied in R2.1 and R2.2, it is stated specifically with a view to drawing attention to the terminal routes *inside* the Terminal Airspace. As such, this Guideline suggests that the terminal route structure for one runway configuration should **seek to mirror** that of the inverse runway configuration so as to minimise operational complexity. Naturally, neither R2.1 nor R2.2 should be compromised, as far as practicable.

The difficulty inherent in this guideline occurs particularly in those instances when the geographic distribution of traffic is unequal – as is often the case with Terminal Airspaces located on the geographic periphery of Europe (see Part C, Chapter 4, para. 4.3.1.2).

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In Figure 2-8 below, the crossing point marked with an X may appear to be contradict R1.2 above. This said, a calculation using the Graph 5-1 is likely to reveal that the crossing is workable.

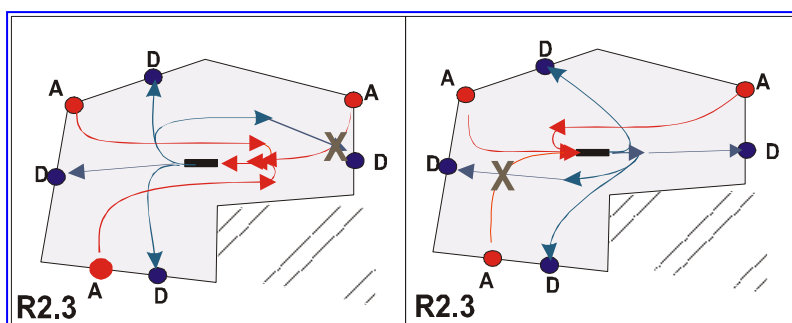


Figure 5- 11: Application R2.3



Whenever possible, this guideline should be applied in particular to VFR routes so as to minimise the likelihood of adding to complex operations when a change is made to the runway in use.

➔ **R3. TERMINAL ROUTES SHOULD BE MERGED PROGRESSIVELY AS THEY APPROACH THE TERMINAL AIRSPACE**

R3 FULL DESCRIPTION: TO THE EXTENT POSSIBLE, PUBLISHED TERMINAL ROUTES SHOULD BE PROGRESSIVELY MERGED AS THEY APPROACH THE TERMINAL AIRSPACE SO AS TO LIMIT THE NUMBER OF ARRIVAL GATES INTO THE TERMINAL AIRSPACE TO A MAXIMUM OF FOUR.

This guideline aims to simplify the route structure within Terminal Airspaces by ensuring that the complex task of traffic merging is done *outside* the Terminal Airspace (which is usually constrained in size).

Whilst the merging of arrival traffic flows should (ideally) be accomplished outside the Terminal Airspace, this does not suggest that the Terminal Airspace should only have four entry points. Indeed, there are two well known instances where it is desirable *not* to merge the arrival flows towards a common point. These are –

- ❑ where the aircraft performance mix is such that there is a marked speed difference in a large percentage of the traffic; or (/and)
- ❑ where the Terminal Airspace contains several major airports.

In either of the above cases, it is usually better to merge the arrival flows towards what might be called entry *gates*, each of which may contain arrival flows which are segregated either for different performance or for different airport destinations. In exceptional circumstances, it may even be necessary to split a common arrival flow into segregated routes inside the Terminal Airspace, especially to segregate different aircraft (speed) performance.

To appreciate the difference between merging arrival flows merged towards one entry point and one entry gate, where arrival routes remain segregate to accommodate different aircraft performance, (a) and (b) of Figure 5- 12 can be compared. Similarly, Figure 5- 12 *can be compared to* diagrams in Chapter 7.

Note: This Guideline does not suggest that Terminal Airspace **exit** points should be limited in number. See illustration at para. Figure 5- 6.

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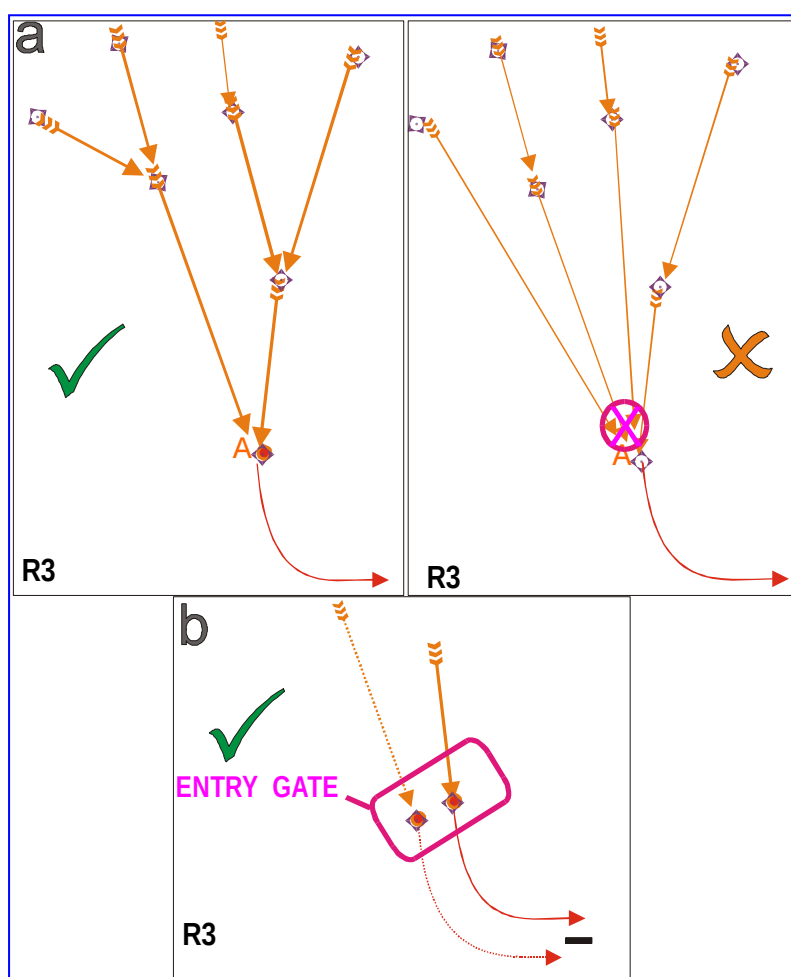


Figure 5- 12: Application of R3

5.4.3 HOLDING AREAS

➔ H1 HOLDING AREAS SHOULD BE LOCATED WHERE THEY WILL CREATE MINIMUM OPERATIONAL COMPLEXITY.

H1 FULL DESCRIPTION: TO THE EXTENT POSSIBLE, PUBLISHED HOLDING AREAS SHOULD BE LOCATED SO AS TO ENSURE MINIMUM OPERATIONAL COMPLEXITY BETWEEN EN ROUTE AND TERMINAL AIRSPACE (AND ADJACENT TERMINAL AIRSPACE).

Two methods are commonly employed to meter aircraft bound for congested Terminal Airspaces: one uses departure delay mechanisms (to avoid aircraft holding on entering the Terminal Airspace), and the other uses holding patterns to stack aircraft for sequencing into the Terminal Airspace.

Comment:

Whilst the choice of either method can be argued convincingly and applied efficiently, it is opportune to mention the reason commonly cited by proponents of the "holding pattern" method for this choice of option. The placement of holding patterns at strategic points prior to Terminal Airspace entry is based upon the idea that by keeping constant 'pressure' on the Terminal Airspace, less airspace is likely to be 'wasted' because the 'metering' of traffic is done closer to landing. Thus where "holding patterns" are used, the metering and sequencing is likely to be tactical and respond in real time to the actual traffic situation (as opposed to the longer range/strategic mechanism that the departure delay method involves).

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Because VFR flights usually hold over a visual reference point and the airspace required for VFR holding is generally much smaller than that required for IFR flights.

This Guideline H1 has two elements, both of which are integral parts of the whole – and related to Guideline R3.

- ❑ **H1.1:** TO THE EXTENT POSSIBLE, HOLDING PATTERNS SERVING A TERMINAL AIRSPACE SHOULD IDEALLY BE LOCATED EITHER AT AN ENTRY POINT OR GATE OR OUTSIDE THE TERMINAL AREA.

The reason for this is the same as that given for R3. This Guideline implies that holding patterns should not be located at Terminal Airspace *exit* points/gates or at the crossing point of Terminal Departure and Arrival Routes. (See Guidelines for Routes).



In contrast what this guideline suggests for IFR holding patterns, many designers find it useful to locate the VFR holding areas relatively close to the airport so as to facilitate the sequencing of VFR flights with IFR arrivals.

- ❑ **H1.2:** TO THE EXTENT POSSIBLE, THE LOCATION OF HOLDING PATTERNS SHOULD BE SUCH AS TO CREATE MINIMUM OPERATIONAL COMPLEXITY FOR BOTH EN ROUTE AND TERMINAL AIRSPACE AND FOR ADJACENT TERMINAL AIRSPACES.

Ideally, the location of holding patterns should strive to create minimum overall complexity for the entire air traffic system. This implies the need for a collaborative approach (between En Route and Terminal and between Terminal Airspaces) and making the necessary trade-offs when seeking to locate holding patterns.

- ❑ **H1.3:** TO THE EXTENT POSSIBLE, THE LOCATION OF HOLDING PATTERNS SHOULD REMAIN CONSTANT, IRRESPECTIVE OF THE RUNWAY IN USE.

This guideline supplements R3. The location of the holding patterns should not be affected by change to the runway in use.



This guideline is of particular importance as regards VFR holding areas, and should be applied to the extent possible.

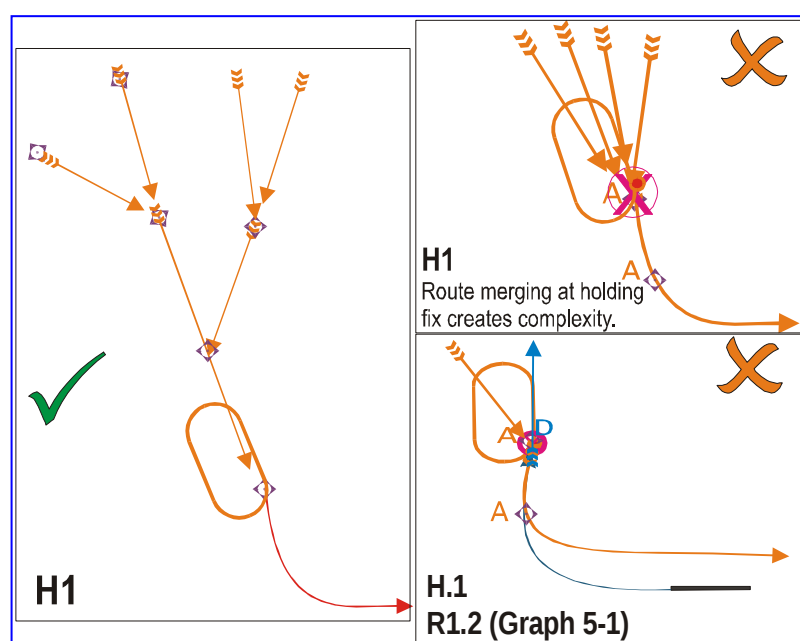


Figure 5- 13: Application of H.1

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As far as practicable, Terminal Holding Areas should not be located in areas of known and/or frequent turbulent weather phenomena, so that they can be used when airport operations have been suspended due to adverse weather..



When the traffic mix is populated by a high-number of low performance aircraft, it may be useful to design separate Terminal Holding Areas to accommodate these aircraft. This can be advantageous as regards noise and simplify sequencing for ATC.

➔ **H2 THE INBOUND TRACK OF A HOLDING PATTERN SHOULD BE CLOSELY ALIGNED WITH THE SUBSEQUENT TERMINAL ARRIVAL ROUTE.**

H2 FULL DESCRIPTION: TO THE EXTENT POSSIBLE, THE INBOUND TRACK OF PUBLISHED HOLDING PATTERN SHOULD BE ALIGNED WITHIN 30° OF THE SUBSEQUENT TERMINAL ARRIVAL ROUTE.

This guideline aims to enhance the efficiency of the holding pattern by assuring that aircraft are not required to make excessive turn manoeuvres when leaving the holding pattern and thus risk over-shooting the turn. If such excessive turn manoeuvres are inevitable, a speed restriction could be included into the procedure to reduce the risk of overshooting the turn.

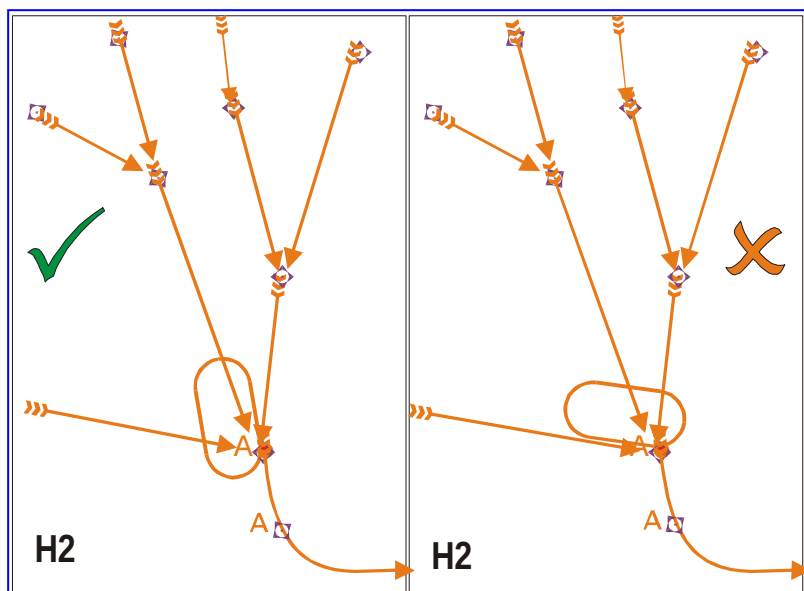


Figure 5- 14: Track Alignment, H.2

5.5 SUMMARY

Design Guidelines for the design of Routes and Holding areas have been presented in this chapter. To the extent possible, designers are encouraged to apply the above guidelines when designing arrival and departure routes. In most instances, these guidelines are applied in combined form. Where specification situations render it impossible to successfully apply combinations of guidelines, trade-offs are required. (See Chapter 7).

The attention of designers is drawn to the fact that these guidelines **do not** constitute design criteria. It is incumbent upon designers to use the design criteria for Routes and Holds contained, inter alia, in ICAO Doc. 8168 and Annex 11 when designing these routes and holds. A full set of document references pertaining to Terminal Airspace design are located at Part C, Chapter 1 **Attachment C.1-1**.

A checklist for undertaking the Conceptual design of Routes and Holds can be found at Chapter 8, **Attachment C.8-5**.

RNAV Routes & Holds

Although the guidelines contained in this chapter make several references to RNAV-based terminal routes, some additional information concerning RNAV Routes and Holds is provided in this Attachment in recognition of the increased use of RNAV in European Terminal Airspaces. A comparison between Conventional and RNAV routes is provided and particular information is provided on route information and the design of turns in RNAV routes.

This attachment is of relevance to paras. 5.2.1 & 5.4 of this chapter, as well as Attachment C.3-1 of Part C, Chapter 3.

Differences and Similarities between Conventional and RNAV Routes

→ **Route Placement**

The most obvious difference between RNAV and conventional routes concerns the freedom the designer has as regards route **placement**. In contrast to conventional terminal routes, RNAV routes need not be designed so as to pass directly over or be aligned directly with a ground-based navigation aid. This means that although RNAV-based routes rely on the navigation infrastructure (including GNSS which is not used to design conventional Routes), greater flexibility is provided as regards where the routes can be placed.

→ **Way-points**

Another significant difference between RNAV and conventional routes is that RNAV routes are defined by **way-points** as opposed to conventional fixes. (Note, however, that a conventional fix may also be defined as an RNAV way-point). Unlike conventional routes which are usually defined by tracks between fixes, an RNAV route is defined by tracks between way-points.

→ **Route Information**

A third noteworthy difference between RNAV and Conventional terminal routes is the way in which **route information** is provided to the operator. Whilst route information for both conventional and RNAV routes is provided to operators in 'original' AIP format consisting of charts and explanatory text, RNAV route information needs to 'translated' into a format which can be stored in a navigation database before it can be *used* by the aircraft navigation system.

This transformation of aeronautical data from 'State' published format into usable data for the operator occurs in a series of steps. Using State-originated aeronautical information, data base suppliers collect and code this information in a standard data format known as ARINC424 (Navigation System Database Specification). This data format, which is usable by navigation system databases, is then 'packed' by the original equipment manufacturer (OEM²) for use in the database of a particular operator (the 'end' user).

This transformation of route information into ARINC 424 format is made possible by the use of 'Path and Terminators' developed by ARINC. Simplistically, 'Path Terminators' can be described as industry standard for describing a route information. These Path Terminators are two-letter codes: the first describes the type of flight path (e.g. a track between two way-points) and the second the route termination point (e.g. a fix). Thus, for example, track to a fix (TF) path terminator would be used to "code" a route between two way-points.

² Original Equipment Manufacturer of the RNAV system.

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→ Turns

From an airspace designer's perspective, it is useful to understand that the design of turns on RNAV routes by PANS-OPS designers is different to conventional routes. As with straight segments of routes, turns also have to be coded into the route information using the Path and Terminator system. Turns can be coded in one of four ways:

Fly-By Transitions	Fly-Over Transitions	Fixed-Radius Transitions	Conditional Transitions
The navigation system anticipates the turn onto the next leg. In en route mode (see below) turn anticipation can start as much as 20NM before the (turning) way-point.	The aircraft over-flies the way-point before starting the turn onto the next leg. This type of turn is exclusive to Terminal Airspace, and then only when it is not possible to use a fly-by or fixed-radius transition e.g. to define an extended centre line.	In this instance, the aircraft flies a specific turn with a defined radius. This type of turn provides the most accurate, predictable and repeatable turn performance by all aircraft and is, generally, the preferred method for transitions with large track angle changes. Most current RNAV systems cannot accommodate this coding at present.	where the RNAV system initiates a transition once a specific altitude has been reached. Conditional transitions that involve a turn are defined by the preceding leg, the subsequent leg and an altitude restriction.

Note: From the designer's perspective - particularly that of the PANS-OPS specialist – it is useful to be aware that the way in which the RNAV system executes the turn is determined by whether the RNAV system (or FMS) is operating in 'en route' or 'Terminal' mode. Generally, it may be said that when in 'en route' mode, the turn anticipation for fly-by transitions will be considerably greater in Terminal mode. Significantly, the designer should be aware that the all RNAV systems (and FMS) do not necessarily define 'en route' and Terminal' mode the same way. Being aware of these aspects, the PANS-OPS procedure designer strive to design routes so that its coding ensures the greatest track predictability for air traffic control.

RNAV Holds

With the existing RNAV standards currently used in Europe – particularly P-RNAV in Terminal Airspace – it is possible to design RNAV holding patterns. Given the absence of fixed radius turn capability in such standards, however, the holding areas of current RNAV holding patterns is of similar shape and dimension to those whose designs are based on conventional navigation. Should the design of holding patterns become based upon RNP RNAV in the future, it should become possible to make significant reductions to size of the holding area (MASPS DO236()). This will provide interesting possibilities for Terminal Airspace designers. On some occasions, it may allow for holding patterns to be placed where it is currently not possible so to do, or for three holding patterns to be placed in an space currently limited to two holding patterns.

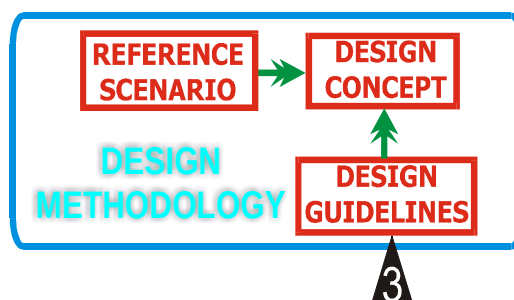
RNAV – future prospects

Increasingly, airspace designers and developers of ATM/CNS standards are becoming interested in the potential benefits that may accrue to ATM thanks to the potential availability of containment integrity inherent in the RNP RNAV MASPs³. Should this, it is hoped that it will become possible to reduce the spacing between parallel RNAV routes and enhance or develop or extend the use of RNAV-based separation standards

³ In the MASPS (DO-236()), **containment integrity** is defined as .." A measure of confidence in the estimated position, expressed as the probability that the system will detect and annunciate the condition where TSE is greater than the cross track containment limit. Containment integrity is specified by the maximum allowable probability for the event that TSE is greater than the containment limit and the condition has not been detected. That is, $P(E2) = \Pr(TSE > \text{containment limit and no warning is given})$

CHAPTER 6

- DESIGN GUIDELINES: STRUCTURES & SECTORS -



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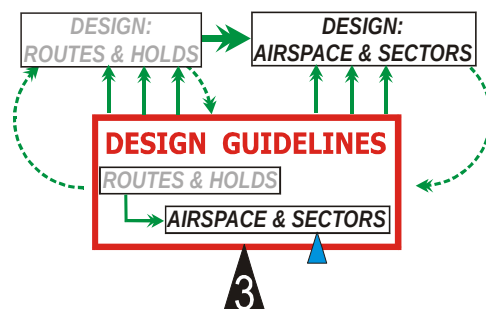
ATTACHMENTS

C.6-1: Sample Sector Options and Evolution

Terminal Airspace Design Guidelines - Part C

6.1 INTRODUCTION

This chapter presents Design Guidelines for *Structures and Sectors*. They are intended to support creation of the *design concept* for for a specific Terminal Airspace. This design concept would be based on certain assumptions. The design of Structures and Sectors follows the design of Routes and Holds (previous chapter). Given the phased approach described in Chapters 4 and 5, constraints and enablers for Structure and Sectors are identified in a phased manner as described in 6.4.1, below. As with Routes and Holds, the structures and sectors need to be subjected to a qualitative assessment against the selected safety and performance criteria as well as the Reference Scenario, if appropriate.



6.2 STRUCTURES AND SECTORS

Given the generic meaning to be attributed to Terminal Airspace (Part A, Chapter 1) and that the controlled airspace surrounding an airport can be designated in various ways in accordance to ICAO, the Guidelines for Terminal Airspace structures are slightly less specific than those pertaining to Routes, Holding patterns – and sectors.

Comment: *In practice, many designers give little attention to the shape of the Terminal Airspace structure. Indeed, many designers are disposed to the idea that the shape and size of the Terminal Airspace structure is fixed and cannot be changed. This point of view is difficult to defend, particularly when one consider the purpose of the (controlled) airspace structure i.e. the protection of IFR flight paths.*

As an entity, the Terminal Airspace structure plays an important role in the overall 'equation' of the type of air traffic service provided within the airspace. Because the ICAO airspace classification system determines the extent of the ATS provided within a particular airspace, the airspace classification to attributed to an airspace is important when designing the shape of the structure. Whilst some airspace classifications prohibit VFR flights, others cater for a mix of IFR and VFR and provide for different levels of service to be provided to them. Thus designer should, when designing the airspace, be mindful of the type of service that will be provided in the airspace. (See EUROCONTROL Manual for Airspace Planning, Section 2)

6.3 STRIKING THE BALANCE

A diagram oriented towards airspace structures and Sectors based upon a variation of the diagram from Part A, of this document is inserted below. Intentionally, its depiction is such as to draw designers' attention to the fact that diverging user requirements – and national interests most frequently challenge the design of the airspace structure and ATC sectorisation.

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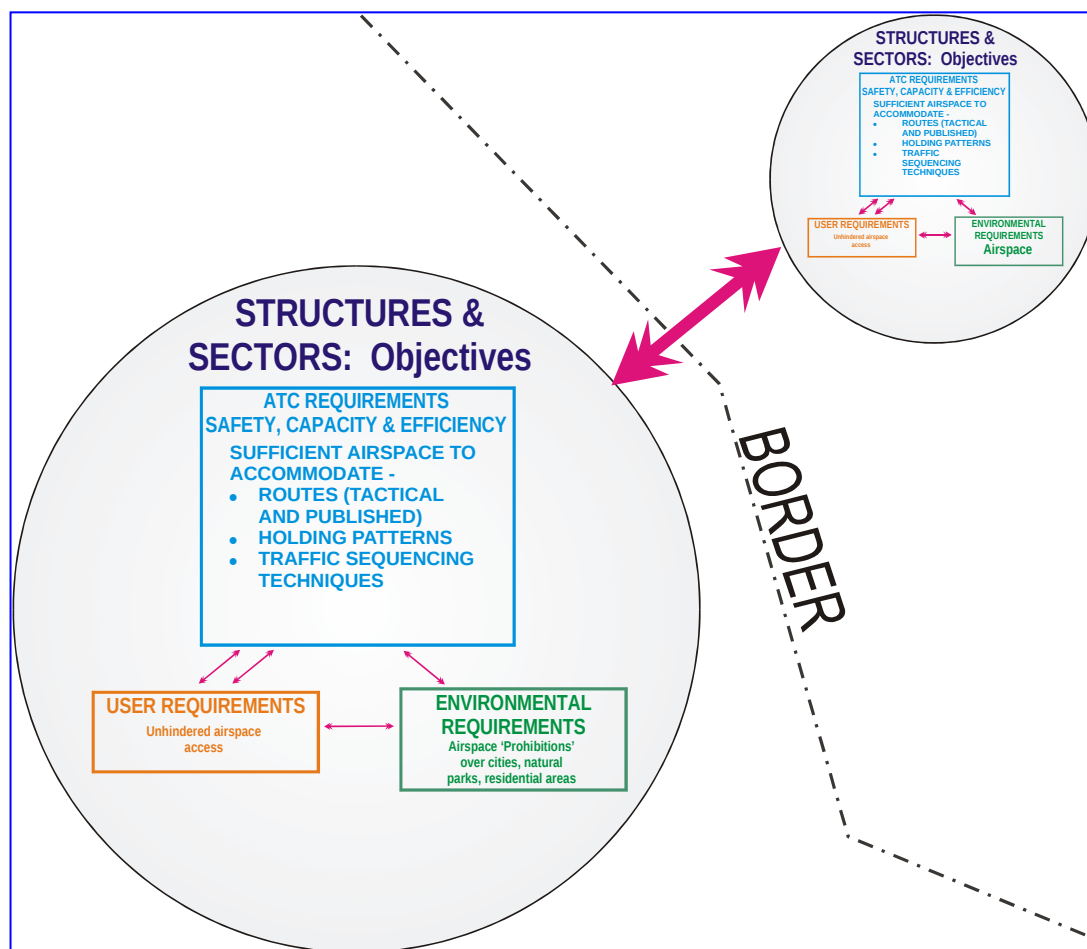


Figure 6- 1: Striking the balance

Whereas the triangular tensions between ATC-environment- users dominate the design of routes and holds, different tensions emerge when it comes to designing an airspace structure or an ATC sector. This is because 'airspace' (or airspace structures) have traditionally been linked to (national) sovereignty. Steeped in history and inherited from different political eras, varying perceptions of 'exclusive' airspace 'ownership' is visible between States in ECAC today. In a similar vein, it is not uncommon within one State, to find 'civilian' or 'military' making claims for exclusive airspace use – or for recreational aviation to insist upon their slice of the airspace.

Fortunately, these problems are being actively tackled in various fora – see EUROCONTROL Manual for Airspace Planning (Section 3) and the *Airspace Management Handbook*.

6.4 GUIDELINES

In this section, design Guidelines related to Terminal Airspace Structures and ATC Sectorisation are described. Those related to Terminal Airspace Structures are preceded by a “**St**” and those to Sectorisation, by an “**Se**”. They are not prioritised.

Both sets of Design Guidelines are based on the four assumptions:

Assumption 1: An air traffic control service is provided and Radar Surveillance is available within the Terminal Airspace; and

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Assumption 2: Within the context of needing to strike a balance between competing interest referred to in para. 6.3, (above), these Design Guidelines aim primarily for ATM efficiency and capacity.

Assumption 3: Strategic and Design Objectives, Assumptions, enablers and constraints have been identified by the design team. A concept design for Routes and Holds has also been developed.

Assumption 4: the expression terminal routes is used in the same context as in Chapter 5.

6.4.1 PHASED DESIGN APPROACH

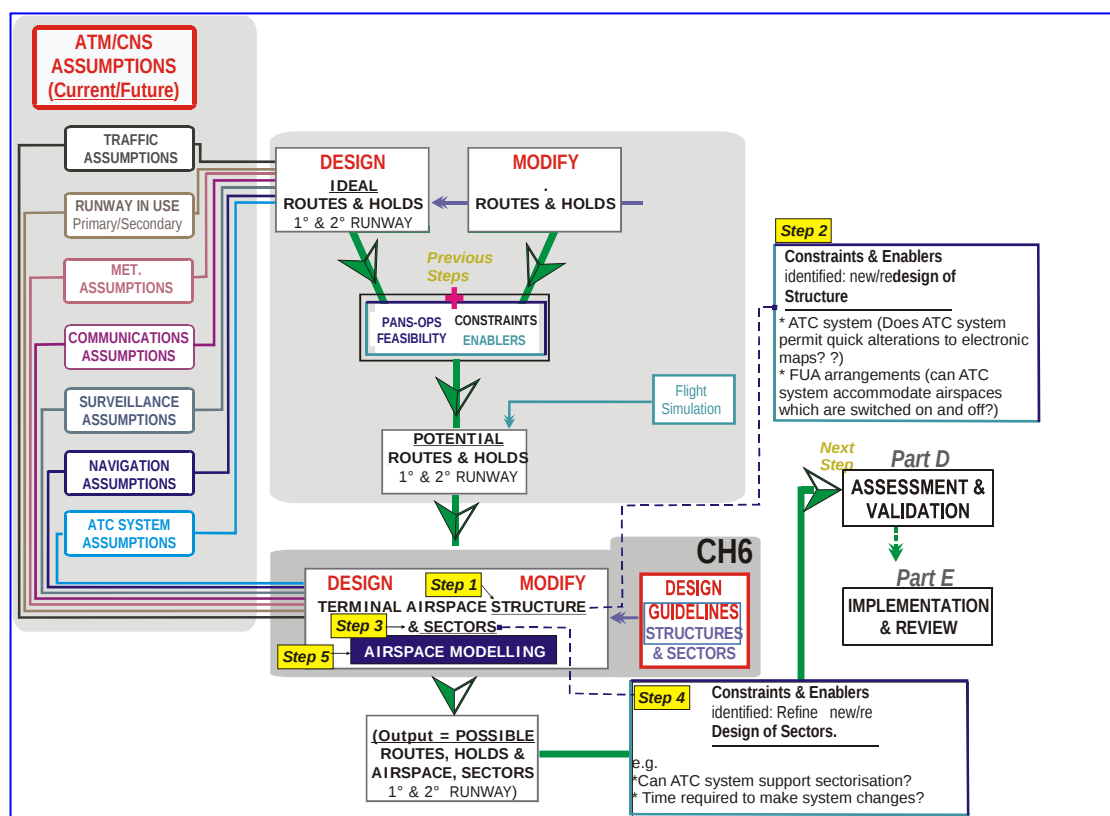


Figure 6-2: Phased Approach

Whilst consideration of all assumptions, enablers and constraints is crucial to creating the design concept for the Structure and Sectorisation (*after the routes and holds*) those most relevant at this stage of the design are shown on the left.

As with routes and holds, a **phased approach** is suggested for the design of structures and sectors and identification of constraints and enablers.

- Step 1: Using assumptions already identified, create a conceptual design of the Terminal Airspace structure to protect the Routes and Holds already designed.
- Step 2: Refine the output of Step 1, by adding in constraints and identifying enablers.
- Step 3: Building on Step 2 and based upon certain assumptions explore sectorisation options, if required (see below).
- Step 4: Refine output of Step 3, add in constraints and identify enablers.
- Step 5: Qualitatively assess the viability of Routes & Holds with new Structures and Sectors, using an Airspace Modeller, for example. (See Part D, Chapter 2)

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The output from this phase together with the Routes and Holds designed previously constitutes the product of the design concept. This is then subjected to assessment and validation in the next phase

Note 1: Because the 'structure' is sectorised, the structure is built first.

Note 2: Throughout the design process, a qualitatively analysis should be undertaken – see Part C, Chapter 3.

Note 3: Designers' attention is drawn to the importance of the ATC System as an enabler (or constraint) in the context of defining the ATC sectors. See Chapter 4, **Attachment C.4-2**

6.4.2 TERMINAL AIRSPACE STRUCTURES

➔ **ST1: TERMINAL ROUTES, HOLDING PATTERNS AND THEIR ASSOCIATED PROTECTED AIRSPACES ARE TO BE CONTAINED WITHIN CONTROLLED AIRSPACE (SEE ANNEX 11)**

ST1 FULL DESCRIPTION: TO THE EXTENT POSSIBLE, WHERE THE TERMINAL AIRSPACE IS SURROUNDED BY UNCONTROLLED AIRSPACE, THE PROTECTED AIRSPACE OF DESIGNATED TERMINAL ROUTES AND HOLDING AREAS ARE TO BE CONTAINED WITHIN THE TERMINAL AIRSPACE IN BOTH THE LATERAL AND VERTICAL PLANE.

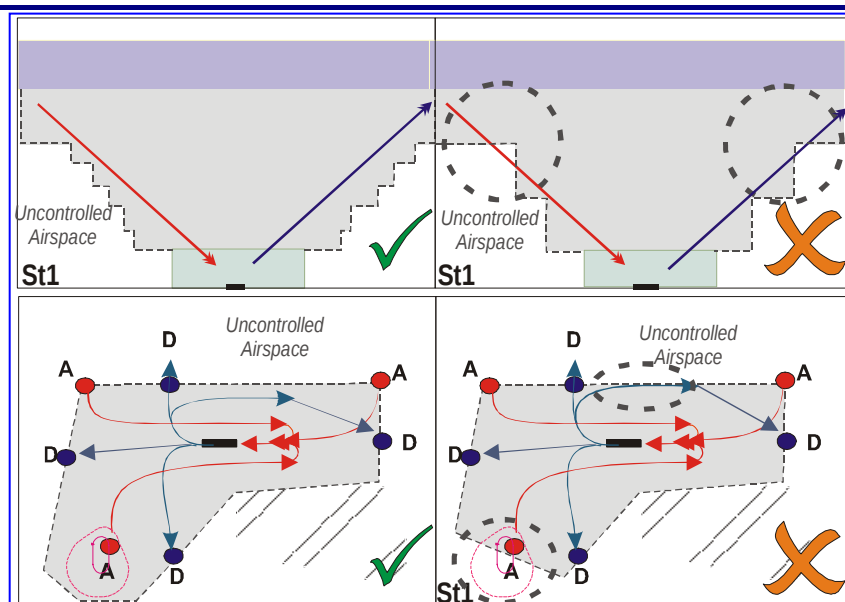


Figure 6- 3: Protection of IFR flight paths

Two sub-guidelines complement St1.

□ **ST1.1:** TO THE EXTENT POSSIBLE AND WHEN NECESSITATED BY OPERATIONAL REQUIREMENTS, THE UPPER LIMIT OF TERMINAL AIRSPACE SHOULD COINCIDE WITH THE LOWER LIMIT OF SUPERIMPOSED CONTROLLED AIRSPACE IN ORDER TO PROVIDE CONTINUOUS PROTECTION TO IFR FLIGHT PATHS.

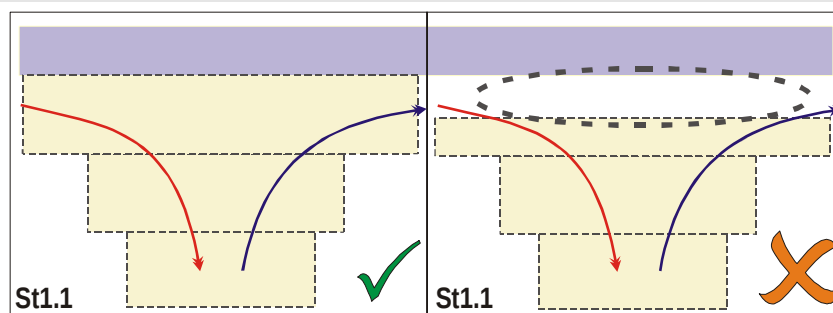


Figure 6- 4: Continuous Protection for IFR Flights

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The circle in the right hand diagram shows the area in which no protection is given to IFR flights on leaving the upper limit of the Terminal Airspace. Where Terminal Airspaces are located in remote areas, this design may be intentional.

→ **ST2: TO THE EXTENT POSSIBLE,. A TERMINAL AIRSPACE SHOULD BE COMPATIBLE WITH THE ROUTES AND HOLDS TO BE CONTAINED WITHIN IT.**

Because the shape and design of a Terminal Airspace depends upon the Terminal routes and holds to be contained within it, and that Terminal routes/holds are based on certain assumptions, it follows that the shape of each Terminal Airspace will be unique

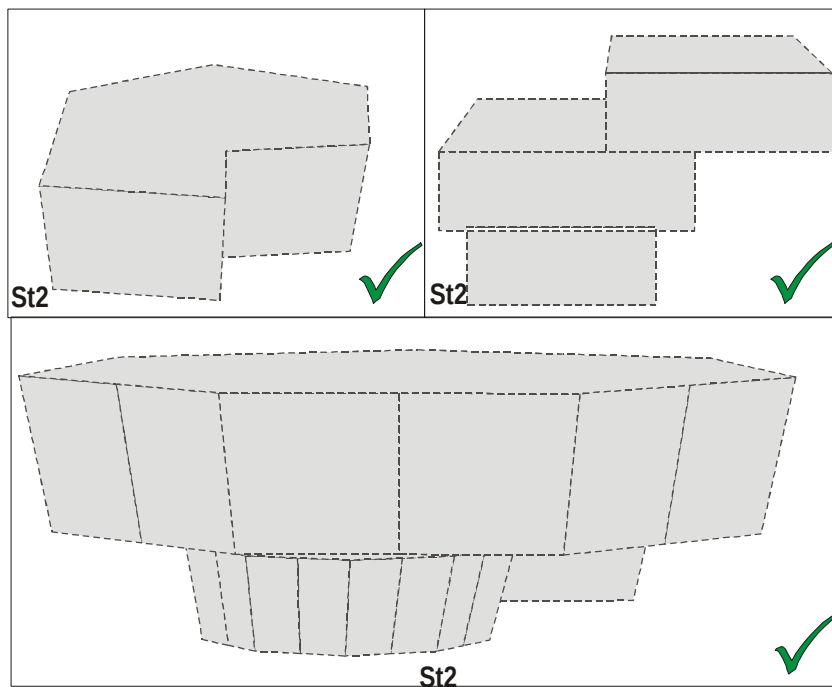


Figure 6- 5: No 'fixed' shape for Terminal Airspace

Being three dimensional, Terminal Airspace structures have width, length and height/depth with defined lateral and vertical limits. That these limits need not be uniform is a natural result of this Guideline. Indeed, the structure's lower limits are frequently stepped as may be the case with the upper limit.

***Note 1:** If tactical vectoring is to be used by ATC, the Terminal Airspace dimensions should ensure that sufficient space is provided for sequencing and separation of traffic.*

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- ❑ **ST2.1:** TO THE EXTENT POSSIBLE, BOTH VERTICAL AND LATERAL DIMENSIONS OF A TERMINAL AIRSPACE STRUCTURE SHOULD BE COMPATIBLE WITH AIRCRAFT FLIGHT PROFILES, HAVING TAKEN OBSTACLE CLEARANCE CRITERIA INTO ACCOUNT.

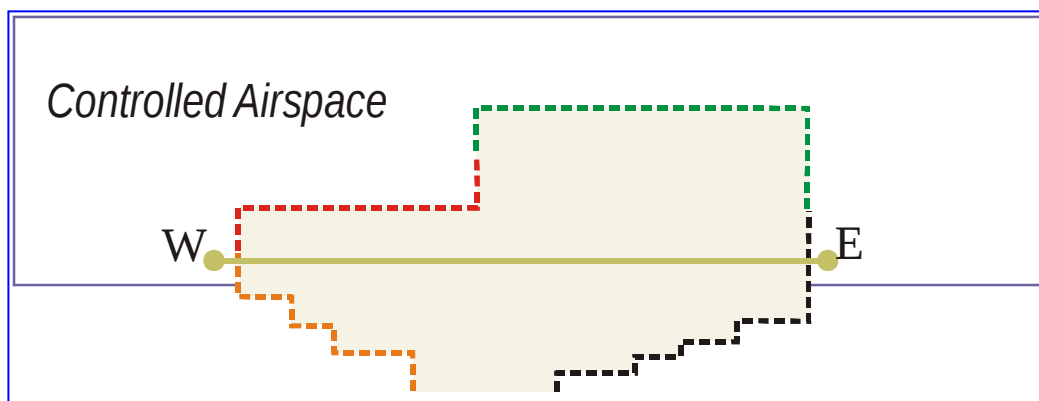
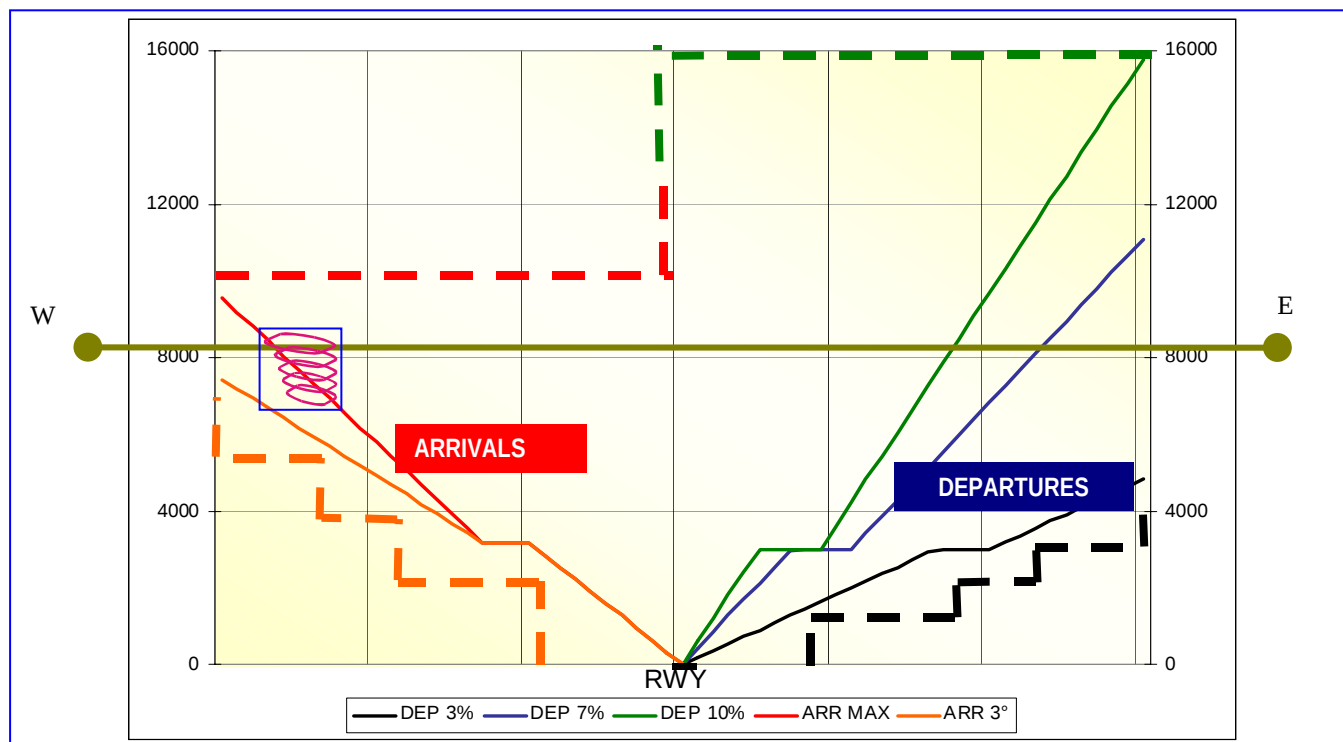


Figure 6- 6: 'Compatibility' between Routes & Structure (Simplified)

Whilst the above diagrams suggest that the Terminal Airspace structure is a function only of the aircraft performance, obstacle clearance must be accounted for as well. As such, they illustrate (simplistically) how to arrive at compatibility between the Structure and the routes and holds protected by the structure. The diagrams show how the vertical limits and horizontal limits of the Terminal Airspace may be arrived at with sample climb and descent profiles based on Graph 5-1 from Chapter 5. Significantly, tactical vectoring routes should also be accounted for when deciding the structure's dimensions. The conclusion that may be drawn from these diagrams is that there is a relationship between the width/height of a Terminal Airspace and aircraft profiles.

In effect, designers creating the Terminal structure would have available several graphs showing an extensive spread of performances. Importantly, the lower limit of the airspace

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must not be lower than a minimum height described by ICAO – excluding the part of the structure that is to serve as a CTR (which by definition, starts at the surface).

For complex airspace structures, see Chapter 7.

Compatibility needs also to be assured as regards non-designated Terminal routes e.g. Radar Vectoring. The Terminal Airspace should allow for sufficient space for Radar Vectoring to occur.

➔ **ST3: TO THE EXTENT POSSIBLE, ONLY THE AIRSPACE NECESSARY TO CONTAIN THE TERMINAL ROUTES SHOULD BE DESIGNATED AS TERMINAL AIRSPACE SO AS NOT TO CONSTRAIN THE OPERATION OF NON-PARTICIPATING (USUALLY VFR) FLIGHTS.**

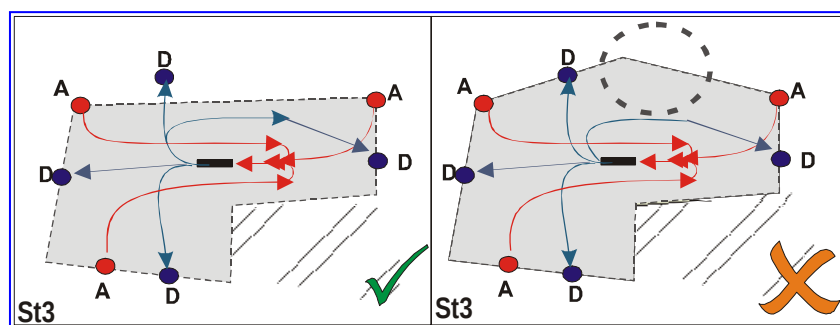


Figure 6- 7: Application St3

Despite the non-desirability of ‘taking’ more airspace than is required, designers should keep in mind that VFR pilots usually navigate by visual reference points and as such, the boundary of the Terminal Airspace should be ‘easy’ for VFR pilots to detect.

To this end, two sub-guidelines are provided.

❑ **ST3.1: TO THE EXTENT POSSIBLE, IN ORDER TO AVOID UNAUTHORISED PENETRATIONS OF THE TERMINAL AIRSPACE, THE DETERMINATION OF ITS LATERAL LIMITS SHOULD TAKE INTO CONSIDERATION THE ABILITY OF NON-PARTICIPATING VFR FLIGHTS TO IDENTIFY VISUAL REFERENCE POINTS DENOTING THE CONTROLLED AIRSPACE BOUNDARY**

Although it is tempting to design a complex structure to avoid airspace wastage, if the limits of the structure are difficult for VFR pilots to detect, the structure could be instrumental in reducing the safety of operations by increasing the likelihood of unauthorised airspace penetrations. :

❑ **ST3.2 TO THE EXTENT POSSIBLE, IN ORDER TO AVOID UNAUTHORISED PENETRATIONS OF THE TERMINAL AIRSPACE, THE DETERMINATION OF ITS LOWER LIMITS SHOULD TAKE INTO CONSIDERATION THE NEEDS OF NON-PARTICIPATING (USUALLY) VFR TRAFFIC TO OPERATE FREELY BENEATH THE TERMINAL AIRSPACE (1).**

Examples of Terminal Airspace whose lower limit is not the surface of the earth include TMAs and CTAs.

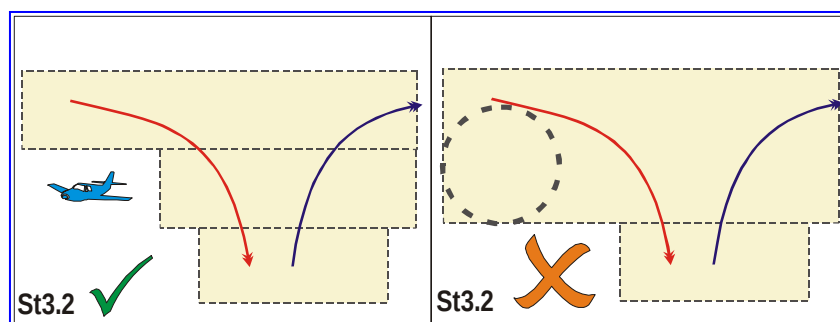


Figure 6- 8: Application St3.2

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- While the circle in the right hand diagram suggests airspace 'waste' (due to a fixed single lower limit of the Terminal Airspace, Chapter 7 will discuss how this trend is common in complex airspace structures.

➔ **ST4: WHEN NECESSITATED BY OPERATIONAL REQUIREMENTS DESIRABLE, ADJACENT TERMINAL AIRSPACES SHOULD BE FUSED INTO ONE TERMINAL BLOCK SO AS TO REDUCE OPERATIONAL COMPLEXITY.**

ST4 FULL DESCRIPTION: WHERE ADJACENT TERMINAL AIRSPACES WHICH ARE IN CLOSE PROXIMITY TO ONE ANOTHER AND HAVE INTER-DEPENDENT TERMINAL ROUTEING SCHEMES, CONSIDERATION SHOULD BE GIVEN TO NEGOTIATING WITH THE APPROPRIATE AIRSPACE AUTHORITY TO FUSE THE TERMINAL AIRSPACES INTO ONE TERMINAL AIRSPACE BLOCK WITH A VIEW TO INCREASING THE ATM EFFICIENCY IN THE TOTALITY OF THE SINGLE BLOCK.

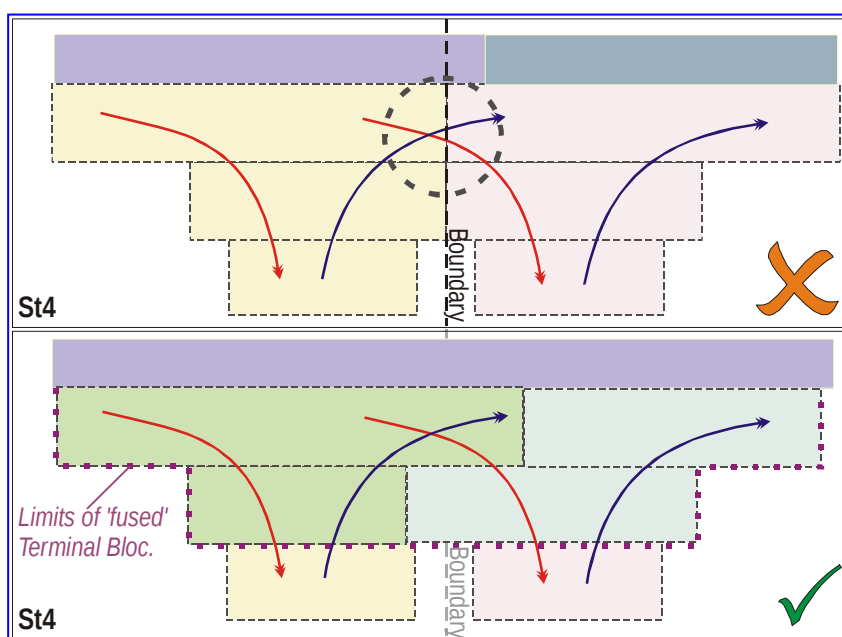


Figure 6- 9: Fused Terminal Airspaces to improve ATM

- The circle in the upper diagram of denotes both interacting traffic flows and a potential problem area in terms of crossing routes close to the Terminal Airspace limits, the problem is created by the fact that the boundary has been 'forced' to coincide with another e.g. a national boundary. The lower diagram shows that by creating one Terminal Airspace 'Bloc', ATM can be rendered more efficient by increasing the sectorisation options in the total airspace. See S3, below.

➔ **ST5: WHEN NECESSITATED BY OPERATIONAL REQUIREMENTS, CONSIDERATION SHOULD BE GIVEN AS TO WHETHER AND TO WHAT EXTENT, CERTAIN PARTS OF THE AIRSPACE ARE TO BE SWITCHED "ON" OR "OFF" IN ACCORDANCE WITH THE FLEXIBLE USE OF AIRSPACE CONCEPT.**

To accommodate such needs, a portion of the TMA can be published with its own identifier e.g. TMA II having its own dimensions, so airspace users and controllers can easily identify that portion of the airspace which is subjected to FUA.

❑ **ST5.1: WHERE AIRSPACE RESTRICTIONS OR RESERVATIONS ARE ESTABLISHED ABOVE OR BELOW TERMINAL AIRSPACE, IT IS ESSENTIAL THAT, DEPENDENT ON THE ACTIVITY CONDUCTED THEREIN, ADEQUATE BUFFERS BE ESTABLISHED ABOVE/BELOW THESE AIRSPACES RESTRICTIONS OR RESERVATIONS, IN ORDER TO ENSURE THAT ATS CAN PROVIDE AN ADEQUATE MARGIN OF SAFETY.**

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See Sections 1 and 3 of the ECAC Airspace Planning manual which respectively provide *General Guidelines* and guidelines relating to Airspace Restrictions/Reservations in support of the FUA concept.

6.4.3 SECTORS

From a design perspective, the sectorisation of a Terminal Airspace is one of the most common ways in which to distribute workload between controllers so as to ensure the safe and efficient management of air traffic within the airspace volume. Whether Sectorisation is *necessary* is decided – almost exclusively – on the basis of ATC workload which may impact upon safety. Because the frequency and number of air traffic movements constitutes one of the main factors affecting ATC workload, the importance of the selection of a **realistic traffic sample** and identification of the predominant **runway in use** cannot be over-stressed. As discussed in Chapter 3, the selected traffic sample is one of the major assumptions of the design process. Once it has been properly analysed (as regards *time* and *geographic* distribution), it is assigned to the modified or new Terminal routes which have been designed. Qualitative assessment of the traffic sample supported by Airspace Modelling are common methods used to identify the need for Sectorisation.

Comment: *Is there a generic rule of thumb that allows designers to estimate the need for Sectorisation?* Airspace designers will be aware that, for the most part, States do not publish capacity figures for Terminal Airspace (or TMA) sectors. There could be several explanations for this e.g. (i) it is too difficult to calculate; or (ii) capacity limitations are 'hidden' by published airport capacity and/or en-route sector capacity; or (iii) capacity figures are not calculated for Terminal Airspace or its sectors. There is a fourth possibility – which is unlikely – and that is that there are no capacity problems in Terminal Airspace sectors in ECAC. Whatever the reason, there appears to be agreement on the fact that capacity is difficult to estimate in a Terminal Airspace – perhaps because it is sandwiched between En route and the airport.

In order to appreciate the complexity of determining capacity of a Terminal Airspace volume (or sector), it is worth mentioning the variety of factors which affect the number of aircraft that can be handled by a single controller in a given time period. Importantly, **none of these factors can be viewed in isolation**. Each factor is a 'variable' in the overall capacity 'equation'.

- ❑ Design of Terminal routes. *The more segregated the routes both vertically and laterally, the less the 'active' the workload of the controller;*
- ❑ Use of designated arrival and departure routes such as SIDs/STARs. *Generally, the greater the number of published routes, the less RTF required (Note, however, that an excessive number of SIDs/STARs can create a high pilot workload or introduce errors).*
- ❑ The accuracy of the navigation performance of aircraft operating on designated routes. *The greater the accuracy, the less the need for controller intervention.*
- ❑ Phase of flight. *Generally, arrivals are more labour intensive than departing flights especially if extensive use is made of tactical routeing as opposed to designated routes such as STARs.*
- ❑ The complexity of the instrument approach procedure : *especially in terrain rich areas or for reasons of environmental mitigation, the Radar monitoring workload can be high with respect to complex manoeuvres.*
- ❑ The altitude of the airport, ambient temperature and airport infrastructure affect runway occupancy and in-trail spacing interval. *At 'hot and high' airports, holding may be required to compensate for any of these factors – which is work intensive.*
- ❑ High mix of aircraft performance and/or aircraft navigation performance: *Generally, the greater the mix, the higher the workload as speed differences and navigation performance differences have to be catered for by the controller.*
- ❑ Capabilities and facilities provided by the Radar System and the Flight Planning Data Processing system. *For example, if a controller is required to 'manually' perform the code-call-sign conversion, this creates additional workload.*

In view of the above, it can be seen that it would be difficult to provide a 'rule of thumb'. Where fifteen aircraft an hour in a particular Terminal Airspace may appear – to most – to be indicative that Sectorisation is not required, it could be required if the 'lowest' denominator of all of the points in the bulleted list (above) constitute the 'general' operating conditions. Conversely, where 40 aircraft an hour would suggest a need to sectorise the Terminal Airspace volume, it may prove unnecessary in those instances where the 'highest' common denominator of all of the points in the bulleted list (above) constitute the 'general' operating conditions.

Once the need for Sectorisation has been identified, the next question to be decided is whether sectorisation is possible. This possibility is determined by the available staff holding

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the appropriate qualifications, the availability of working positions and the capabilities of the ATM system. In this context, 'available' staff/working positions may be included in the assumptions i.e. those that will be available when the project is implemented. If staff and or working positions are not available, designers could plan for sectorisation in the longer term and identify more qualified staff and working positions as enablers.

Having determined that sectorisation is required and possible, the next decision concerns the type of sectorisation to be used. Generally, two types of Sectorisation are used in Terminal Airspace. These are –

- ❑ Geographical Sectorisation : where the airspace volume is divided into 'blocks' and a single controller is responsible for all the traffic in a single block i.e. sector; or
- ❑ Functional "Sectorisation" where divisions of the Terminal Airspace volume is determined as a function of the aircraft's phase of flight. The most common type of Functional Sectorisation is where one controller is responsible for arriving flights in the Terminal Airspace whilst another is responsible for departing flights in the same Terminal Airspace volume.

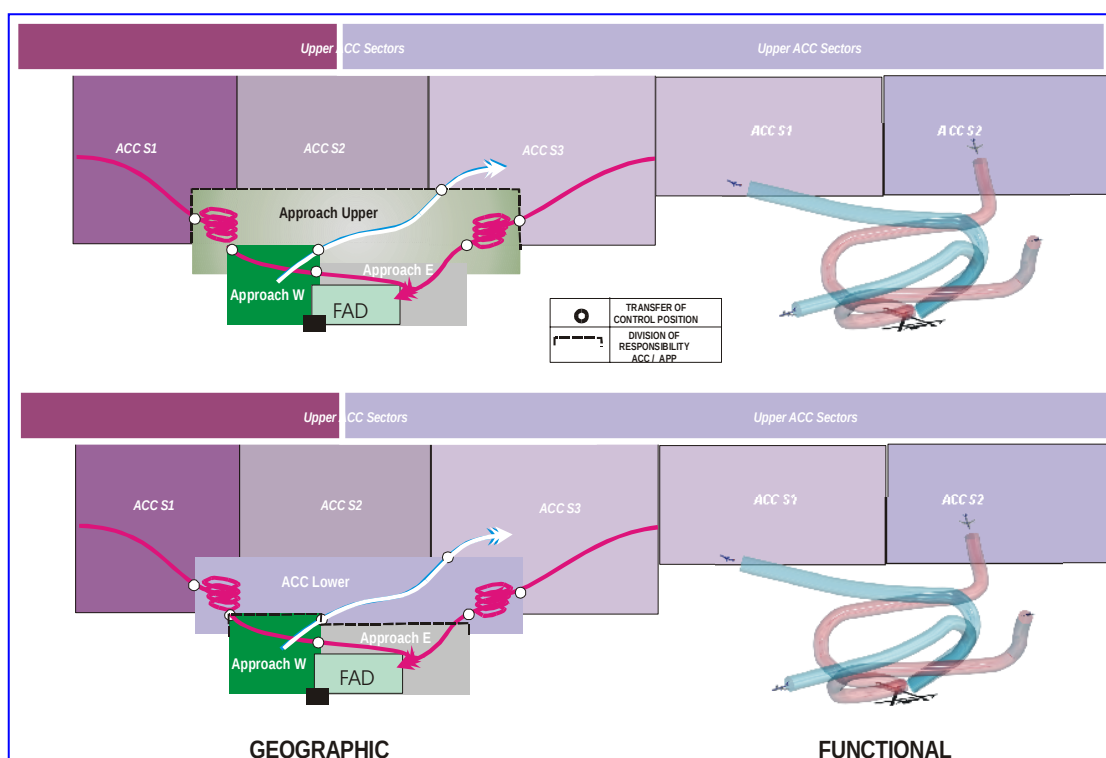


Figure 6-10: Sectorisation Types

Several points are worth noting concerning sectorisation methods:

- ❑ As it is commonly understood, 'Sectorisation' generally refers to geographical Sectorisation. As such, it could be argued that Functional 'sectorisation' is a sub-set of geographical Sectorisation.
- ❑ Secondly, there are very few Terminal Airspaces which are sectorised either geographically or functionally. In reality, most Terminal Airspaces use a combination of functional and geographic sectorisation.

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- ❑ Sectorisation of the Terminal Airspace volume can be demanding in terms of ATC system capability. When (geographic) sectors are stepped or when functional Sectorisation is used, the ATC system should be capable of supporting the sectorisation option e.g. by 'filtering' out traffic that is not under the direct control of the controller responsible for a sector.

6.4.3.1 Geographic Sectorisation

<u>Advantages</u>	<u>Disadvantages</u>
➔ Controller can fully exploit the space available in sector to manipulate best levels for inbounds/outbounds and expedite climb and descent without need for co-ordination. ➔ Easier to balance workload between sectors. ➔ Can be less demanding in terms of the Radar Display and ATC system ➔ Relatively easily to describe operational instructions for ATC areas of responsibility.	➔ Controller handles mixed traffic i.e. arrival, departure and transit traffic. ➔ In instances where the sector division runs along the runway centre-line, departing aircraft departing in different directions may be controlled by different controllers after take-off. (Effective mitigation can be provided by putting appropriate procedures in place). ➔ In cases where an aircraft is required to transit more than one geographic sector in the Terminal Airspace, this can add to complexity by requiring additional co-ordination.

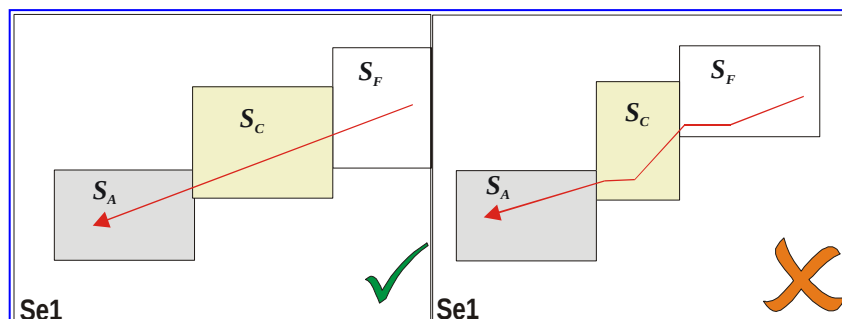
6.4.3.2 Functional Sectorisation

<u>Advantages</u>	<u>Disadvantages</u>
➔ Controller handles one traffic type i.e. either departures or arrivals because sector defined as a function of task. ➔ Usually, <i>all</i> Departing aircraft are on the same frequency after take-off. ➔ In some configurations, can prove more flexible to operate.	➔ Vertical/Lateral limits of sector can prove overly restrictive as one (vertical) band is unlikely to cater for all aircraft performance types. ➔ Difficult to balance workload between sectors especially where departure and arrival peaks do <i>not</i> coincide. ➔ Can be demanding in terms of the Radar Display and ATC System ➔ Operating instructions for ATC can be difficult to formulate with respect to areas of responsibility;

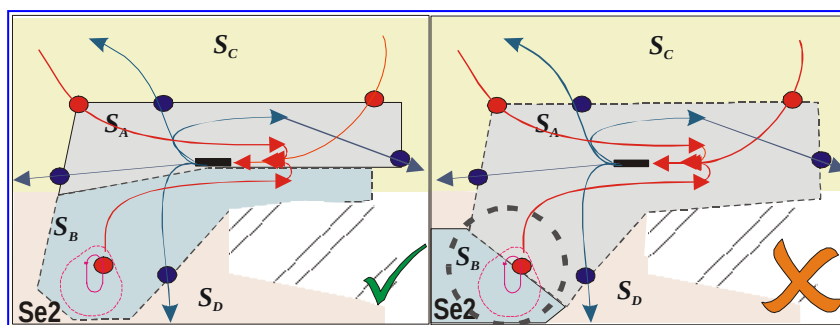
Comment: What is the difference between division of responsibility and areas of responsibility in the context of ATC Sectorisation? Usually, the former refers to division of responsibility between the different ATC Units i.e. between the Area Control Unit, Approach Control Unit and Aerodrome Control Unit. In contrast, the latter refers to dividing the workload of any one unit i.e. dividing the workload of the Approach Control Unit into two sectors such as Approach East and Approach West. In those cases where one Area Control sector is responsible for the entire FIR and one Approach Control sector is responsible for the entire Terminal Airspace, the division of responsibility is the 'same' as the sectorisation.

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- **Se1: TO THE EXTENT POSSIBLE, LATERAL AND VERTICAL DIMENSIONS OF SECTORS SHOULD BE DESIGNED SO AS TO AVOID A REQUIREMENT TO ISSUE STEPPED LEVEL CLEARANCES, ESPECIALLY OVER SHORT DISTANCES.**

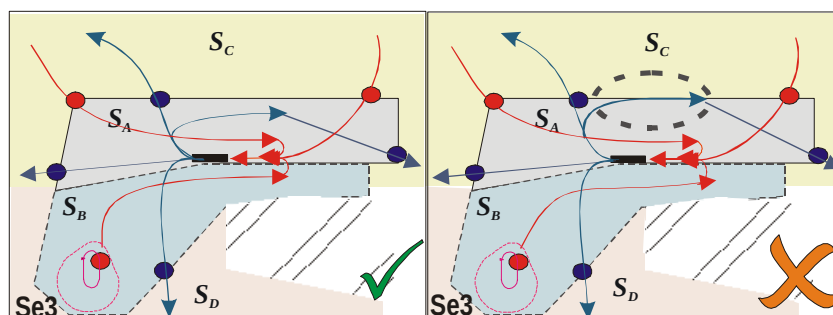
**Figure 6-11: Application Se1**

- **Se2: THE PROTECTED AIRSPACE AROUND A HOLDING PATTERN SHOULD BE INCLUDED IN A SINGLE GEOGRAPHICALLY DEFINED SECTOR.**

**Figure 6-12: Placement of Holding Areas**

- **Se3: THE PROTECTED AIRSPACE OF A PUBLISHED TERMINAL ROUTE SHOULD BE CONTAINED WITHIN A SINGLE GEOGRAPHICALLY DEFINED SECTOR.**

Full Description: WITH A VIEW TO PREVENTING UNAUTHORISED SECTOR PENETRATIONS, THE PROTECTED AIRSPACE OF PUBLISHED TERMINAL ROUTES SHOULD BE CONTAINED WITHIN A SINGLE GEOGRAPHICALLY DEFINED SECTOR WHERE A ROUTE CENTRE IS PARALLEL TO A SECTOR BOUNDARY, OR IT IS INTENDED THAT AIRCRAFT REMAIN WITHIN THE ORIGINAL SECTOR AFTER COMPLETING A TURN.

**Figure 6-13: Protected Airspace – Sector Boundary**

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In those instances where extensive tactical vectoring is expected within a particular sector, it is advisable to place the sector boundary in such a manner so as to minimise the need for co-ordination between sectors.

→ **SE4: WITH A VIEW TO ENSURING MINIMUM OPERATIONAL COMPLEXITY, A SECTOR SHOULD NOT BE DESIGNED IN ISOLATION FROM SURROUNDING SECTORS.**

This guideline is complementary to Se1. It is amplified by several sub-guidelines.

□ **SE4.1: TO THE EXTENT POSSIBLE, CROSSING POINTS OF TERMINAL AND/OR OTHER ROUTES SHOULD NOT BE PLACED TOO CLOSE TO A BOUNDARY OF A GEOGRAPHICALLY DEFINED SECTOR SO AS TO ALLOW THE RECEIVING CONTROLLER SUFFICIENT ANTICIPATION TIME TO RESOLVE THE CONFLICT.**

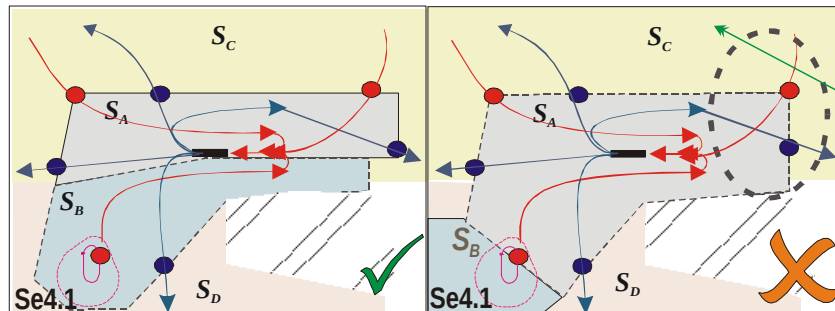


Figure 6-14: Lateral Sector boundaries and crossing routes

This sub-guideline infers that the *lateral limits* of sectors need not be straight lines.

□ **SE4.2: THE VERTICAL LIMITS OF A GEOGRAPHICALLY DEFINED SECTOR NEED NOT BE UNIFORM I.E. FIXED AT ONE UPPER LEVEL OR ONE LOWER LEVEL, NOR NEED THESE VERTICAL LIMITS COINCIDE WITH THE VERTICAL LIMITS OF (HORIZONTALLY) ADJOINING SECTORS.**

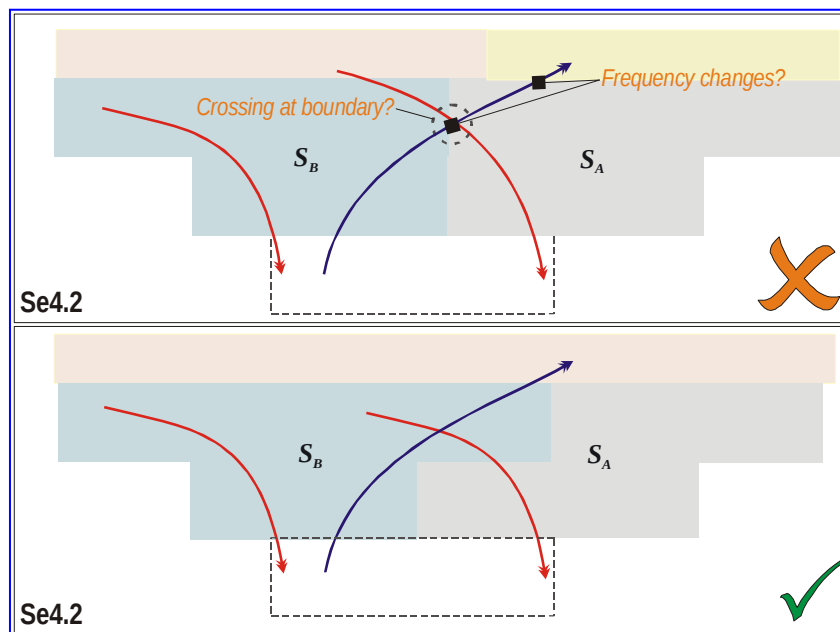


Figure 6-15: Vertical Sector boundaries and crossing routes

□ **SE4.3: WHERE AIRSPACE RESTRICTIONS OR RESERVATIONS ARE ESTABLISHED ABOVE OR BELOW TERMINAL AIRSPACE SECTORS, IT IS ESSENTIAL THAT, DEPENDENT ON THE ACTIVITY CONDUCTED THEREIN, ADEQUATE BUFFERS BE ESTABLISHED ABOVE/BELOW THESE AIRSPACES RESTRICTIONS OR RESERVATIONS, IN ORDER TO ENSURE THAT ATS CAN PROVIDE AN ADEQUATE MARGIN OF SAFETY.**

This is the 'equivalent' of Guideline St.5.1

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→ **SE5: POTENTIAL SECTOR COMBINATIONS SHOULD BE TAKEN INTO ACCOUNT WHEN DETERMINING SECTOR CONFIGURATION.**

SE 5 FULL DESCRIPTION: POTENTIAL VERTICAL AND HORIZONTAL SECTOR COMBINATIONS SHOULD BE TAKEN INTO ACCOUNT WHEN DETERMINING SECTOR CONFIGURATIONS WITHIN A TERMINAL SO AS TO RESPOND MORE REALISTICALLY TO CHANGES IN TRAFFIC DEMAND. ANY SECTOR COMBINATION SHOULD ENSURE THAT OPERATIONAL COMPLEXITY IS KEPT TO A MINIMUM. (For complex sector configurations, see Chapter 7)

SE6: GEOGRAPHICALLY DEFINED PRE-SEQUENCING SECTORS SHOULD BE DESIGNED TO ENCOMPASS THE MAIN ARRIVAL FLOWS WITH A VIEW TO MERGING ARRIVAL FLOWS AS PER GUIDELINE R3 (SEE CHAPTER 5) .

For complex Terminal Airspace sectors, see Chapter 7.

→ **SE7 TO THE EXTENT POSSIBLE, THE CONFIGURATION OF GEOGRAPHICALLY DEFINED SECTORS SHOULD REMAIN CONSTANT IRRESPECTIVE OF THE RUNWAY IN USE. (GEOG ONLY)**

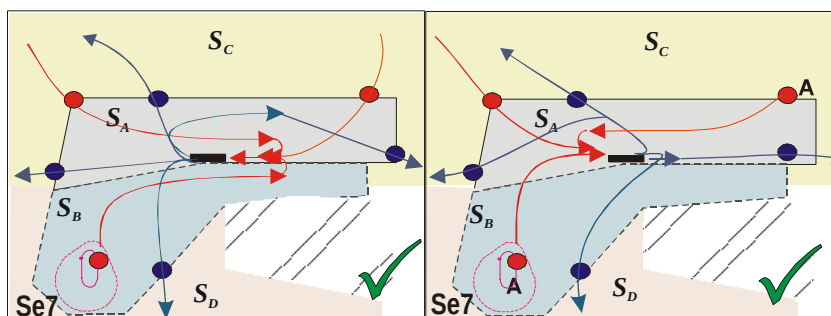


Figure 6-16: Sector configuration and Runway in Use (I)

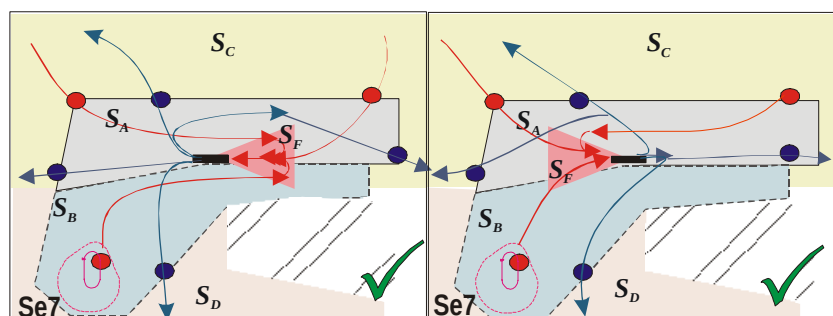


Figure 6-17: Sector Configuration & Runway in use (ii)

This guideline is aimed at avoiding unnecessary co-ordination between upstream or downstream sectors and avoiding complex changes to the FDPS and RDPS which may not be capable of accommodating such changes.

Naturally, if a Final Approach director sector exists, this sector would have to be changed when a change is made to the runway in use.

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→ **SE8: WHEN NECESSITATED BY OPERATIONAL REQUIREMENTS, THE UPPER LIMIT OF A SECTOR SHOULD COINCIDE WITH THE LOWER LIMIT OF SUPERIMPOSED SECTORS IN ORDER TO PROVIDE PROTECTION TO IFR FLIGHTS.**

This guideline is the sector 'equivalent' to Guideline St1.1

6.5 SUMMARY

Design Guidelines for the design of Structures and Sectors areas have been presented in this chapter. To the extent possible, designers are encouraged to apply the above guidelines when designing structures and sectors. In most instances, these guidelines are applied in combined form. Where specification situations render it impossible to successfully apply combinations of guidelines, trade-offs are required. (See Chapter 7).

The attention of designers is drawn to the fact that these guidelines **do not** constitute design criteria. It is incumbent upon designers to use the design criteria for Routes and Holds contained, inter alia, in ICAO Doc. 8168 and Annex 11 when designing these routes and holds. A full set of document references pertaining to Terminal Airspace design are located at Part C, Chapter 1 **Attachment C.1-1**.

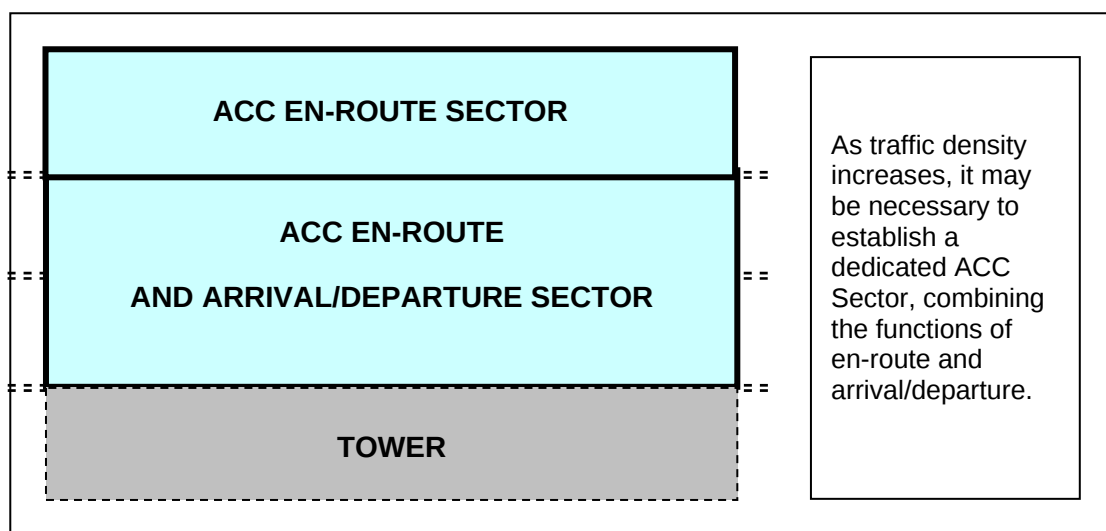
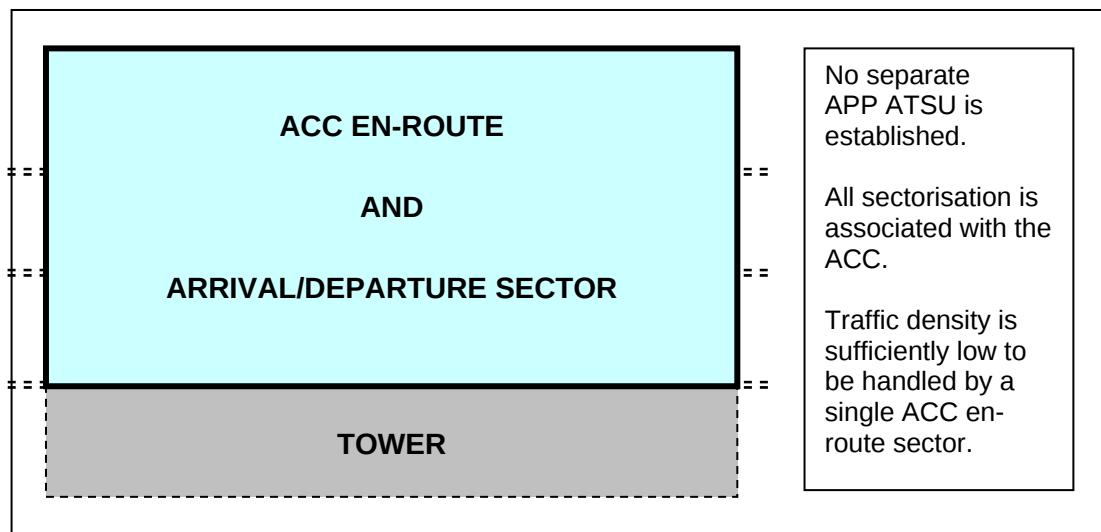
A checklist for undertaking the Conceptual design of Structures and Sectors can be found at Chapter 8, **Attachment C.8-1**.

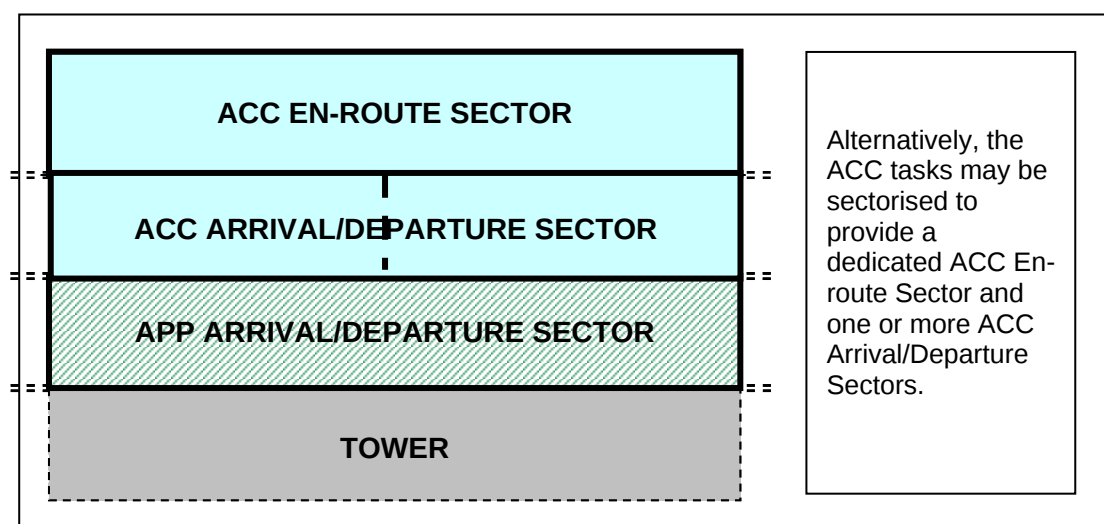
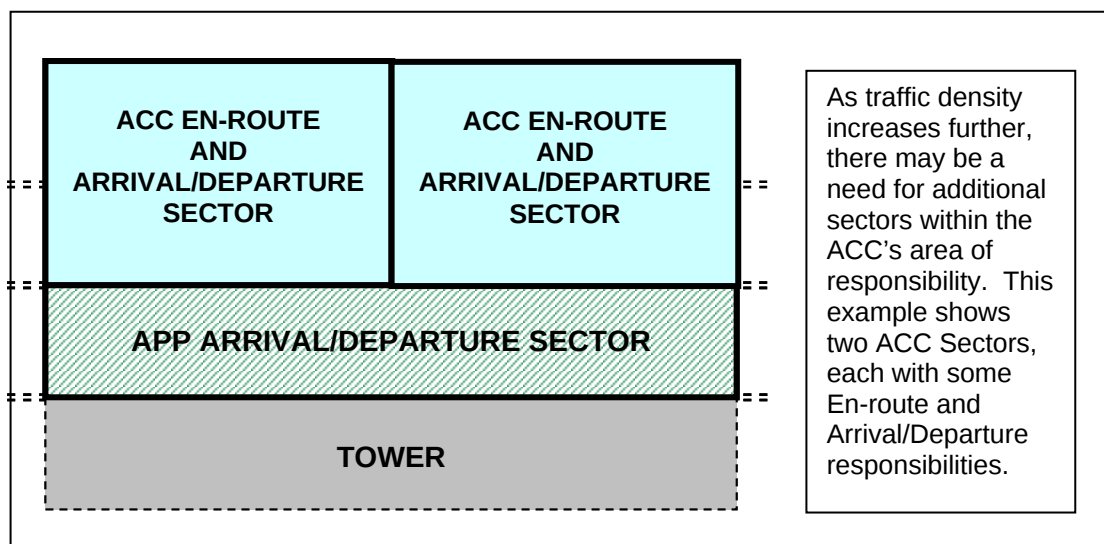
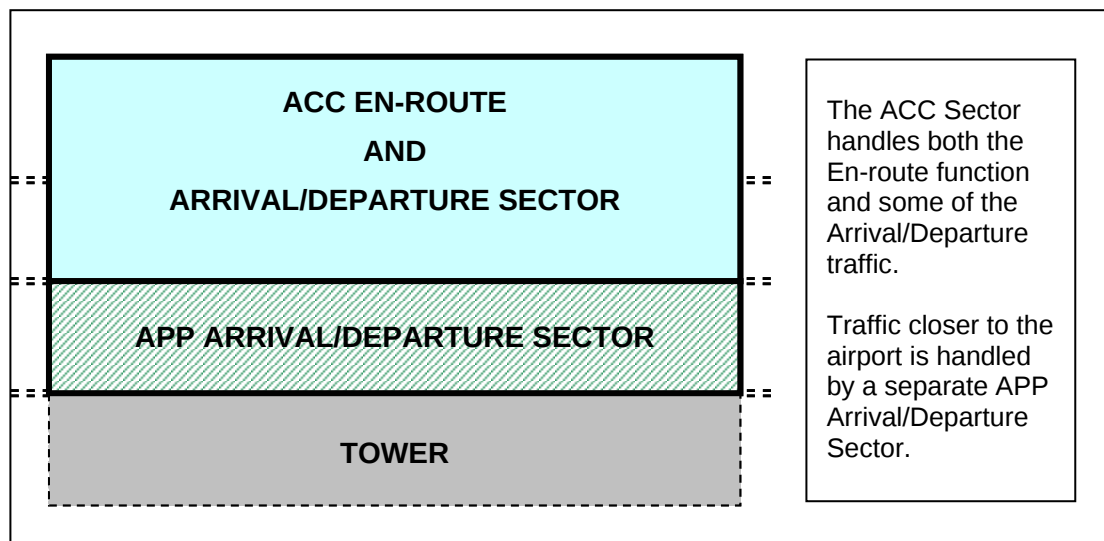
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Attachment C.6-1

Sample Sector Options & Evolution

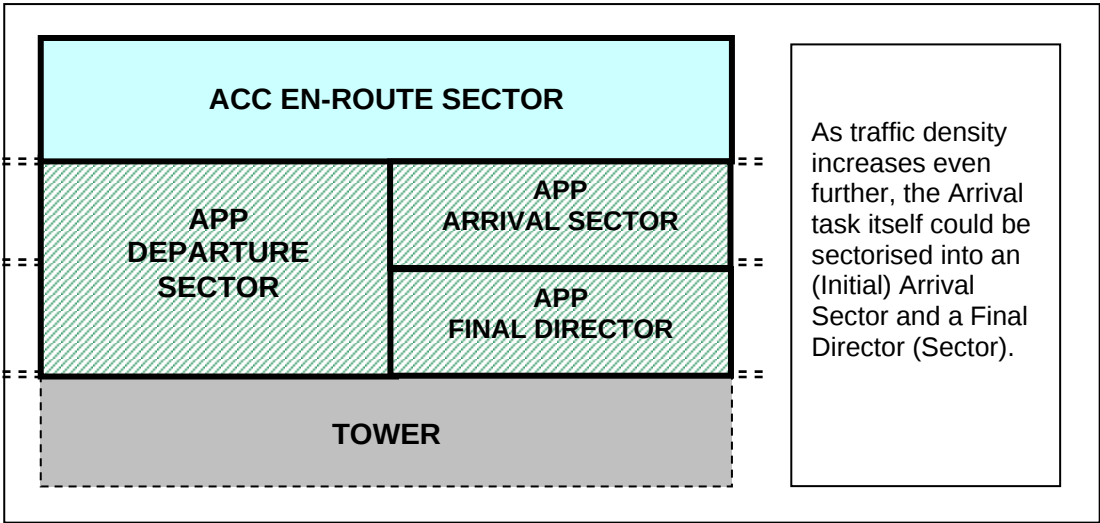
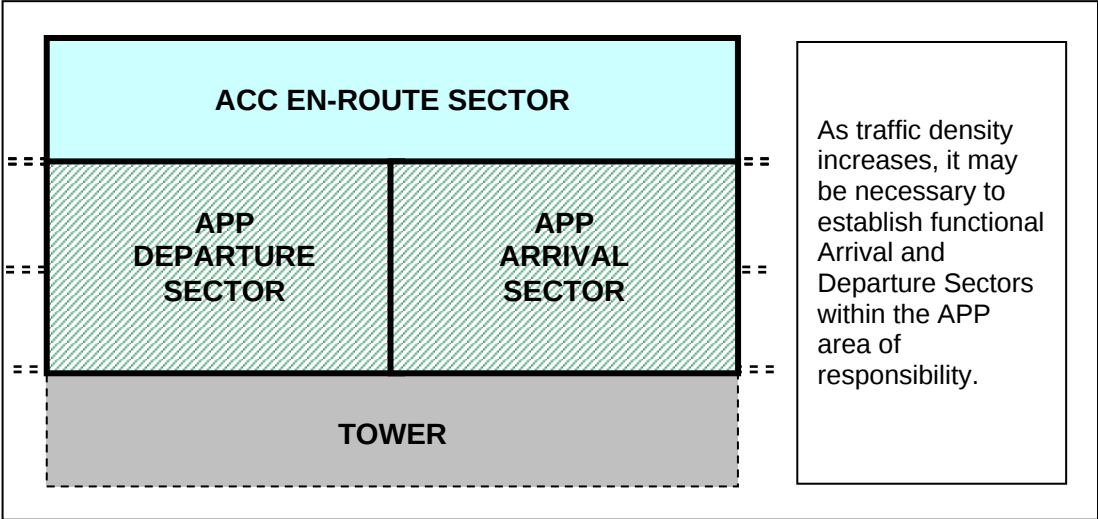
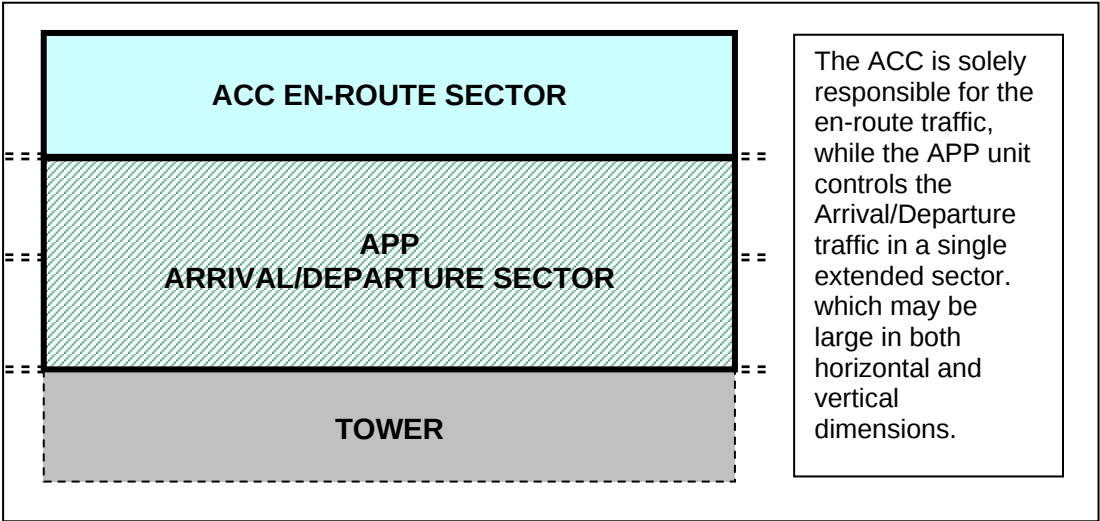
OPTION 1

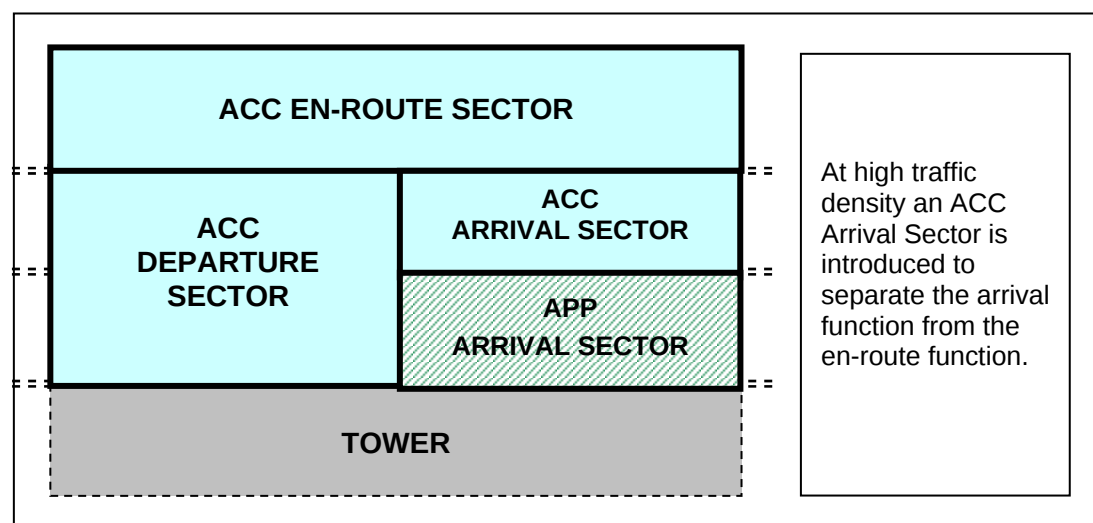
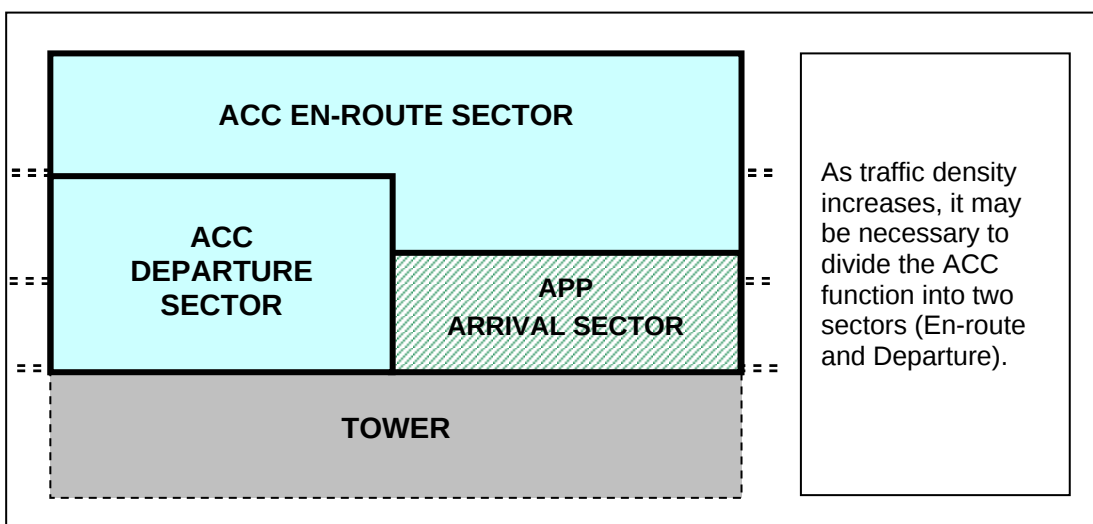
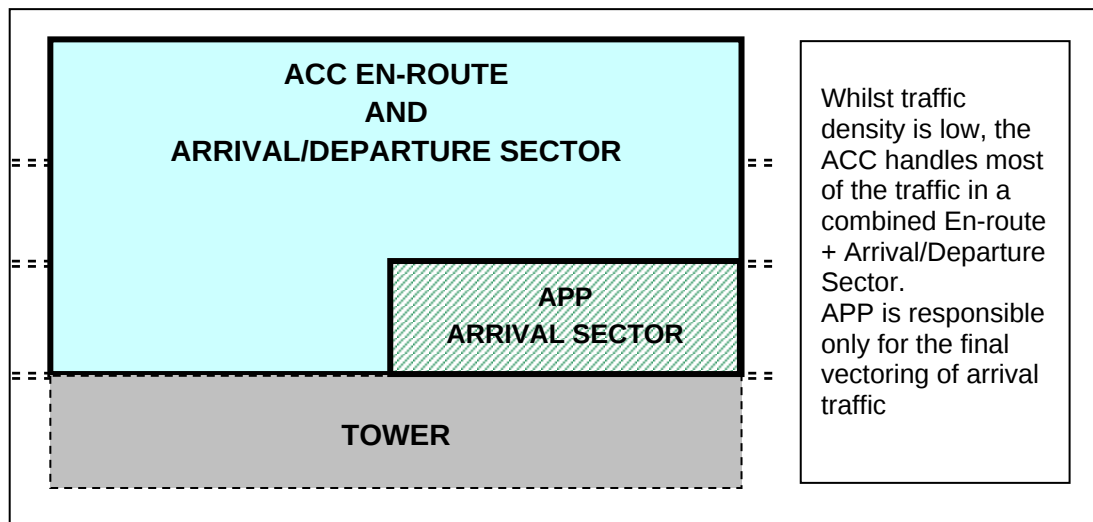


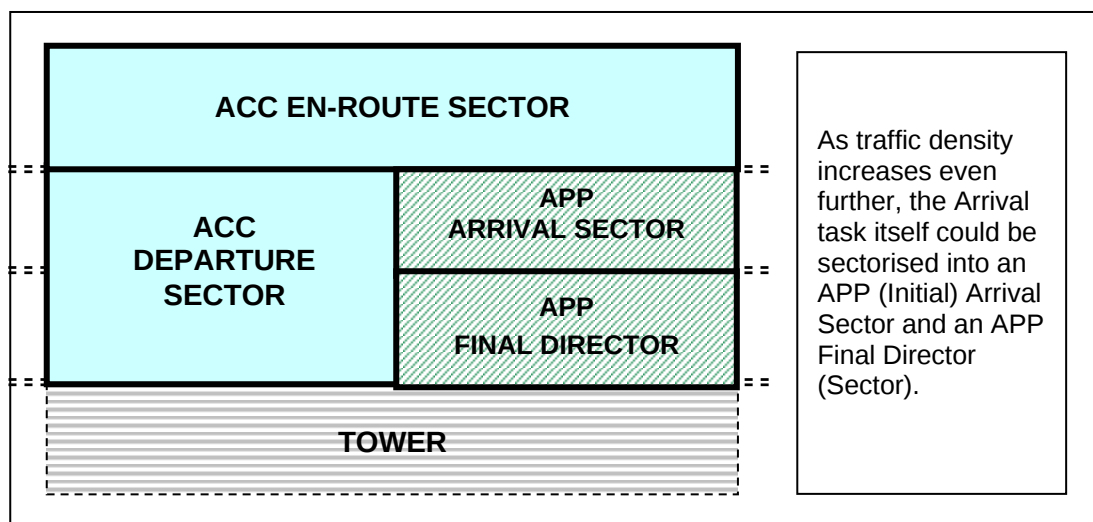
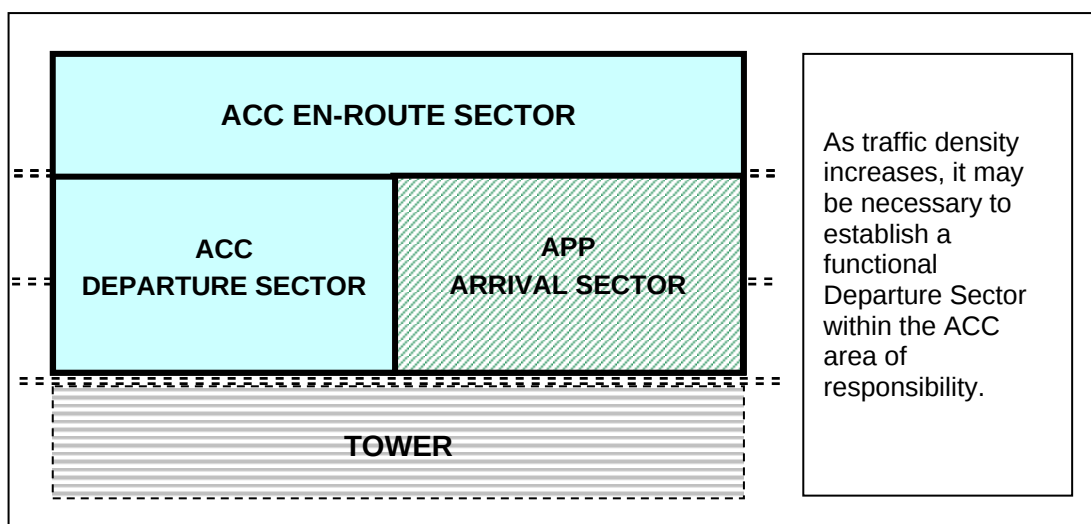
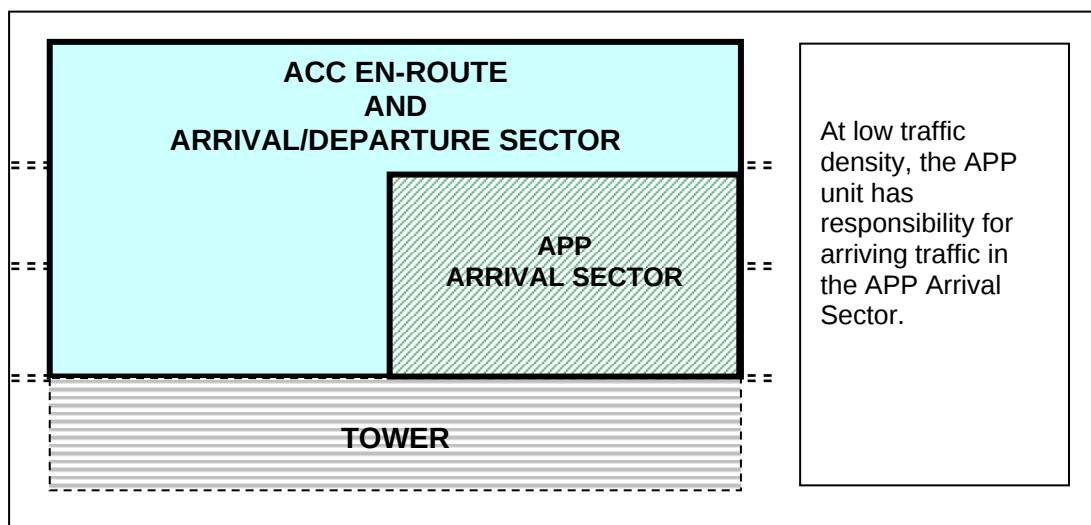
Terminal Airspace Design Guidelines - Part C**OPTION 2**

Terminal Airspace Design Guidelines - Part C

OPTION 3



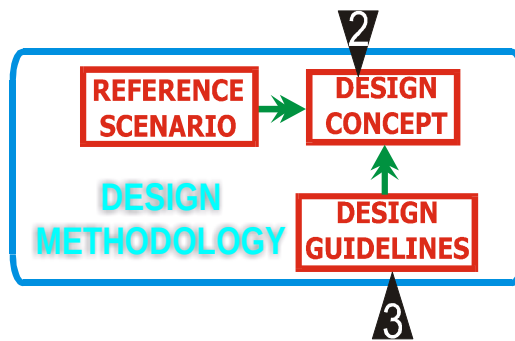
Terminal Airspace Design Guidelines - Part C**OPTION 4**

Terminal Airspace Design Guidelines - Part C**OPTION 5**

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CHAPTER 7

- CONCEPT EVOLUTION -



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7.1 INTRODUCTION

The Design Concept discussed in previous chapters has provided guidelines on the design of Routes, Holding areas, the Terminal Airspace Structure and ATC Sectorisation. Although it has not been explicitly stated in these chapters, most designers will recognise that the explanatory diagrams in Chapters 5 and 6 show airspace that is relatively 'uncomplicated' in that most of the Stages show only one airport within (one) Terminal Airspace. In design terms, this scenario – or that of one *major* airport and two 'minor' airports – is relatively straight forward.

In view of this, it is considered appropriate to focus upon more complex Terminal Airspace. As such, this Chapter primarily discusses the evolution of Terminal Airspaces into what may, for convenience, be described as a Terminal Airspace system i.e. a Terminal Airspace block which is operated as an integrated system when it is no longer feasible to treat as separate entities, several Terminal Airspaces which have grown into each other over time .

7.2 EVOLUTION OF TERMINAL AIRSPACE

The evolution from Terminal Airspace to Terminal Airspace system is almost exclusively a function of increased traffic demand and resultant complexity of air traffic operations. Simplistically, this evolution can be illustrated as follows (and of course, there are possible variations on this theme):

Starting with one 'major' airport that has grown to the extent where it can no longer be expanded (e.g. the maximum number of extra runway or terminal buildings have been added), the airport and its Terminal Airspace become unable to meet the increasing demand. At this point, a second (usually smaller) airport in the vicinity is expanded with its own Terminal Airspace. As traffic grows, and this second airport and its surrounding airspace reaches its limits, a third airport might be built or expanded. Thus over a period of decades, a 'major' Terminal Airspace and neighbouring smaller ones, evolve – each vying for more space with the traffic complexity increasing at each evolutionary step.

This evolutionary process is depicted in Figure 7- 1, Stages 1 to 5, each showing two fictitious airports and their Terminal Airspace. Terminal Airspace **X** surrounds the 'major' airport, and Terminal Airspace **Y** surrounds what is originally the lesser airport. A commentary on these Stages now follows, For simplicity, these Terminal Airspaces are only referred to as X and Y.

Stage 1: 1 Terminal Airspace (as per Stages in Chapters 5 and 6)

Stage 2: Shows that X has three entry points and four exit points, that the arrival and departure routes are fairly well segregated and that the Terminal Airspace is Sectorised. Y, on the other hand, is evidently less complex: it has one arrival point and one departure point. Of interest are the arrivals from the south for both X and Y. Evidently they share one ATS route prior to being split to enter X and Y respectively.

Stage 3: Both X and Y show signs of growth. As regards X, a parallel runway has been added to, a southern holding area has been introduced and X remains sectorised. For its part, Y has a new arrival route from the west, a new exit point and a new merging point in the south of the Terminal Airspace.

Stage 4: X and Y have both grown again. X has now introduced two-phase holding, an additional set of holds have been added inside the enlarged Terminal Airspace. The southern entry point for Y has now had a holding pattern added to it – to sequence traffic. Notably, Y's airport now has an additional runway – a sign of growth.

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Stage 5: This stage is a watershed – and a decision to move to this stage is likely to be outside the scope of the design team. In recognising that the traffic density and traffic complexity has increased to the extent that the ‘separate’ Terminal Airspaces of X and Y can no longer be managed as ‘separate’ entities, the two Terminal Airspaces have been integrated into a single Terminal Airspace system and this new ‘system’ block has been re-sectorised. Effectively, X and Y’s Terminal Airspaces have disappeared, as have their respective sectors which were a function of the airports serviced by each Terminal Airspace. In Stage 5, it has become possible to sectorise the whole Terminal Airspace system in the most efficient manner for the total airspace and to create dedicated Final Approach Director sectors for the airports at X and Y respectively. Furthermore, it has become possible to expand the single Terminal arrival points into three Entry Gates for the whole Terminal Airspace system, two to the north and one to the south. In this manner, arrival flows are contained inside the entry gates to facilitate the segregation of SIDs and STARs.

One of the most difficult routes to accommodate in this Scenario is the arrival route from the north-east to Y. One additional point worth noting is how the ATS route system has been developed to the South, where two parallel routes now service the South entry gate.

Note: In accordance with Principle 5, in Part A, Chapter 2, the boundaries of Terminal Airspace systems should not be constrained by State boundaries.

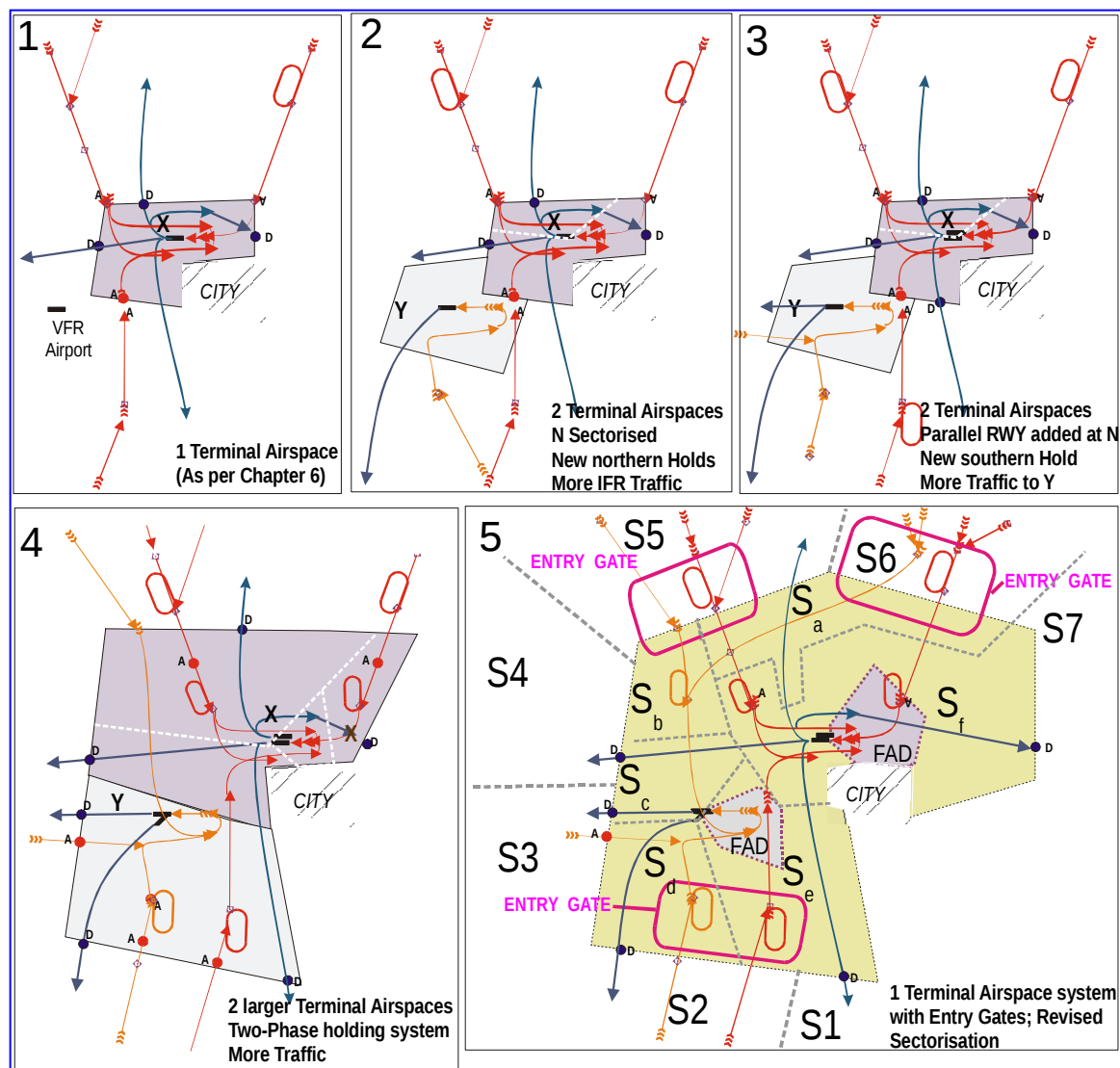


Figure 7- 1: Sample Evolution of Terminal Airspace system

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7.2.1 EVOLUTION OF THE APPROACH CONTROL FUNCTION

The evolution of the Terminal Airspace through various stages the vertical dimension also tends to follow a pattern when a Terminal Airspace system is created. This is illustrated in the next diagram which has used Terminal Airspace X (above) as an example for Stages 1-4.

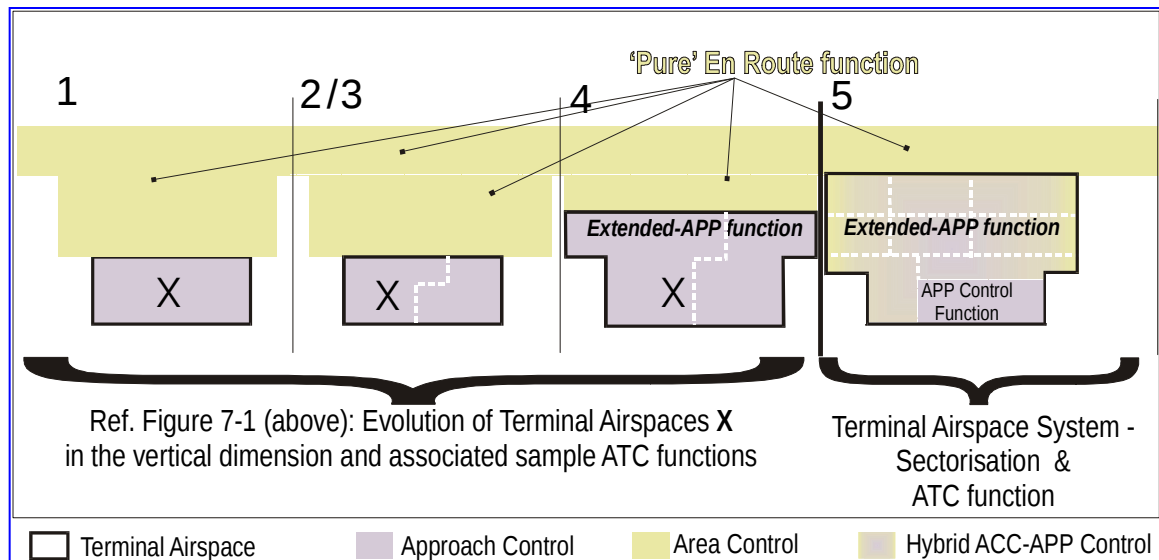


Figure 7- 2: Evolution Terminal Airspace dimensions and ATC 'functions'

Comments on Figure 7-2:

- ❑ ATC Sectorisation is frequently the first 'solution' when traffic levels increase significantly in a Terminal Airspace X; this is shown at Stage 2.
- ❑ In turn, Stage 3 does not reveal a change in dimensions but as shown in Figure 7-1, the holding system has been increased;
- ❑ At Stage 4, the Terminal Airspace has grown in size – both vertically and laterally to accommodate the increased traffic and traffic complexity.
- ❑ Significantly, from Stages 1 – 4, the Approach Control function is likely to be carried out by the ATC Unit responsible for X but this is not the case in Stage 5. In this stage, the importance of the Terminal Airspace structure is superseded by the emphasis on ATC sectorisation across the Terminal Airspace system (See Note 2). Here the extended approach function is raised and spread through the greater part of the Terminal Airspace system between an extensive network of sectors and the 'pure' Approach function 'limited' to a small Final Approach Director sector.
- ❑ In **Stage 5**, extended-approach functions in a Terminal Airspace system typically involve a hybrid of (Lower) Area Control and (Extended) Approach Function. These can be executed by controllers specially trained for these (hybrid) tasks or ACC or Approach Controllers.

Note 1: In context, 'extended approach function' refers to pre-sequencing, or first phase sequencing prior to sequencing for Final Approach.

Note 2: Whilst ICAO's division of airspace system makes no provision for a change in emphasis from airspace structure to ATC Sectorisation, Terminal Airspace systems in ECAC appear to share this characteristic.

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7.3 EVOLUTIONARY CHARACTERISTICS

The evolutionary 'patterns' described in para. 7.2, suggest that (especially large) Terminal Airspaces (Stages 1-4) and Terminal Airspace systems (Stage 5) are likely to share certain characteristics.

7.3.1 GENERAL CHARACTERISTICS

At a general level, shared characteristics (for Stages 1-5) include -

- ❑ areas of high population surrounding the airports serviced by the Terminal Airspace (and/or system). This population provides a substantial part of passenger market;
- ❑ increasing pressure from environmental groups;
- ❑ increasing requirements from diverse airspace users;
- ❑ increasing requirements for noise abatement procedures to be implemented which affect departure and arrival flight profiles and an increasing use of Continuous Descent Approaches (CDA) as a method of environmental mitigation;
- ❑ significant air traffic density and a complex system of Terminal Routes;
- ❑ extensive use of holding areas to sequence traffic;
- ❑ increasing airspace requirements and the resultant 'encroachment' of one Terminal Airspace structure on another.;
- ❑ complex sectorisation modules;

As regards Stages 4 and 5,

- ❑ airspace designers find it difficult to find sufficient space to place holding patterns; as such, one holding pattern (outside the Terminal Airspaces) may be required to serve two airports which limits the regular flow of traffic to the separate airports;
- ❑ increasingly, complex sectorisation of the Terminal Airspaces serve to constrain flight profiles which may undo environmental mitigation measures already in place;
- ❑ increasing use if made of metering tools to assist pre-sequencing of traffic into the various Terminal Airspaces;

As regards Terminal Airspace systems (**Stage 5**) in particular –

- ❑ ATC sectorisation is no longer airport-centred i.e. linked to a particular airport, but rather modular to the entire Terminal Airspace System; and
- ❑ The 'importance' attached to the Terminal Airspace *structure* is overtaken by ATC sectorisation of the Terminal Airspace system block.

7.3.2 SPECIFIC CHARACTERISTICS

At a more specific level, certain characteristics – and trends – can be catalogued in the evolutionary process and an overview of these is provided in tabular form below. Specifically, the Table focuses upon, Terminal Routes, the placement of Holding patterns and the Sectorisation type during the Terminal Airspace's evolution. Attention is drawn to the fact that this Table deals with examples of evolutionary trends.

Reading Table 7- 1

In this table, the **Stages 1-4** (top row) match the Stages in Figure 7- 1 & Figure 7- 2. The shaded cells represent Terminal Airspace **X**, (therefore Routes, holds, Sectors in Terminal Airspace **X**), and the white cells refer to the controlled airspace beyond Terminal Airspace **X**.

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Because **Stage 5** represents the Terminal Airspace system, there is no distinction between the (original) Terminal Airspace (X) and airspace beyond it; as such, only one cell (shaded yellow) is shown. Remarks relating to **Stage 5** in Table 7- 1 are stated separately to those related with Stages 1-4.

*Note: In Table 7- 1, under **Terminal Routes**, RV* means that extensive use is likely to be made by ATC of Radar Vectors for both arrivals (ARR) and departures (DEP); ARR RV means that extensive use is likely to be made by ATC of Radar Vectoring for arriving aircraft. RNAV IAP stands for Instrument Approach Procedure based on RNAV, excluding the Final and Missed Approach segment. ATS Routes (beyond X) refers to ATS routes forming part of EUR ARN (and mostly based on B-RNAV in ECAC). In turn, under **Sectorisation**; Geog. indicates geographic sectorisation; Fn indicates functional sectorisation, and G/F indicates a combination of these two methods.*

Stage		1	2	3	4	5
Traffic Density	X	Low	Medium	High	Very High	Very High
Traffic Complexity	X	Low	Medium	Medium	High	Very High
Terminal Routes	X	RV*	RV*	SID/STARs + Rv	SIDs/ARR RV	SIDs/STARs, RNAV IAPs & RV
		ATS Routes	ATS Routes	ATS Routes	STARs/DEP ATS Routes	
'Prevailing' Route System(s)		EUR ARN	EUR ARN	EUR ARN	Terminal	Terminal
Hold Placement	X	No	No	No	Yes	Yes
		Yes	Yes	Yes	Yes	
Terminal Airspace Structure	X	Lower limit stepped	Lower limit stepped	Lower limit stepped	Lower limit flattens out	Lower limit tends to be flat (see Figure 7-3)
Sectors	X	No	Geog.	Geog.	Fn+FAD	Functional and Geographic
		Geog.	Geog.	Geog.	Geog.	

Table 7- 1: Example of Characteristics of an Evolving Terminal Airspace

Commentary on Table 7- 1:

- ❑ **Terminal Routes:** The less 'busy' Terminal Airspace (Stages 1 or 2), the greater the use made of Radar Vectors inside the Terminal Airspace.
 - Generally, as ATM complexity increases (this is a function of traffic density and other factors such as ATC System, Communication and Navigation Equipment available etc.- see Chapter 4, Attachments C.4-1 and C.4-2) the Terminal Route system tends to become more rigid and therefore **less flexible**;
 - Significantly, STARs associated with **Stage 5** in existing ECAC Terminal Airspace systems tend to commence in the EUR ARN and terminate inside the Terminal Airspace system at a holding stack (see Part C, Chapter 5).
- ❑ **'Prevailing' Route System:** Generally, the less busy a Terminal Airspace, the more likely the prevalence of the EUR ARN. This means that the Terminal Route connections to the EUR ATS Routes are required to 'fit in' with the requirements of EUR ARN.

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- As the Terminal Airspace becomes busier, this prevalence tends to shift from EUR ARN to the Terminal Routes which means that the EUR ATS Routes in the vicinity of the Terminal Airspace (system) are required to fit in with the prevalence of the Terminal Routes. This shift is already in evidence in Stage 4 – and considerable operational difficulties may arise if this switch in prevalence does not occur.
- ❑ **Hold Placement:** Given the smaller size of the Terminal Airspace in 1 to 3, it is not surprising that most holding (for sequencing purposes) is likely to occur outside the Terminal Airspace. As more airspace becomes available - in 3 and 4 – and more holding is required, holding areas may also be added inside the Terminal Airspace. One of the problems which remains, however, is that there is often insufficient space to create the necessary amount of holds (as mentioned at para. 7.3.1).
- Given the larger airspace which tends to be provided by the creation of a Terminal Airspace system, the holds tend to be placed inside the Terminal Airspace system in **Stage 5**.
- ❑ **Sectors:** The busier an airspace becomes, the more complex the mixture of Geographic and Functional Sectorisation. (see explanations in Chapter 6). This may be explained by the fact that high-density Terminal Airspaces tend to have less prominent Arrival and Departure peaks
- It is not possible to state which sectorisation type is preferred in **Stage 5**. Usually, the traffic density and airspace complexity is such that sectorisation is decided on the basis of what is safe, efficient and workable from an ATC perspective.
- ❑ **Metering Tools:** Several types of metering tools are already in use in Europe's major Terminal Airspaces and these tend to facilitate pre-sequencing into the Terminal Airspace to avoid a 'traffic bunching' in an airspace which is naturally constrained in size. Although these metering tools can be tailored to meet the needs of individual airspaces, 4D traffic managers are being developed to improve the sequencing assistance within Terminal Airspace.

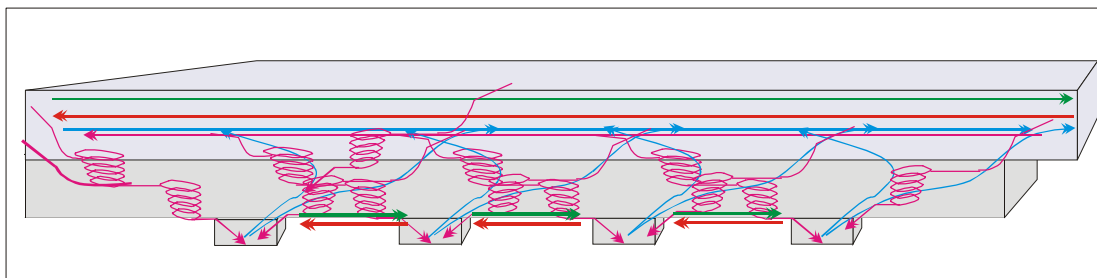


Figure 7- 3: Flattened lower limit of Terminal Airspace 'system' (Example)

7.4 FROM HIGH DENSITY TERMINAL AIRSPACE TO TERMINAL AIRSPACE SYSTEM

Whilst many large Terminal Airspaces co-exist in ECAC, it is seldom that the design and planning of these large Terminal Airspaces are treated as a seamless Terminal Airspace system. This is undoubtedly because the switch from Stage 4 to Stage 5 is not as natural a step as those which evolve from Stages 1-4. Though the operational requirements may signal the need to develop a Terminal Airspace system, these requirements need to be supported by high-level policy decisions given the implications of creating such a system. Examples of such implications may include human resource management, considerable investment in new ATC system architecture, increased requirements for environmental mitigation as public awareness grows of the level of traffic density and complexity.

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7.4.1 OPERATIONAL DRIVERS¹

Given Europe's geography, it is not surprising to find a significant number of large airports and their associated Terminal Airspace in close proximity. But geography in itself is not enough to trigger the need for the development of a Terminal Airspace system. The factors are usually cumulative – the compounding of factors and the accommodation of modern-day realities. These (European) factors include: -

- ❑ Co-ordination difficulties between sectors/centres;
- ❑ Requirement to mitigate environmental impact;
- ❑ Capacity shortfalls;
- ❑ Safety 'alert' e.g. frequent airspace violations; aircraft unable to comply with climb profile published in SID;

7.4.2 CORE AREA

Considering the operational drivers above, it is unsurprising that the next 'upward' step in the complexity ladder – beyond the Terminal Airspace System – is that of a cluster of Terminal Airspace systems and /or other high- or medium Terminal Airspaces. This configuration already exists in Europe in what is generally described as the 'Core Area'. Covering the general area of south-east England, the northern half of France, the south-western part of Germany, Switzerland, the Netherlands and Belgium, this Core Area is often colloquially described as a huge Terminal area below (approximately FL285). In the future, it is not impossible to imagine the development of a Core Area System, along the lines of a Terminal Airspace system.

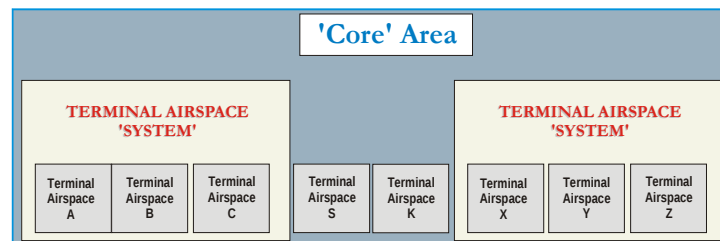


Figure 7- 4: Terminal Airspace 'system' and 'Core' Area

7.4.3 OPERATIONAL REQUIREMENTS

In order to keep *ahead* of the evolution of a Terminal Airspace to a Terminal Airspace system (or beyond), designers should periodically assess their operational requirements and work on their realisation. Given the dependence on aircraft equipage as regards some of these requirements, it may be necessary to define these requirements some 10 to 15 years in advance of the anticipate implementation time-frame. (Readers are referred to Part B, *Planning*, concerning the discussion on *Requirements/Objectives* in C.

7.5 SUMMARY

This chapter has described the evolution of Terminal Airspaces from a simple (single) Terminal Airspace to a complex Terminal Airspace system. It has stressed that whilst the evolution from Stages 1-4 usually occur as a consequence of operational requirements, the move to a Terminal Airspace system requires policy decisions because of the significant implications of this step.

¹ See Also Part B, Chapters 1 & 2

CHAPTER 8

- DESIGN METHODOLOGY: QUICK REFERENCE LISTS -

This Chapter is comprised of one diagram which brings together the elements of the Design Methodology.

It also contains six Attachments; each of which is a quick reference list for various parts of the Design Methodology.

ATTACHMENTS

- C.8-0: High Level Project Checklist
- C.8-1: Checklist – Writing the Reference Scenario
- C.8-2: Checklist – Critical Review of Reference Scenario
- C.8-3: Checklist – Performance Criteria
- C.8-4: Checklist – Assumptions, Constraints & Enablers
- C.8-5: Checklist – Design Concept Routes and Holds
- C.8-6: Checklist – Design Concept Structures and Sectors

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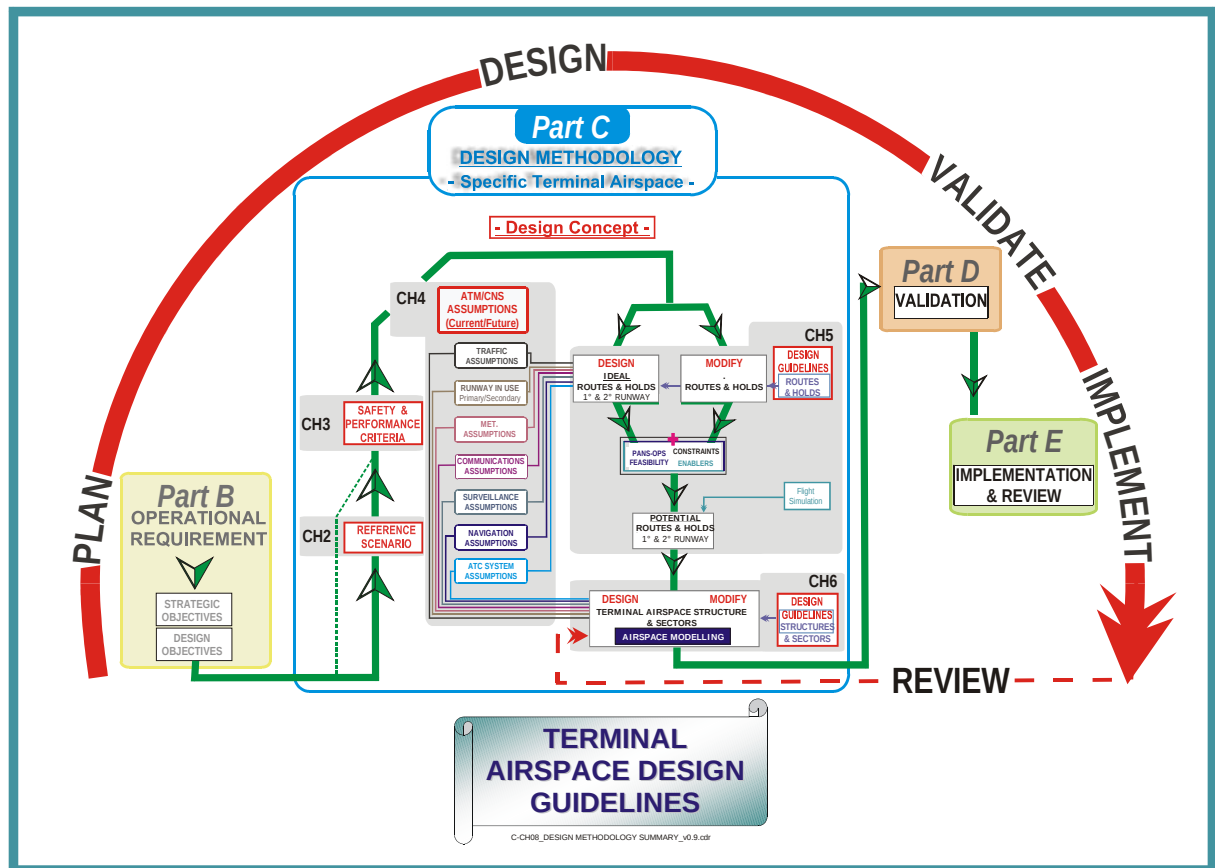


Figure 8- 1: Design Methodology

Terminal Airspace Design Guidelines - Part C**Attachment C.8-0****Sample High-Level Project Checklist for Terminal Airspace Projects**

Note: For completeness, this form has been replicated from Part B because it forms the broad basis for the work schedule undertaken by the Terminal Airspace Design team.

Note: This form is intended as a high-level quick reference list for Specific Terminal Airspace Projects. Its aim is to ensure that project objectives and scope are appropriately identified and the airspace improvements undertaken in accordance with the appropriate **Airspace Design Guidelines**.

TERMINAL AIRSPACE DESIGN PROJECT (ref. Part B)			
PROJECT NAME:	START: [date]	TARGET ↓IMPLEMENTATION↓ [DATE]	
ESTIMATED EFFORT (TOTAL)	END: [DATE]		
BACKGROUND & CONTEXT:			
INTERNAL DESIGN TEAM MEMBERS:	[NAME]	[NAME]	[NAME]
	[NAME]	[NAME]	[NAME]
EXTERNAL TEAM, MEMBERS:	[NAME]	[NAME]	[NAME]
INTERNAL REPORTS TO:	[NAME]	[NAME]	[NAME]

STRATEGIC CONSIDERATIONS

1. OBJECTIVES:

DESIGN CONSIDERATIONS

1. OBJECTIVES:

2. SCOPE:

3. DEPENDENCIES:

4. RISKS: performance indicators

5. PERFORMANCE INDICATORS:

Safety:

Capacity:

Environmental:

Terminal Airspace Design Guidelines - Part C**A. WORKING ARRANGEMENTS**

- Members of Terminal Airspace Design Team
- Leader of Terminal Airspace Design Team, (if applicable)
- Operation Manager, (if applicable)
- Project Steering Group, (if applicable)
- Additional team members (recruit, latest, after Tasks are identified (see below))

Number of days required to set up working arrangements	
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B. POLICY AND REGULATORY MATERIAL

- Safety Policy
- Environmental Policy.
- Safety Assessment requirements and guidelines
- Environmental guidelines
- Approved Airspace Design Methodology
- Approved Validation methods (that may be used to validate design)
- Relevant International material e.g. ICAO SARPs, PANS etc.

Number of working days required to identify relevant Policy and Regulatory material	
--	--

C. PROJECT DEPENDENCIES

- Availability of
 - ATC Training Facilities
 - Simulation facilities (once validation method selected)
 - Specialists to undertake specialist/technical studies e.g. Environmental Impact studies.
- Tentatively reserve facilities for ATC Training, Simulation;
- Prepare draft calls for tender w.r.t anticipated technical/specialist studies
- Content and Schedule of other airspace/airport projects
- PANS-OPS specialist (availability)
- Tentatively reserve services of PANS-OPS Specialist.
- AIRAC cycle dates(affects implementation)

Number of working days required to identify project dependencies and complete (tentative) preparatory work	
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Terminal Airspace Design Guidelines - Part C**D. PROJECT TASKS & RELATED /ACITIVITES**

1. Propose design objectives
2. Feasibility Assessment (including Cost Benefit Analysis and Preliminary Safety Assessment)
3. Finalise Design Objectives and Scope
 - a) Decide implementation date as a function of Tasks to be completed; or
 - b) Tailor Scope/Objective to fit into available time.
4. Firm up Calls for tender w.r.t specialist/technical studies
5. Confirm reservation for ATC training facilities and Simulation
6. Cost Benefit analysis and Preliminary Safety Assessment
7. Statement and Critical Review of Reference Scenario
8. Selection of Performance and Safety Criteria
9. Identification of Assumptions, Constraints and Enablers
10. Development of Terminal Airspace design concept, including
 - a) Routes and Holds
 - b) Structures and Sectors
 - c) Qualitative assessment of concept
 - d) Impact assessment of proposed concept (e.g. Environmental impact study)
11. Select Scenario(s) to be Validated
12. Validation of proposed Scenarios and Safety Assessment
 - a) Prepare simulation
 - b) Run simulation
 - c) Data analysis
 - d) Write up final report of findings
13. Complete safety assessment documentation as per Safety Policy
14. Finalise outstanding reports
15. Obtain approval for implementation
16. Prepare for implementation
 - a) PANS-OPS Specialist to design SIDs/STARs as per PANS-OPS Criteria
 - b) AIP and other relevant Publications (NB AIRAC cycle dates)
 - c) ATC Training
 - d) Amend Letters of Agreement (if required)
 - e) Amend local/national ATC Procedures, (if required)
 - f) Amend local/national regulations, (if required)

Number of working days required for each identified Task/Activity

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E. TASK ALLOCATION			
Task No:	Responsible Person/s	Due date (Draft Report)	Due Date (Final Report)
1			
2			

ESTIMATED TOTAL NUMBER OF DAYS (A+B+C+D+E)	
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Terminal Airspace Design Guidelines - Part C**Attachment C.8-1****Checklist – Writing the Reference Scenario**

WRITING THE REFERENCE SCENARIO (ref. Part C 2.2, 2.3)	
1. Runways	
	Which runways are in use?
2. Traffic Types and Distribution	
	- What is the quantity of the traffic in terms of Arrival, Departure and Transit Traffic in combination with different traffic types? - What are the Traffic Mix in categories (H/M/L) and Navigation Capabilities (Conventional / NAV)?
3. Terminal Airspace	
	- What are the lateral dimensions of the Terminal Airspace? - What are the Airspace Classifications in, <u>and</u> if deemed of interest, outside the Terminal Airspace? - What is the Transition Altitude in the Terminal Airspace? - Are there Airspace Reservations (military/VFR corridors/ recreational flying)? - Are there Airspace Restrictions that have an impact on the Terminal Airspace? - Are there Holding Areas and is there a Minimum Safe Altitude? - Are there Approach procedures published and to what extent are they used? - Are there Departure and Arrival procedures published? - Are there Radar Vectoring Patterns & MRVA defined and/or published?
4. Traffic Management	
	- How is the airspace surrounding the TMA organised? Are there adjacent ACC Sectors, ACC Sectors above and/or adjacent Terminal Airspace(s) and what is their relation with the TMA? - How is the Arrival Traffic managed? - How is the Departure Traffic managed? - How is the Transit Traffic managed? - If applicable, how are Military, VRF and Recreational Traffic managed?
5. Technical Support Infrastructure	

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	• What are the System Capabilities and Availability for: Radar Data Processing, Flight Data Processing and HMI? • What are the System Capabilities and Availability for Voice Communication Systems i.e. Radio and Phone? • What are the System Capabilities and Availability for Navigation and Landing Aids?
6. Weather and Terrain	
	• What does the terrain in, <u>and</u> surrounding the TMA Look like? • What are the Weather patterns / thunderstorm activities? • What is the impact of low pressure on FL availability in Terminal airspace (Transition level)?
7. Environmental Constraints	
	• Are there Environmental Constraints in terms of Noise restrictions (time/location/level)?

Outstanding Actions/Issues

Action	Due date	Responsible

Reports

REPORT TYPE	DUE DATE	RESPONSIBLE	CONSULTATION PERIOD
DRAFT REPORT			
REVIEW			
FINAL REPORT			

Terminal Airspace Design Guidelines - Part C**Attachment C.8-2****Checklist - Critical Review of Reference Scenario**

Note 1: The statement of the (Pseudo) Reference Scenario (at A, above) forms the basis of the Critical Review.

Note 2: The first two questions as regards every item of the Reference Scenario could be:

- ☐ Does this {element} work well?
- ☐ What doesn't work (about this particular {element})?

Note 3: **Project design objectives** as well as the **Design Guidelines** for Routes, Holds, structures and Sectors can be used as the benchmark for the Critical Review i.e. to decide whether a particular item is un/satisfactory. To this end, some (additional) sample questions are provided.

CRITICAL REVIEW OF THE REFERENCE SCENARIO (ref. Part C 2.4)**1. Runways**

Which runways are in use?

- What are the Primary and Secondary Runways in Use in main & adjacent TA?
- Is the mode of operation of the existing runways likely to change prior to the implementation of the existing project?
- Are additional runways likely to be in use prior to the implementation of the existing project? If so, in what mode?
- When was the mode of use for the runways implemented?
- Have other modes of use been considered – and discounted? If so, why?

2. Traffic Types and Distribution

What is the quantity of the traffic in terms of Arrival, Departure and Transit Traffic in combination with different traffic types?

- What is the geographic distribution of the traffic (in %)?
- What is the time distribution of the traffic (seasonal/daily)?
- What is the ratio between Arriving and Departing Traffic during peak hours?
- What is the ratio between IFR/VFR, Military/Civil?
- Do recreational-type-flying activities take place in the Terminal Airspace?
- For items (1) to (5) on left, does the future traffic sample deliver the same results as the existing traffic sample used?

What are the Traffic Mix in categories (H/M/L) and Navigation Capabilities (Conventional / NAV)?

- Does the future traffic sample deliver the same results as the existing traffic sample used?

3. Terminal Airspace

What are the lateral dimensions of the Terminal Airspace?

- Are all IFR Flight paths contained inside controlled airspace?

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	What are the Airspace Classifications in, <u>and</u> if deemed of interest, outside the Terminal Airspace?
	- Does the airspace classification meet current operational requirements? - Is there a high incidence of unauthorised penetrations of the Terminal Airspace? If so, why?
	What is the Transition Altitude in the Terminal Airspace?
	Is the Transition Altitude too low or too high?
	Are there Airspace Reservations (military/VFR corridors/ recreational flying)?
	Are all of these Reserved Airspaces used? If so, Frequently?
	Are there Airspace Restrictions that have an impact on the Terminal Airspace?
	Is each of these Airspace Restrictions still valid?
	Are there Holding Areas and is there a Minimum Safe Altitude?
	- What are the minimum holding levels of each hold? - What are the maximum holding levels of each hold? - Are the holding areas located where they are most needed? - What factors have determined these minimum and maximum holding levels? Are these reasons still valid? - Would the holding patterns be better placed inside (or outside) the Terminal Airspace?
	Are there Approach procedures published and to what extent are they used?
	- To what extent are Approach Procedures used? - Why are some Approach Procedures not used?
	Are there Departure and Arrival procedures published?
	- Do all SIDs have a common initial published level restriction? - Does the initial published level restriction coincide with the transition altitude? - Why are some SIDs/STARs not used? - Do SIDs/STARs cover all requirements e.g. sufficiently service major traffic flows? - Ref. 1, are difficulties created by different initial level restrictions? - If the answer to 2 is 'Yes', is there a high incidence of level busts?
	Are there Radar Vectoring Patterns & MRVA? Defined and/or published?
	- Is the MRVA chart complex? - Can the MRVA be depicted on the Radar Display? - Does the MRVA chart need updating? - Can it be simplified?
4. Traffic Management	
	How is the airspace surrounding the TMA organised? Are there adjacent ACC Sectors, ACC Sectors above and/or adjacent Terminal Airspace(s) and what is their relation with the TMA?

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	• <i>Are the crossing points of routes too close to any of the sector boundaries?</i> • <i>Does traffic transit unnecessarily through too many sectors?</i>
	How is the Arrival Traffic managed?
	• <i>To what extent are existing STARs/Holds used?</i> • <i>To what extent are existing CDAs used?</i> • <i>Are transfer of control arrangements between adjacent sectors and the Terminal Airspace generally similar? (I.e. does transfer generally occur at a level, or at a point?)</i> • <i>Where transfer of control arrangements are affected with an adjacent State, is this covered by an Inter-centre Letter of Agreement?</i> • <i>Are there incidences of Level busts?</i> • <i>To what extent to Low Visibility procedures impact upon the runway acceptance rate?</i> • <i>Why are some STARs or CDAs not used?</i> • <i>Can transfer of control arrangements be standardised?</i>
	How is the Departure Traffic managed?
	• <i>To what extent are SIDs used?</i> • <i>Are there many 'special' SIDs e.g. for use by low performance aircraft or for use in particular circumstances?</i> • <i>Are transfer of control arrangements between Terminal Airspace and adjacent sectors generally similar? (I.e. does transfer generally occur at a level, or at a point?)</i> • <i>Where transfer of control arrangements are affected with an adjacent State, is this covered by an Inter-centre Letter of Agreement?</i> • <i>Are there incidences of Level busts?</i> • <i>Why are some SIDs not used?</i> • <i>Can transfer of control arrangements be standardised?</i>
	How is the Transit Traffic managed?
	• <i>Do transit flights in the TMA operate on published ATS routes?</i> • <i>Where transfer of control arrangements are affected with an adjacent State, is this covered by an Inter-centre Letter of Agreement?</i> • <i>Why are some published ATS routes in the TMA not used?</i>
	If applicable, how are Military, VRF and Recreational Traffic managed?
	• <i>Are parts of the Terminal Airspace 'switched on' (and off) to accommodate the requirements of different users?</i> • <i>Are there frequent unauthorised airspace penetrations of the Terminal Airspace? Transfer procedures and LoAs?</i> • <i>Does the airspace classification outside the Terminal Airspace affect the incidence of unauthorised airspace penetrations?</i>
5. Technical Support Infrastructure	
	What are the System Capabilities and Availability for: Radar Data Processing, Flight Data Processing and HMI?

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	• <i>What is the Availability and coverage of the Radar system?</i> • <i>What is the Availability of the Flight Data Processing system?</i> • <i>What is the Availability of the HMI?</i> • <i>Are outages frequent? Is this due to maintenance or technical difficulties?</i> • <i>Does the system provide consistent and easy manageable environmental data?</i> • <i>Does the system provide timely and accurate flight plan distribution?</i> • <i>Does the system provide for tools for sectorisation management?</i> • <i>Does the system provide for automatic co-ordination?</i> • <i>Does the system provide for Code/ Call-sign correlation?</i> • <i>Do maintenance slots affect traffic management?</i> • <i>Is there a need to change the maintenance slots?</i> • <i>Does the system have a fallback capability?</i>
	What are the System Capabilities and Availability for Voice Communication Systems i.e. Radio and Phone?
	• <i>What are the Radio Facilities and what is the coverage?</i> • <i>Are downtimes frequent? Is this due to maintenance or technical difficulties?</i>
	What are the System Capabilities and Availability for Navigation and Landing Aids?
	• <i>What are the Availability of navigation and landing aids and coverage e.g. VOR/DME/ILS Categories?</i> • <i>Are downtimes frequent? Is this due to maintenance or technical difficulties?</i>
6. Weather and Terrain	
	What does the terrain in <u>and</u> surrounding the TMA Look like?
	• <i>Is the obstacle catalogue up to date?</i>
	What are the Weather patterns / thunderstorm activities?
	• <i>Are the weather trends described?</i>
	What is the impact of low pressure on FL availability in Terminal airspace (Transition level)?
	• <i>Does low pressure occur more frequently than in the past?</i> • <i>Is this a trend?</i>
7. Environmental Constraints	
	Are there Environmental Constraints in terms of Noise restrictions (time/location/level)?
	• <i>Are there noise curfews?</i> • <i>Are there noise sensitive areas that require conditions for over-flight?</i> • <i>Are there limitations on holding areas and lowest available holding level due to environmental requirements such as visual intrusion?</i> • <i>Are the noise curfews still valid?</i>
8. Specific Questions relating to published regulatory material	

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	• ICAO SARPs: Has ICAO been notified of non-compliance with SARPs where required by the Convention? • AIS: Have any inconsistencies/errors been found in AIP/Supplements to AIP e.g. outdated material or wrong co-ordinates. If so, list. • LoAs: • Have any errors been detected in LoAs, if so list these. • Do all parties to LoAs have the same version of the LoA? If not, note this. • Local ATC Instructions: Have any inconsistencies/errors been detected in these instructions? If so, list.
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Outstanding Actions/Issues

Action	Due date	Responsible

Reports

REPORT TYPE	DUE DATE	RESPONSIBLE	CONSULTATION PERIOD
DRAFT REPORT			
REVIEW			
FINAL REPORT			

Terminal Airspace Design Guidelines - Part C

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Terminal Airspace Design Guidelines - Part C*Attachment C.8-3***Checklist – Performance Criteria**

Checklist: PERFORMANCE CRITERIA (ref. Part , Ch.3)	
ASSESSMENT AND MEASUREMENT (ref. Part C 3.2)	
	- Is the chosen Assessment methodology (qualitative vs. quantitative) the correct methodology for the required measurement? - Do the people that are assigned to the assessment have the suitable background and support tools to do the assessment? - Is the assessment done by people from the project team or by external parties? - Is the assessment done repetitive during the design process?
SAFETY CRITERIA (ref. Part C 3.3)	
	- What has been the motivation to decide on either relative or absolute measurement of safety? - What is the chosen frequency approach on safety assessment (phased vs. once-only) and why was this approach chosen? - What is the chosen support to substantiate the safety assessment; simulations (fast- real-time), analysis and/or expert judgement? - What is the “benchmark” used in the determination of safety criteria?
PERFORMANCE CRITERIA (ref. Part C 3.4, 3.5)	
	- Are the design objectives met? - Depending on the objectives were quality and or quantity measured in order to determine if the objectives are met? - Are there measurement tools used, that would normally be outside the scope of the design project, to measure if the objectives are met (e.g. noise modelling tools)?

Outstanding Actions/Issues

Action	Due date	Responsible

Reports

REPORT TYPE	DUE DATE	RESPONSIBLE	CONSULTATION PERIOD
DRAFT REPORT			
REVIEW			
FINAL REPORT			

Terminal Airspace Design Guidelines - Part C

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Terminal Airspace Design Guidelines - Part C*Attachment C.8-4***Checklist – Assumptions, Enablers, Constraints****Checklist ASSUMPTIONS, CONSTRAINTS & ENABLERS**

(ref. Part C , Ch.4)

1. What are ASSUMPTIONS, CONSTRAINTS & ENABLERS (ref. Part C 4.2)

- Are all the assumptions established after verification with experts on the subject of the assumptions?
- Are there assumptions that are based on factors beyond ATM/CNS e.g. weather phenomena?
- Is there a sufficient level of confidence in the project team that the assumptions were established cautiously?
- Is the traffic sample chosen as the baseline for the design considered as representative?
- Are all the enablers that are identified as outside the design scope, adapted by the ANSP and defined as functional requirements?
- If the functional requirements derived from design enablers are defined as functional requirements, is action taken to fulfil these requirements (thereby creating the enabler).
- Does the planning/project of a functional requirement meet the design project planning (if not, the constraint that is to be mitigated by the requirement/enabler becomes a negative constraint)?
- Are all possible ways to mitigate constraints investigated?
- Are all the Assumptions Constraints & Enablers derived from the reference scenario?

2. Selecting ASSUMPTIONS, CONSTRAINTS & ENABLERS (ref. Part C 4.3)

- Are all the assumptions established after verification of publications in state originated documents such as the Aeronautical Information Publication (AIP)?
- Are the Assumptions, Constraints & Enablers linked to a certain date (where appropriate)?
- When choosing a representative traffic sample, was the traffic distribution over time taken into consideration?
- When choosing a representative traffic sample, was the geographic traffic distribution taken into consideration?
- Is the option considered to create two (or more) sets of Terminal Routes to accommodate significant changes in traffic density or distribution?
- Is it considered as necessary to sort the geographic traffic distribution by origin and destination so as to identify the raw demand (this is only necessary when doubt exists that the current En-Route ATS route network is not sufficiently refined)? (note: see next bullet)
- Has there been a “raw-demand” investigation done by En-Route airspace designers within the greater EUR ARN in the course of a project that is connected to the TMA design project? If so, the previous bullet has become obsolete.
- Has there been an assessment of the relative certainty of “triggering event” that may influence Forecast Traffic Samples?

3. When to identify ASSUMPTIONS, CONSTRAINTS & ENABLERS (ref. Part C 4.4)

- Where the Assumptions, Constraints & Enablers identified, reviewed and verified at the different stages of the design process as suggested in the guidelines?

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Outstanding Actions/Issues

Action	Due date	Responsible

Reports

REPORT TYPE	DUE DATE	RESPONSIBLE	CONSULTATION PERIOD
DRAFT REPORT			
REVIEW			
FINAL REPORT			

Terminal Airspace Design Guidelines - Part C**Attachment C.8-5****Checklist – Design Concept Routes and Holds**

Checklist ROUTES & HOLDS (ref. Part C, Ch.5)	
1. General	
	- Is there a general consensus on the “geographic” location of a STAR in the flight profile i.e. what is the general approach on where STARS begin and end in relation to the Terminal Airspace? - Are the STARS in the design to be considered Open or Closed?
2. Terminal Routes (ref. Part C 5.4.2)	
	- Are all Arrival and Departure routes as much as possible laterally segregated? - Are all Arrival and Departure routes as much as possible vertically segregated as a function of aircraft performance? - Are all Arrival and Departure routes as much as possible laterally segregated as soon as possible after departure? - Are the missed approach tracks segregated as much as possible from each other and of terminal departure routes? - Are all terminal routes consistently connected with the ATS route network? - Are all terminal routes consistently connected with the ATS route network irrespective of the runway in use? - Are all terminal routes compatible with routes in adjacent terminal airspaces (where applicable)? - Are all terminal routes compatible with routes in adjacent terminal airspaces (where applicable) irrespective of the runway in use? - Is the impact of a change of the runway in use on the operational complexity to the terminal route structure as minimal as possible? - Are the terminal routes merged progressively as they approach the terminal airspace?
3. Holding Areas (ref. Part C 5.4.3)	
	- Are the holding patterns, serving a terminal airspace, located either at an entry point or outside the terminal area? - Are the locations of the holding patterns as such that they create minimum operational complexity for both En-route and terminal airspace and where applicable for adjacent terminal airspaces? - Do the locations of the holding patterns remain constant irrespective of the runway in use? - Are the inbound tracks of the holding patterns closely aligned with the subsequent arrival routes?

Outstanding Actions/Issues

Action	Due date	Responsible

Terminal Airspace Design Guidelines - Part C

Reports

REPORT TYPE	DUE DATE	RESPONSIBLE	CONSULTATION PERIOD
DRAFT REPORT			
REVIEW			
FINAL REPORT			

Terminal Airspace Design Guidelines - Part C*Attachment C.8-6***Checklist – Design Concept: Structures and Sectors**

Checklist STRUCTURES AND SECTORS (ref. Part C, Ch.6)	
1. Terminal Airspace Structures (ref. Part C 6.4.2)	
	• Are all terminal routes, holding patterns and their associated protected airspaces contained within controlled airspace? • Does the upper limit of the terminal airspace coincide with the lower limit of the superimposed controlled airspace in order to continuous protection of IFR flight paths? • Is the terminal airspace compatible with the routes and holds that are to be contained within it? • Are both vertical and lateral dimensions of the terminal airspace structure compatible with aircraft flight profiles? • Have obstacle clearances been taken into account while determining if both vertical and lateral dimensions of the terminal airspace structure compatible with aircraft flight profiles? • Is the lateral airspace designated to the terminal airspace restricted to the airspace necessary to contain terminal routes (in order not to constrain the operation of non-participating flights)? • Is the lower limit of the airspace designated to the terminal airspace restricted to the necessary airspace to contain terminal routes (in order not to constrain the operation of non-participating flights)? • Is the possibility investigated to fuse adjacent terminal airspaces into one terminal block so as to reduce the operational complexity? • Is flexible use of airspace implemented or envisaged in the design (activation and de-activation of parts of the TMA subject to real-time operational requirements of different airspace users)? • Are buffers incorporated or envisaged in the design with respect to airspace reservations outside the terminal airspace in order to ensure that ATS can provide an adequate margin of safety?
2. Sectors (ref. Part C 6.4.3)	
	• Are the lateral and vertical dimensions of sectors designed as such that stepped level clearances, especially over short distances are avoided to the extent possible? • Are the protected airspaces surrounding holding patterns included in single geographically defined sectors? • Is the design of each sector done in accordance with the design of adjacent, subjacent and superimposed sectors? • Does the design of sectors meet the rationale that crossing points of terminal and/or other routes should not be placed too close to a boundary of a geographically defined sector as so to allow the receiving controller sufficient anticipation time to resolve conflicts? • Is the fact considered that the vertical limits of a geographically defined sector need not be uniform i.e. fixed at one upper level or one lower level, nor need these vertical limits coincide with the vertical limits of (horizontally) adjoining sectors? • Are buffers incorporated or envisaged in the design with respect to airspace reservations outside the terminal airspace in order to ensure that ATS can provide an adequate margin of safety? • Are all potential sector combinations taken into account when determining the sector configuration? • Are the geographically defined pre-defined sequencing sectors designed to encompass the main arrival flows designed with a view to merging arrival traffic progressively as they approach the terminal area? • Is it operationally required that the upper limit of a sector coincides with the lower limit of superimposed sectors in order to provide protection for IFR flights?

Outstanding Actions/Issues

Terminal Airspace Design Guidelines - Part C

Action	Due date	Responsible

Reports

REPORT TYPE	DUE DATE	RESPONSIBLE	CONSULTATION PERIOD
DRAFT REPORT			
REVIEW			
FINAL REPORT			

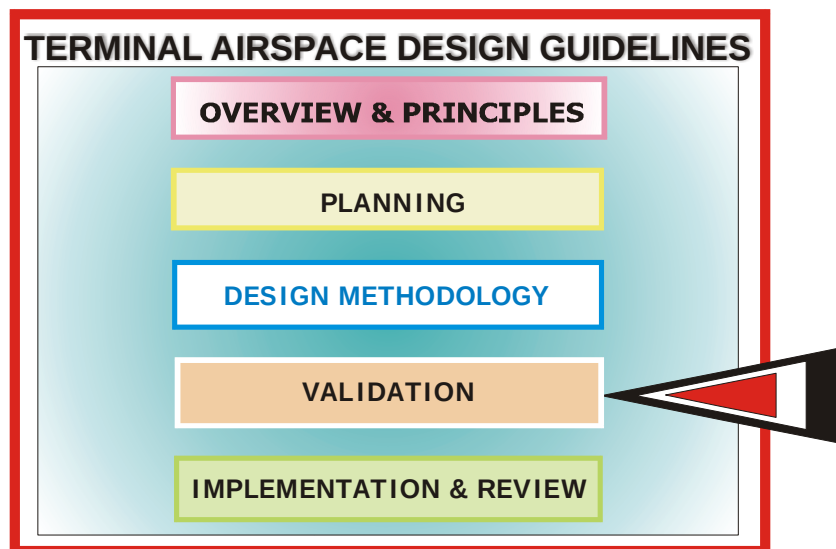
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PART D

VALIDATION



CHAPTER 1

– VALIDATION: AN OVERVIEW –

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Terminal Airspace Design Guidelines - Part D**1.1 INTRODUCTION**

This chapter provides an overview of various *Validation* methods in general, and quantitative validation methods (especially simulation) in particular. Qualitative and Quantitative Validation methods include Assessment, Airspace Modelling, Fast- and Real-Time Simulation, Live ATC Trials and Flight Simulation.

In particular, this introductory chapter seeks to emphasise –

- ❑ Where Validation ‘fits’ into the overall Terminal Airspace design project;
- ❑ The purpose of Validation; and
- ❑ different elements of the processes common to most Validation methods; and
- ❑ the fact that different Validation methods are suited to different Validation requirements.

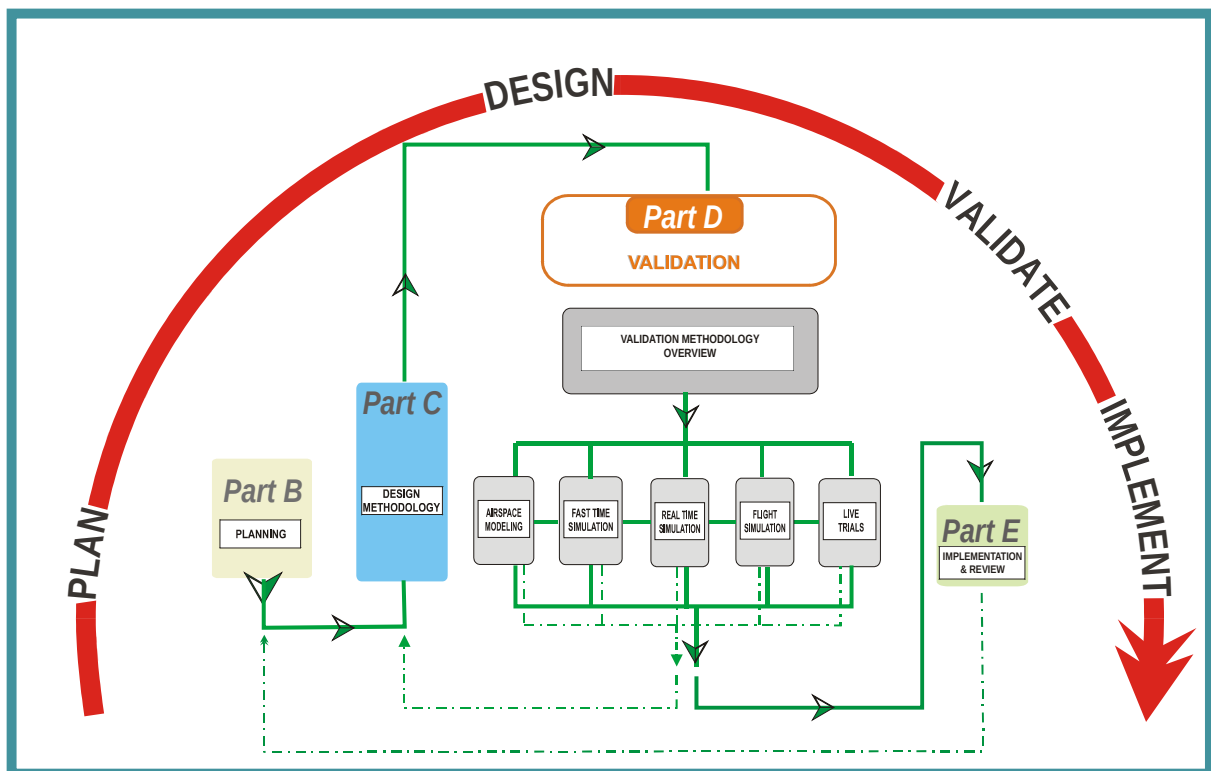


Figure 1 - 1: Roadmap and Validation Methods

Figure 1 - 1, above, shows the place of Validation in the Terminal Airspace design process. Located *after* the completion of the Design Concept and *before* Implementation (and Review), the Validation phase may be viewed as the bridge linking ‘theory’ and ‘practice’ (or concept and reality).

1.2 PURPOSE OF VALIDATION PHASE

The main objectives of the validation phase are:

- ❑ To prove the operational validity of the Terminal Airspace design concept;
- ❑ To assess if the design objectives can be achieved by implementation of the concept;
- ❑ To identify potential weak points in the design and to develop mitigation measures;
- ❑ To provide evidence and proof that the design is safe i.e. to support the Safety Assessment.

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1.2.1 VALIDATION AND SAFETY ASSESSMENTS

Mandatory ICAO and European requirements require states to undertake a safety assessment when making changes to their airspace design. To this end, the member States of ECAC have been required to comply with ESARR/4 since November 2003.

The validation phase of the Terminal Airspace design plays a significant role in the safety assessment process. Most commonly, validation tools are used to provide safety 'evidence' for the safety assessment.

Readers are referred to Part C, Chapter 3 where an overview is provided of the safety case approach to safety assessments.

1.3 VALIDATION TERMINOLOGY

As will become evident, some of the expressions used in Part D differ slightly to those used in previous Parts of the document. These expressions recognise the fact that Validation-specific expressions exist and are used. Even though most of these expressions 'originate' in various validation tools (past and present), their use and meaning have evolved over time and acquired different nuances. Thus there are a variety of expressions in use and most of these are not 'formally' defined.

In recognition of this (Validation) reality, Part D therefore uses a limited set of Validation-specific terms:

Note: *These terms and attributed 'meanings' are **not** formal definitions, nor does their use suggest that they are the only terms in use. These explanations are provided for reasons of clarity, and additional information is provided at para. 1.3.1.*

- **Base Case** and **Test Case:** Respectively, these terms are the 'validation equivalent' of the Reference Scenario and a Proposed Scenario referred to in the conceptual design phase. The Base Case and Test Case have two components viz. Airspace Organisation and the Traffic Sample.

Note: *The Base and Test Case are created for Validation purposes. They are based upon the Design Concept developed as per the Design Methodology (for example) contained in Part C of this document.*

- **Airspace Organisation:** The airspace organisation is made up of five parameters (list below). The first four of these are components of the Base and Test Case - which are based upon the Design Concept following, for example, the guidelines contained specifically in Chapters 5 & 6 of Part C.
 - **Terminal Airspace structure;**
 - **ATC Sectorisation;**
 - **Routes;**
 - **Holds;**
 - **Rules.**
- **Traffic Sample:** The Traffic Sample is made up of three parameters, viz.:
 - **(Air) traffic** which operates in a particular airspace organisation;
 - **Date** e.g. DDMMYY (A Time 'stamp' may also be included;
 - **Rules** of traffic assignment.

Note 1: *See also Part C, Chapter 4 and para. 1.5.4.*

Note 2: *A **Reference Traffic Sample** is usually associated with a **Base Case**.*

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- ❑ **Parameters:** An element of either the Airspace Organisation or Traffic Sample.
- ❑ **Trajectory/Aircraft Trajectory/Flight Trajectory:** refers to the 4D path of an aircraft through (simulated) airspace.
- ❑ **Rules:** Refer to any operational procedure and/or co-ordination agreement that-
 - as regards **Airspace Organisation**, affects the dimensions of the Terminal Airspace structure and/or ATC Sectorisation and/or the definition of or operation along Routes and Holds. Examples of Rules which might affect the operation along Routes and Holds include level/speed restrictions published in SIDs/STARs or inter-sector co-ordination agreements to be replicated on a fast-time simulator.
 - as regards the **Traffic Sample**, affects the way in which the air traffic is assigned to operate, either along pre-defined Routes/Holds or in anticipation of tactical vectoring by ATC.

1.3.1 NAMING BASE AND TEST CASES

In order to trace cause and effect when analysing simulation runs, and as a means of properly recording simulation results, **it is crucial that Base and Test Cases be clearly identified**. More importantly, clear identification is important in order to avoid confusing the vast quantities of numerical data generated by quantitative assessment tools. For this reason, the Terminal Airspace design team (and its Validation counterpart) should agree upon a clear Scenario/Test Case naming convention. As importantly, this naming convention should be systematically used and commonly understood by all participants – see Figure 1 - 2, below, for examples.

It is recommended that such a naming convention should at least provide the following information:

- ❑ Coded designator of the **Airspace Organisation** to be used (e.g. Org PR, Org A etc.)
- ❑ Coded designator of the **Runway in use and associated Traffic Sample** (e.g. 01-RT means RWY01, Reference Traffic Sample or 01-R24022004, where the numbers after the R are a date-time 'stamp' of the traffic sample.)

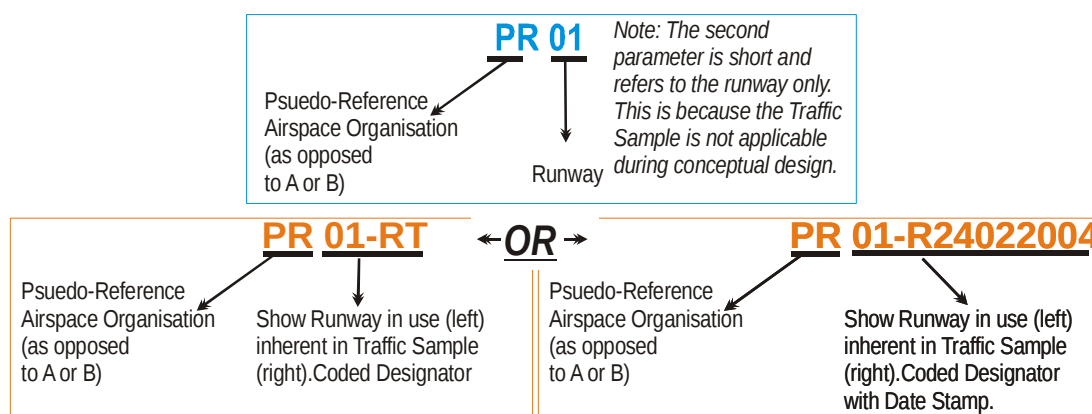


Figure 1 - 2: Sample Coded Identification of Scenarios, Base and Test Cases

The above diagram shows an example of how Scenarios could be named during the conceptual design phase (blue, top) and Validation phase (orange, lower, showing two options). This style of identification is intended to support the contents of Para. 1.5.7, which discusses changing parameters and comparison of Scenarios, Base and Test Cases.

Note: For explanation of 'Pseudo-Reference', see Part C, Chapter 2 – The Reference Scenario.

Terminal Airspace Design Guidelines - Part D**1.3.2 TERMINOLOGY SUMMARY**

Components of a Base or Test Case	
Parameters of Airspace Organisation	Parameters of Traffic Sample
☐ Terminal Airspace Structure ☐ ATC Sectorisation ☐ Routes ☐ Holds ☐ Rules (as per para. 1.3)	☐ Air traffic ☐ Time/Date 'stamp' ☐ Rules (as per para. 1.3) .

1.4 DIFFERENCES BETWEEN VALIDATION METHODS**1.4.1 QUALITATIVE AND QUANTITATIVE ASSESSMENT METHODS**

In contrast to the conceptual design phase (discussed in Part C) where the design concept is systematically checked and cross-checked primarily by one method i.e. Qualitative Assessment, **Validation is undertaken using both Qualitative and Quantitative Assessment. The role of Qualitative Assessment is as important during the validation phase: it is not abandoned in favour of Quantitative Assessment.**

The reason for this statement may be illustrated by a quote from ICAO's ATS Planning Manual, Doc. 9426, Part II, Section 2, Chapter 1, para. 1.1.9. (For 'sound operational judgement', read 'Qualitative Assessment'.)

*"In recent years, work on separation minima, between aircraft has, to a growing extent, been based on the mathematical-statistical treatment of data collected on the performance of aircraft. This approach was used to develop models from which valid information regarding the likely safety of proposed measures could be derived. While such work has been extremely useful as a supplementary means of arriving at valid conclusions, it is, however, not a substitute for **sound operational judgement**. It therefore appears necessary to approach the issue of mathematical models with caution and to make sure that in each individual case, data collections and their subsequent treatment are likely to yield useful results and do not only confirm the obvious."*

In general terms, Quantitative Assessment refers to validation methods that are numerical. Validation by Quantitative Assessment relies on tools which are primarily – but not exclusively - computer-dependent simulators. Whilst a separate chapter is dedicated to **Qualitative Assessment** (Part D, Chapter 2), it is useful to understand the difference between **Qualitative** and **Quantitative** Assessment/tools. This is shown in the table on the next page.

As will become evident, it is the nature of the design concept or the type of changes to the existing routes, holds, structures and sectors that largely determine the most appropriate validation method or combination of methods to use. Thus where in one case it is appropriate to proceed from Qualitative Assessment to FTS, then RTS prior to implementation, there may be instances where Live ATC trials and flight simulation are the most appropriate validation method together with qualitative assessment.

Although it is sometimes appropriate to exploit all validation methods prior to implementation, the differences between the different methods and the *type* of validation provided means that a step-through of each validation method is may be unnecessary.

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	Input	Assessment Bench Mark used	Output	Validation method
Qualitative Assessment	Published & Proposed Terminal Airspace Design (Routes/Holds, Structures and Sectors)	Non-numerical Performance and Safety Criteria based upon ICAO SARPs, Procedures and Guidance material and National/Local regulations and ESARRs.	Mainly textual/ diagrammatic reasoning, argument, justification.	☐ Expert ATM/CNS judgement ☐ Airspace Modelling
Quantitative Assessment	☐ Published and Proposed Terminal Airspace Design (Routes/Holds, Structures and Sectors) usually in computer data format representing Airspace Organisation and Traffic Samples. ☐ surveys - radar data recordings, flight plan recordings, flight recordings, questionnaires ☐ statistics & forecasts - airports operations statistics, meteorological data collections, traffic demand, traffic distribution	Absolute Numerical Performance and Safety criteria based upon Performance and Safety Criteria based upon ICAO SARPs, Procedures and Guidance material and National/Local regulations and ESARRs.	Numerical data (primarily)	☐ Airspace Modelling ☐ FTS/RTS ☐ Live ATC Trials ☐ Flight Simulator ☐ Data Analytical Tools ☐ Statistical Analysis ☐ Collision risk modelling

Table 1 - 1: Qualitative and Quantitative Assessment**1.4.2 SPECIFIC DIFFERENCES**

More specifically it is possible to distinguish between the different validation methods on the basis of Cost, Realism, Time and the number of Traffic Samples and Test Cases used. As can be seen in the diagram below, the more complex the simulation method used, the greater the cost, preparation/run time required and the closer to reality the results become. In contrast, and normally for reasons related to cost/time – the number of traffic samples/test cases tend to decrease as the complexity of the simulation method used increases.

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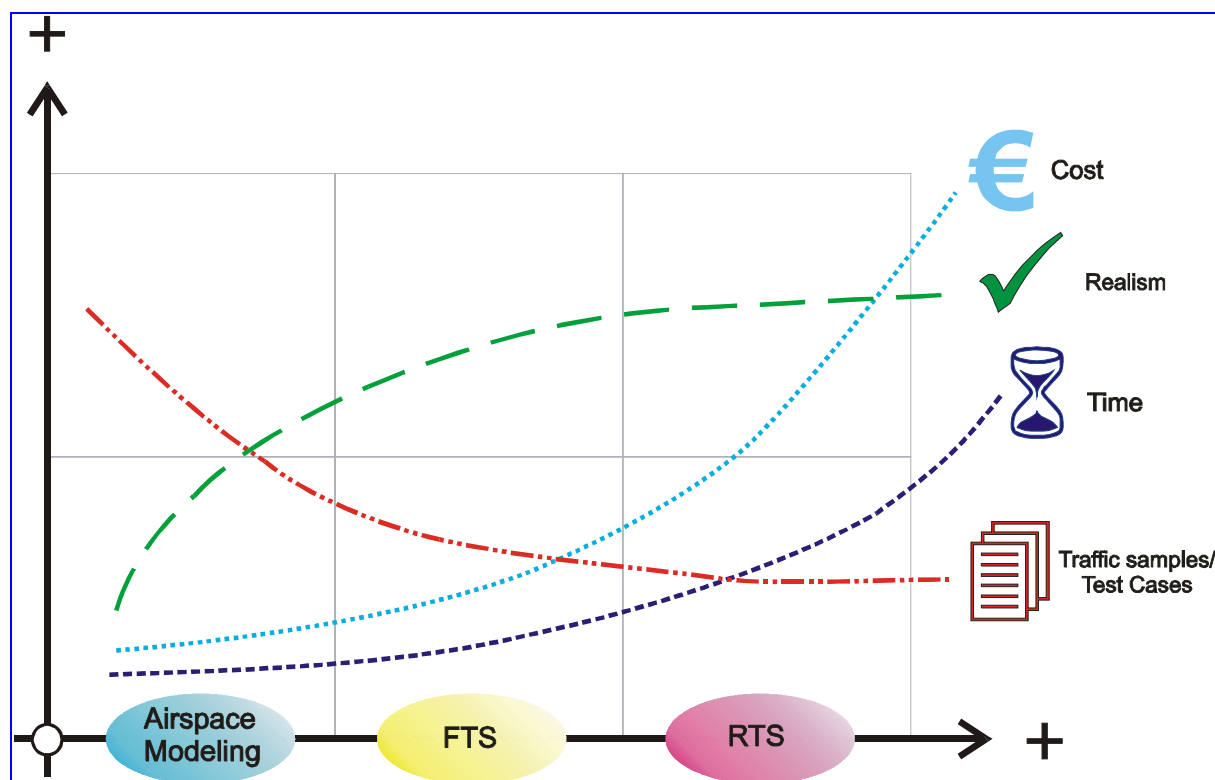


Figure 1 - 3: Specific differences between some Validation methods

Comment: It is frequently claimed that the results/output from a real-time simulation are more reliable than those from a fast-time simulation on the basis that RTS is closer to reality than FTS. This is not a given: a poorly prepared RTS founded on incorrect assumptions e.g. non-representative traffic sample, is unlikely to return a better result than a properly prepared FTS. Furthermore, recent developments in FTS-technology are such that increasing reliance is being placed upon FTS results.

1.4.2.1 Time and Resources

The number and extent of validation methods used and their duration is directly linked to the complexity of the Design Concept and the complexity of the Traffic Sample. As more changes are envisaged and the greater their safety and operational impact, the greater the requirement becomes for accurate and detailed investigation to prove their operational benefits and fulfilment of safety criteria.

The diagram below shows that each validation method has its own requirements with regards to time and resource allocation. In general terms, it may be said that the **preparation time and resource demands increase directly with the complexity of the model used**. The representation shown in Figure 1 - 4 reflect the contents of Figure 1 - 1.

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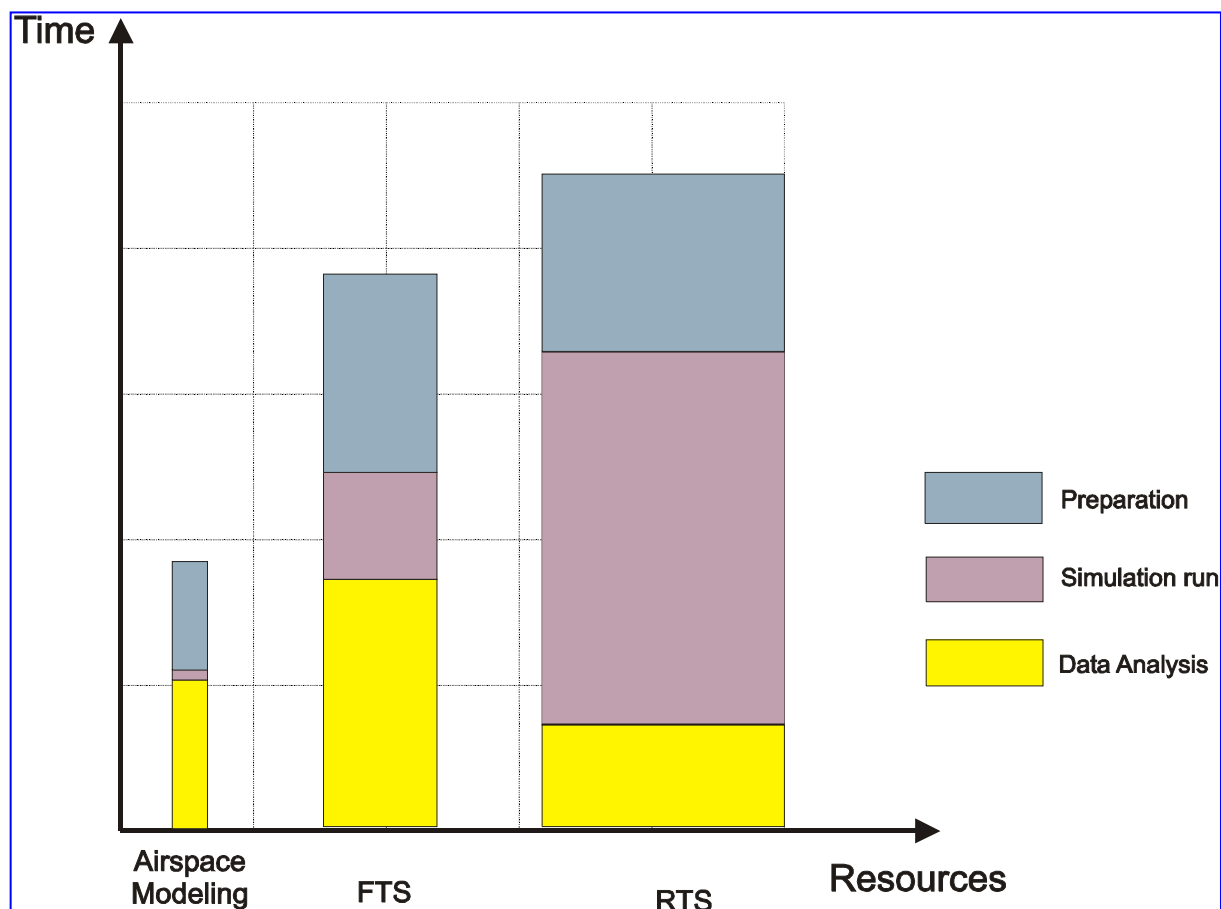


Figure 1 - 4: Time Requirements

For these reasons, the design team should allocate enough time in the project plan for the appropriate level of assessment (modelling, fast time and real time simulation, live trials – See Part B, Planning). The planning should be made as flexible as possible because the results of one Validation method could heavily impact upon the next Validation step in the sequence or could lead to the suspension of the validation process and a return to the design phase – see Figure 1-5.

Naturally, there is merit in returning to the design phase if the combination of a qualitative and quantitative validation method returns a discouraging result. For a variety of reasons, not the least being cost, it is better to return to the drawing board sooner rather than later. This is shown in Figure 1-6.

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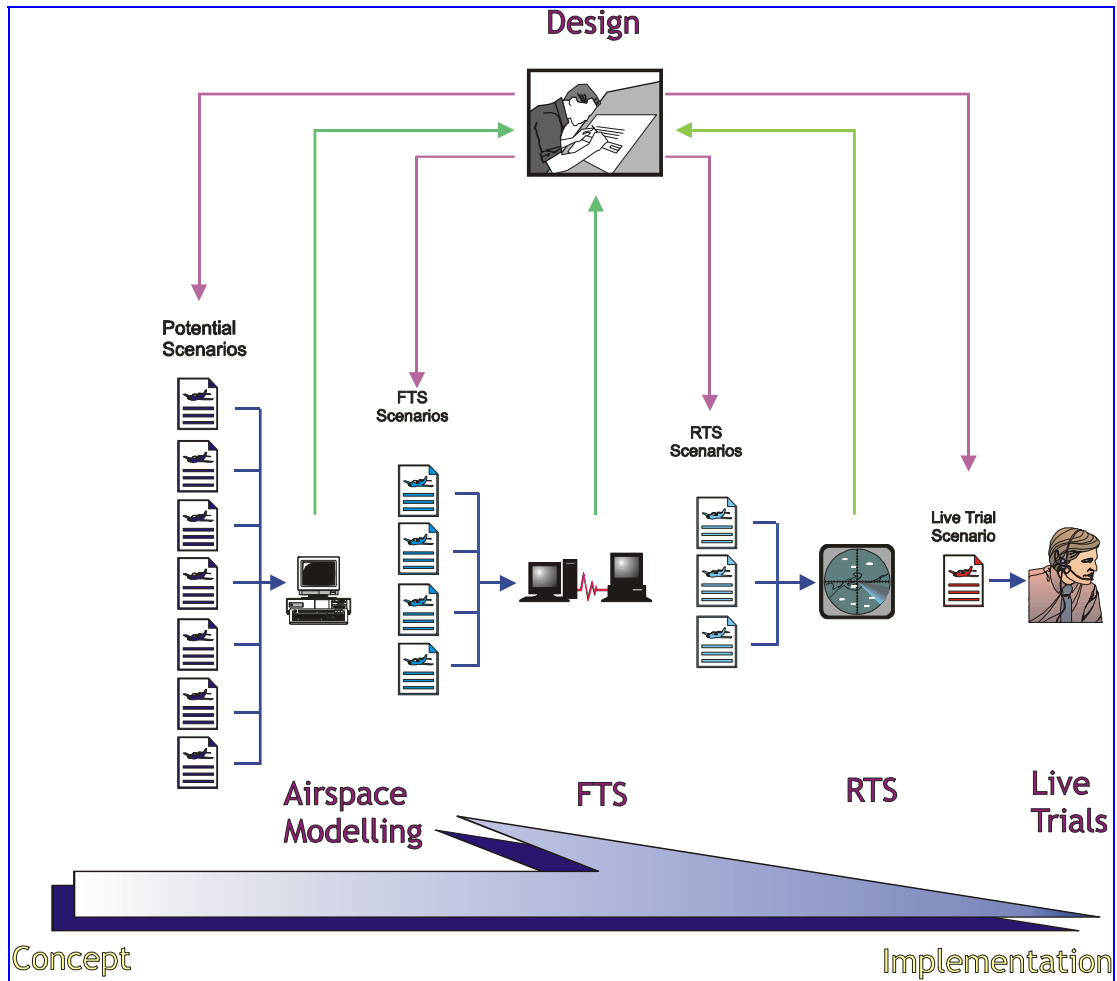


Figure 1 - 5: Knock on effect of validation findings across various methods

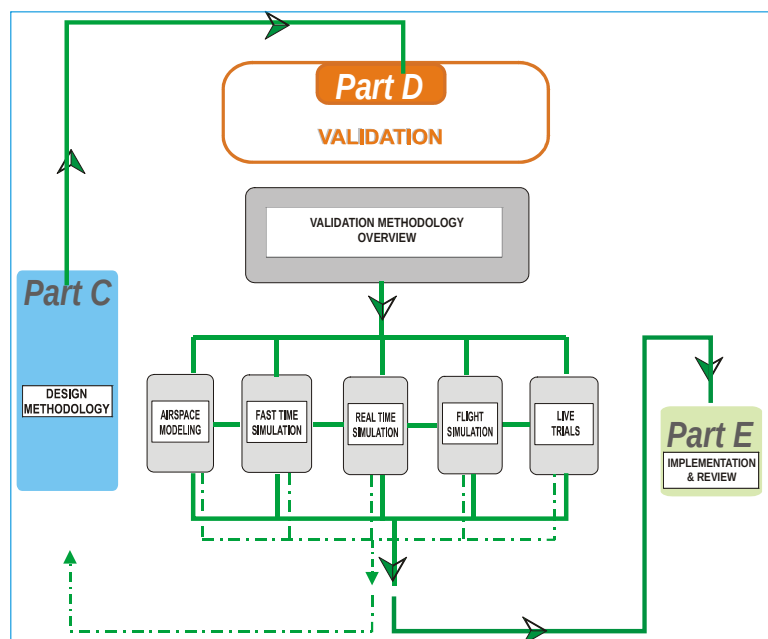


Figure 1 - 6: Return to the design phase – if necessary

Terminal Airspace Design Guidelines - Part D**1.5 VALIDATION BASICS**

As is evident from the preceding paragraph, Validation can be a lengthy and expensive phase of the Terminal Airspace design process and **careful planning and preparation and scheduling of resources is required to optimise the use of the available resources.**

Comment: *Simulations are usually prepared, managed and run by specialists who are experts in a specific type of simulator e.g. fast- or real-time simulator, flight simulator, etc. Nevertheless, it is strongly recommended that the Terminal Airspace design team actively participate in the planning, preparation and running of simulations. Amongst other things, this will help to ensure that the design objectives are maintained, that the **Simulation Base and Test Cases correctly reflect the Reference and Conceptual Scenarios on which they are based**, and that qualitative assessment is not abandoned during the validation phase.*

In the simulation planning phase the Simulation team leader would, together with the Terminal Airspace design team, be expected to:

- ❑ define the generic requirements for the simulations
 - set scope and objectives of simulation
- ❑ identify the data flow between the various assessment phases
- ❑ establish the milestones and target dates for the validation process
- ❑ evaluate the resources required
- ❑ ensure the availability of the simulation platforms
- ❑ ensure the availability of the qualified personnel (simulation experts, ATC controllers, pseudo pilots, pilots, etc)

1.5.1 SETTING VALIDATION OBJECTIVES

The first step in preparation of the process should be the setting of the objectives by the Terminal Airspace design team together with the Validation Team. More specifically, the simulation objectives should be:

- ❑ Based on a specific requirement
- ❑ realistic
- ❑ achievable
- ❑ explicit (oriented to a specific item of the design concept)
- ❑ measurable

The objectives of the process will determine which validation method should be used (airspace modelling, FTS, RTS, live trials, flight trials, etc) and the scope of each step. For this reason, the validation objectives can also be influenced by the available simulation platform. After deciding the required succession of modelling and simulations the design/simulation team should develop specific objectives for each step of the assessment/validation process.

1.5.2 SELECTION OF SIMULATION PLATFORM

After the simulation objectives have been set, and the validation process established, the Terminal Airspace design and Simulation teams should select the simulation platforms which will be used for each step of the process. This decision should be based on various factors, the main ones being:

- ❑ Suitability for the achievement of the objectives;
- ❑ complexity of the objectives;

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- ❑ required accuracy of results;
- ❑ type of required results (statistical data, operational feed-back, etc);
- ❑ availability of the simulation platform and support personnel;
- ❑ cost of the simulation;
- ❑ duration of the simulation process;

1.5.3 CHOOSING DATA COLLECTION METHODS

Each simulation method provides a specific set of the results. The format and type of the output data also varies with each simulation platform. It is very important for the design/simulation team to assess with the simulation experts for each tool to be used in the simulation process, which data can be obtained and how this data is generated and collected by that platform. (See Table 1 - 1, above).

Based on this assessment the design and simulation teams should jointly decide which criteria are to be used for evaluation in order to achieve the simulation objectives and subsequently which data will be collected and analysed during the simulation. (See Part C, Chapter 3).

1.5.4 CHOOSING/CREATING THE TRAFFIC SAMPLE

One of the main distinctions between traffic samples used for validating En Route airspace development as opposed to the Terminal Airspace equivalent concerns the extent to which there is/are predominant Runway(s) or Runway combinations in Use. It is primarily for this reason that the number of traffic samples is determined first by the Runway in Use. If, for example, an Airport has a single Runway 01/19 and each landing/take off direction is used 50% of the time, it will be necessary to have two 'Reference' Traffic samples – one for each landing/take-off direction. If, on the other hand, statistical analysis shows that Runway 01 is used 90% of the time, it could be possible to have one Reference Traffic Sample for Runway 01. Predictably, the number of Reference Traffic Samples increase in a multi-airport Terminal Airspace where each airport may have its own predominant Runway or Runway combinations in use.

For the Base Case(s) it is recommended that a real (Reference) traffic sample be used, (taken from radar data recordings, flight plan system recordings, CFMU database, etc.). A traffic sample should represent real normal operations and traffic distribution on an average day. (See Part C, Chapter 4).

The duration of the traffic sample depends on the objectives and type of the simulation; Usually, a 24 hour traffic sample is used for fast-time simulation and a 1-2 hour traffic sample is used for real-time simulation.

Comment: It is inadvisable to use less than a 1 ½ hour traffic sample for a Real-Time Simulation: Controllers take time to settle into the simulation run and, similarly, it takes time to build up the traffic to required levels.

In order to assess and validate different conceptual design Scenarios, specific traffic samples should be developed, starting from the Reference traffic sample, so as to cover the foreseen changes. These changes in traffic include changes to specific parameters such as:

- ❑ Modification to the amount of traffic;
- ❑ change of traffic distribution (geographical/time)
- ❑ changes to the assignment of air traffic on the Routes/Holds
- ❑ changes of aircraft type, aircraft performance characteristics or aircraft operating procedures

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Examples of changes made to a traffic sample are tabulated below. Importantly: When a single change is made to a parameter of a Traffic Sample, a separate traffic sample is created (with its own separate identifier – see also para. 1.5.7).

RTS Traffic Sample ID.	Source/Basis	Sample Date	UTC Time Period of Traffic Sample	Special Remarks
01-RT	Radar Data Sectors S _A -S _D	24.9.2004	1700-1900	Traffic Sample is representative of average day (2004) in Terminal Airspace Sectors with 100% traffic (01-RT).
01-1T	Validation Team, Based on 01- RT	24.9.2004	1700-1900	RT + Airspace Organisation A with new Routes/Holds as per 01-1T
01-2T	Radar Data Sectors S _A -S _D	24.9.2004	1700-1900	RT + Airspace Organisation A, with new Routes/Holds as per 01-1T with traffic increase to 120%

Table 1 - 2: Example of Traffic Samples developed from a Reference Traffic Sample

Note: In this case, the differences between the traffic samples are based on different routes (RT & 1T) and, in the case of 2T, traffic increase over 1T.

1.5.5 SETTING UP THE RULES

Each simulation method and each simulation platform has a unique way of describing the way in which the airspace is used, the way in which air traffic management is performed and the interactions between ATC and pilots.

The way in which these Rules are translated in the Test Cases is specific to each simulation platform, but the following items should be taken into consideration in the Test Case development:

- ❑ letters of agreement;
- ❑ published level/altitude restrictions (level capping, SID/STARs profiles, etc)
- ❑ published speed restrictions;
- ❑ standing agreements & operational arrangements;
- ❑ operational procedures;

For those simulation platforms which make use of automated functions to replicate the actions of air traffic controllers or pilots, the design/simulation team should ensure that the correct values for the parameters are used (such as separation minima, turn rates, speeds, etc) and that those functions perform in a way which correspond to real operations.

1.5.6 TEST CASE DEVELOPMENT

Development of Scenarios is an iterative process during the conceptual design process, and this is equally true of Test Cases during the validation process. As explained in Part C and Chapter 2 of Part D, the initial Design Concept can lead to large number of potential directions for development (depending on the complexity of the changes required to the actual situation), each described by a potential Scenario.

In moving towards more detailed and accurate evaluations and assessments, only the Scenarios / Test Cases meeting the performance criteria will be kept and further developed. Thus, as the refinement of Scenarios / Test Cases increases, the number of Scenarios/Test

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Cases reduces – and ultimately, this leads to the solution which is developed for implementation.

The design/simulation team should ensure the consistency of Scenarios/Test Cases throughout the process. Continuity can be assured by use of Test Cases which have been validated by one simulation method as a basis for the development of new Scenario / Test Case for the following assessment phase (using, perhaps, a different simulation method). This continuity also reduces the probability of errors – and divergence from design objectives. Furthermore, duplication of effort is avoided; this ensures that both cost and duration do not become excessive.

1.5.7 COMPARING TEST AND BASE CASES

In order to be able to make robust comparisons between Base and Test Cases and/or between Test Cases, these cases should bear sufficient resemblance to each other. If too many changes are incorporated (e.g. changes are made to several parameters of either the Airspace Organisation or Traffic Sample) it becomes difficult to evaluate the impact of each modification and may even make comparison impossible or, worse, produce misleading conclusions.

Therefore, the basic rule for making comparisons can be expressed as follows

“CHANGE ONE PARAMETER AT A TIME”

In view of the number of parameters attached to each of the two components of a Test Case, it is evident that 10 or more Test Cases could be created i.e. for 10 or more Traffic Samples run through the same Airspace Organisation in order to determine the effect of changing one Traffic Sample parameter. This stresses the importance using a naming convention to identify Base and Test Cases.

Thus, for example, in order to compare different airspace organisations, the same traffic sample should be used on different Airspace Organisations. This is shown in the Table below using as a starting point the Pseudo Reference Scenario coded **PR 01-RT**.

Base/Test Case Ident.	Airspace Organisation	Traffic Samples (Coded Identification)			What is being compared? →
PR 01-RT	PR (Pseudo-Reference)	01-RT (100% traffic)	01-1T (120% traffic)	01-2T (150% traffic)	Assess Org PR against traffic increase
A 01-RT	A	01-RT (100% traffic)	01-1T (120% traffic)	01-2T (150% traffic)	Assess Org A against traffic increase
B 01-RT	B	01-RT (100% traffic)	01-1T (120% traffic)	01-2T (150% traffic)	Assess Org B against traffic increase
		Compare Org PR with A and B, and compare Org B with C	Compare Org PR with A and B, and compare Org B with C	Compare Org PR with A and B, and compare Org B with C	What is being compared? ↓

Table 1 - 3: Detailed view of Sample Scenario Comparison

In the Table above, note that the difference between traffic samples is based (across) on a traffic increase (a single parameter, the *amount of traffic* in the Traffic Sample, has changed). In contrast, the downward comparison refers to a changing Airspace Organisation using the same Traffic Sample.

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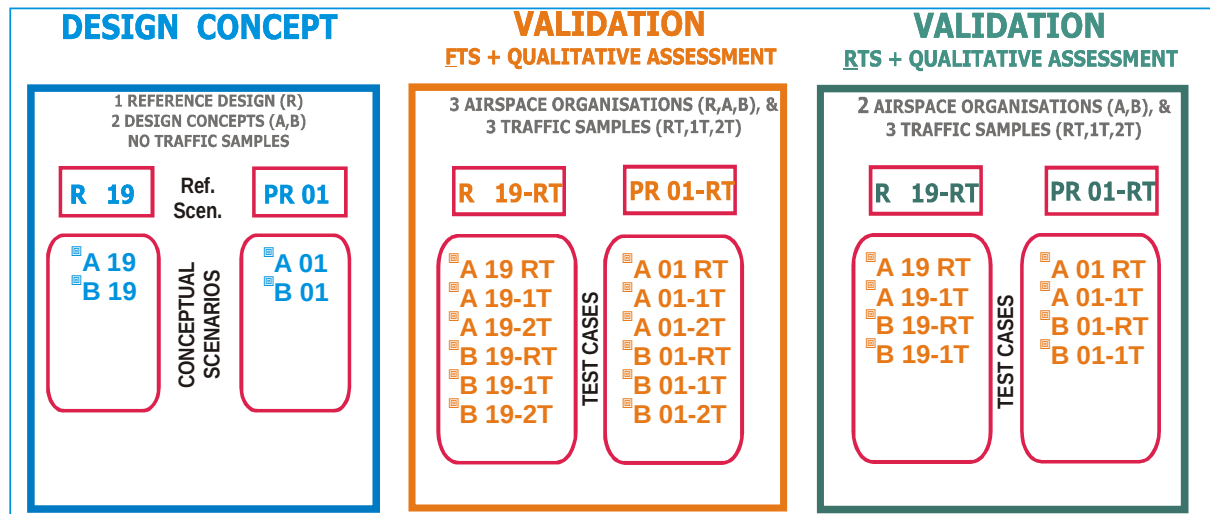


Figure 1 - 7: High Level overview of Scenario & Test Case Comparison

In the above Figure, for each Validation method, every Scenario/Test Case shown in the red rounded-edged box is compared with the Reference/Base Case in the red square box above it.

At the end of the simulation, comparisons and evaluations can be made using absolute values derived from the data collected as workload, capacity figures, etc.

1.5.8 ANALYSING RESULTS

Results obtained from both qualitative and quantitative assessments need to be analysed. In most cases, data obtained from quantitative assessment-type Validation methods need expert analysis e.g. Statisticians. Nevertheless, **it is imperative that numerical data and analysis thereof is also subjected to qualitative assessment** so that the overall impact of the results may be understood.

1.6 SUMMARY

This chapter has introduced Validation in the context of Terminal Airspace design and has explained its purpose and basic principles. In particular, this chapter has stressed the importance of preparation and planning, qualitative analysis and the proper naming and analysis of Scenarios and Test Cases.

Most importantly, this chapter has stressed that when comparing Base and Test Cases, it is imperative that only one parameter be changed at a time so that the effect of the change can be measured.

CHAPTER 2

- QUALITATIVE ASSESSMENT -

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Terminal Airspace Design Guidelines - Part D

2.1 INTRODUCTION

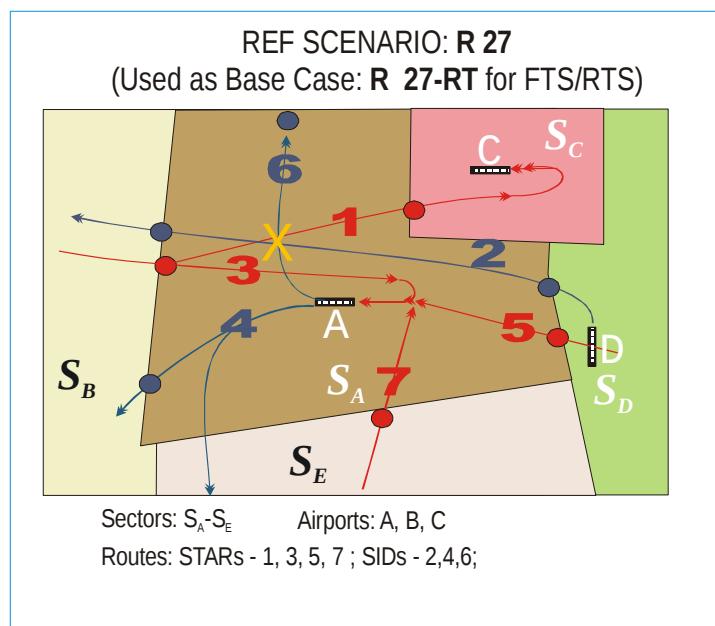
Unlike the topics discussed in other chapters in Part D, (e.g. fast- and real-time simulation), Qualitative Assessment is not a stand-alone method of validation. Indeed, 'assessment' is not exclusive to the validation phase which is why qualitative and quantitative assessment were introduced under the Design Methodology. Assessment - particularly Qualitative Assessment – is a 'constant' through the entire life-cycle of the Terminal Airspace design project i.e. during project planning, the conceptual design phase, validation and implementation/review phase .

For this reason, Qualitative Assessment is not discussed in an exclusive (validation) context in this chapter. Nor is quantitative assessment separated from it. This is because, in the Validation phase, qualitative and quantitative assessment cannot be separated as they can be during the conceptual design phase. (During the conceptual design phase, it is possible and indeed advisable, in some cases, to undertake a Qualitative Assessment prior to embarking upon a quantitative assessment. (See Part C, Chapter 3 and Part D, Chapter 1, para. 1.4.1).

2.2 PRINCIPLES

In order to demonstrate the synergy between Qualitative and Quantitative Assessment, an example is provided using fictitious airspace. This example covers the life-cycle of a small project and illustrates the indivisible relationship between Qualitative and Quantitative Assessment. Because the examples are fictitious, readers should not be surprised should they identify alternative solutions to those proposed.

2.2.1 SAMPLE QUALITATIVE ASSESSMENT



The figure (left) shows a Sample Reference Scenario of a fictitious Terminal Airspace. At the centre is Sector S_A with routes numbered 1-7. S_A is surrounded by four sectors: S_B , S_C and S_D . Airport A lies in S_A , Airport C in S_C and D in S_D .

The Operational Manager has asked the Terminal Airspace design team to investigate complaints of S_A controllers concerning excessive workload in S_A during peak hours, especially in the vicinity of the crossing point X (marked in orange, at left).

Figure 2 - 1: Sample Reference Scenario/Base Case

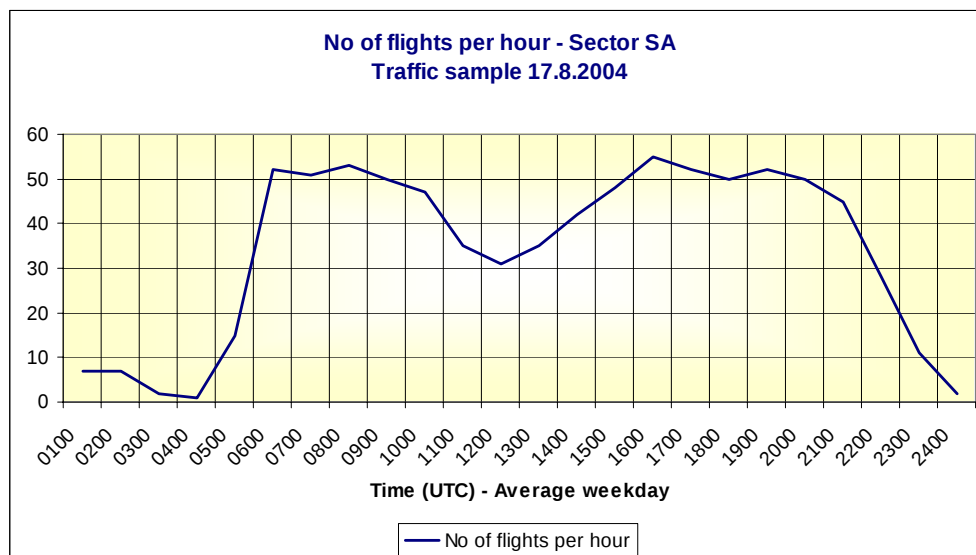
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Preliminary Qualitative Assessment

As per the process described in Part C, the Terminal Airspace design team first describes the Reference Scenario (i.e. sector S_A as it is today) and then critically reviews this sector. To help them, the Terminal Airspace design team invites comments from air traffic controllers who normally manage Sector S_A . During the critical review, it is confirmed that the crossing point X is perceived as the main problem area and the cause of unacceptably high workload during peak periods. (These ‘discussions’ are, in themselves, qualitative’).

Quantitative and Qualitative Assessment.

To further assess the problem, the Terminal Airspace design team uses a spreadsheet (or airspace modeller) to analyse traffic in S_A . What is established is that S_A handles 52 flights in a typical peak hour (see [Graph 2 - 1](#)), and that that 30 of these flights cross at X as – see Table below. (Note: 30/52 is quantitative).



Graph 2 - 1: Sample Traffic Distribution (Time)

No. of flights	Route	No. of flights	Route
10	Route 1 [RNAV/STAR to A]	12	Route 2 [RNAV/SID from D]
10	Route 3 [RNAV/STAR to C]	5	Route 4 [RNAV/SID from A]
4	Route 5 [RNAV/STAR to A]	8	Route 6 [RNAV/SID from A]
3	Route 7 [RNAV/STAR to A]		

Table 2 - 1: Sample Traffic Distribution (Geographic)

The above information does little more than confirm the accuracy of the controllers' assessment and reinforce the concerns of the Operational Manager (which is essential to ensure that all parties understand “the problem”).

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Continuation of Qualitative and Quantitative Assessment

To better analyse the situation in Sector S_A , the Terminal Airspace design team continues its assessment (both qualitative and quantitative), using primarily, information obtained during the critical review.

- (a) Use an airspace modeller to study the actual profile of flights operating on Routes 1, 2 and 6. (See Part D, Chapter 3).
- (b) Use a flight simulator of the most representative aircraft type to determine the unconstrained profiles for flights operating on Routes 1, 2 and 6 (see Part D, Chapter 6).
- (c) Study transfer of control and communications agreements between sector S_A and adjacent sectors are studied;
- (d) Check the traffic sample to establish the point of origin for most flights that use Routes 1 and 3;
- (e) Investigate whether the early left turn on RNAV/SID Route 2 is efficient or whether it causes difficulties between sectors S_A and S_D .
- (f) Assess whether the merging of routes on final approach RWY 27 at A is generating a high workload is assessed;

Sample findings

The data produced by the investigation of items (a) and (b) reveals that actual flight profiles are very close to unconstrained flight profiles. For example, traffic on –

- Route 1, crosses X at FL60 or below;
- Route 2, crosses X at above FL50;
- Route 6, crosses X between FL40 and 50

What this finding shows is that the problem at crossing point X has not been 'created' by imposed flight level restrictions e.g. prescribed by ATC. Thus, as the problem is not in the vertical plane, this may indicate that the solution lies in relocating some of these routes.

Whilst information from (c) reveals no special difficulties (apart from transfer arrangements concerning RNAV/SID 2, information obtained from enquiry (d) reveals that traffic using Route 1 has a point of origin that is due west of airport C. This suggests that Routes 1 and 3 are unnecessarily merged to meet at the arrival point of sector S_A – and then split for destinations C and A. (A VOR is located at this merge point which suggests that this merge point is more a historical legacy than a requirement).

As regards (e), it would seem that the controllers of sector S_D believe that the amount of time available to effect a proper transfer of control and communication from sector S_D to sector S_A is inappropriate, given the current positioning of the sector boundary.

In turn, investigations concerning (f) suggest that the traffic merging on final approach is manageable because aircraft on RNAV/STAR 3 are often extended on down-wind by ATC (which explains the extra space in the eastern part of sector S_A).

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Proposed way forward

Based on the above information, the Terminal Airspace design team decides that they have several alternatives. After considerable debate (i.e. a qualitative review of the options), they are left with two viable options:

- [i] re-design RNAV/SID 2 so that aircraft will be 'forced' to cross X at a higher level than is currently the case; or
- [ii] re-design RNAV/SID 2 so that it does not proceed over X; (this will require a new entry point to be created for S_A) **and** a new route for RNAV/STARs 1 & 3 (which also avoids unnecessary merging at the western entry point).

Because (ii) is considered the better option by the Terminal Airspace design team, this Scenario is selected for further development as a Test Case – see diagram below.

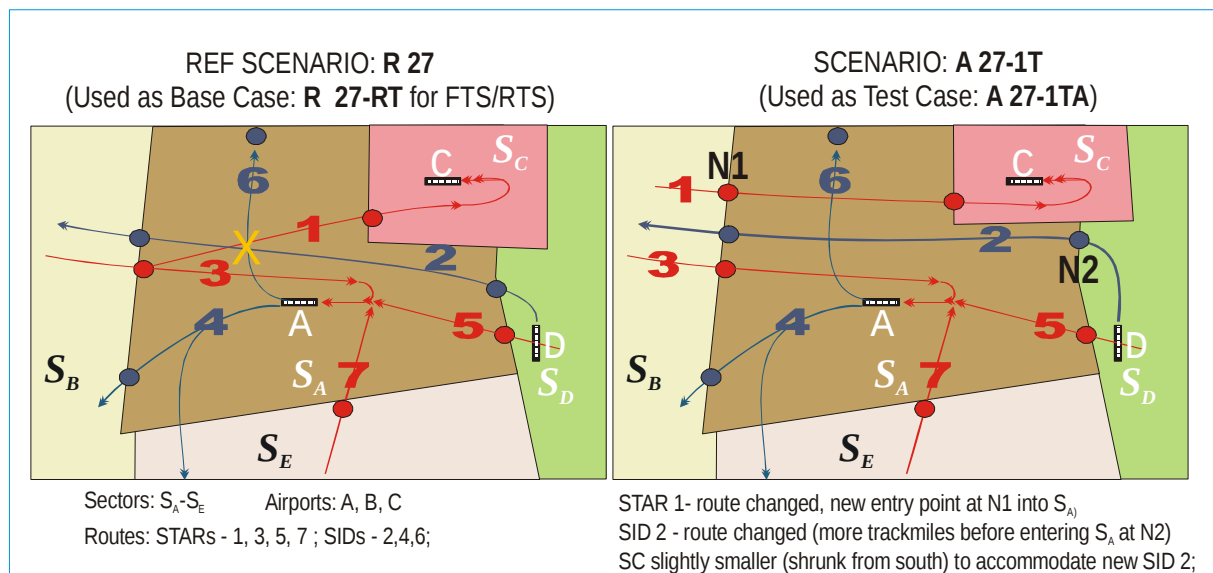


Figure 2 - 2: Potential Solution Scenario T.1

Development of Scenario A-27 / Test Case A 27-1TA reveals the following:

- ❑ Even though the traffic at crossing point X has lessened, a new crossing point has been created between RNAV/SID 6 and RNAV/STAR 1, north of X; whether or not this crossing is viable or efficient (as per Part C, Chapter 5), remains to be explored.
- ❑ Because of the new placement of RNAV/SID 2, the problem between Routes 1 and 2 has been resolved.

As a next step, it is necessary to examine the new crossing point between RNAV/SID 6 and RNAV/STAR 1. What can be expected is that it is unlikely that aircraft operating on these routes will cross each other at the same levels they did when they crossed at X. Again, the Terminal Airspace design team makes use of a flight simulator to examine the unconstrained profiles on RNAV/SID 6 and RNAV/STAR 1. What the flight simulator analysis reveals is that most traffic on RNAV/SID 6 will be above FL90 at the new crossing point, and that on an unconstrained profile, most aircraft on RNAV/STAR 1 would be at FL60 or below.

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Given this promising result, the Terminal Airspace design team decides to test by real-time simulation (RTS) as Test Case A 27-1T – See Part D, Chapter 5. For the most part, the RTS confirms their findings. However, when the RTS results are closely scrutinised, the team realises that the solution presented by Test Case A 27-1T will only be viable as long as traffic increases do not exceed 20% in sector S_A.

In view of this, the Terminal Airspace design team asks for a statistical analysis to be undertaken using a forecast traffic sample (See Part B, Chapter 4) and this reveals that it will take seven years for traffic to increase by 20%.

Sample conclusion

Given the above, the Terminal Airspace design team decides to plan for implementation of the new proposals included in Test Case A 27-1T as validated using RTS and Qualitative Assessment. One year later, the Terminal Airspace design team re-opens the dossier in order to prepare the groundwork for a time when the new capacity once again does not meet demand.

Comment: Note the importance of the critical review of the Reference Scenario. This is an essential step for two reasons: (i) it ensures that the appropriate/correct problem is identified so that the link between cause/effect is properly made; and (ii) it permits the problem to be thoroughly analysed before deciding upon a solution. Importantly, therefore, no assumptions should be made as to what the problem is, or the extent of the problem. Note also, that 'solutions' to problems require account to be taken of future developments. To this end, future traffic samples were used in the fictitious Scenario T.1 so as to determine the point at which/beyond which the solution presented would no longer meet future demand. Recognition of a need for future developments is an essential element of the assessment/validation process.

2.3 ADVANTAGES & LIMITATIONS

As stated several times, qualitative and quantitative assessment complement each other in the validation phase. They cannot be separated.

If undertaken properly, Qualitative Assessment can prevent time and money being wasted on the preparation and running of (expensive) fast- and/or real-time simulation. Qualitative Assessment is an inexpensive way of critically determining whether a particular Terminal Airspace design solution is viable. It also provides the most freedom – especially because the relative costs of changing one's mind are negligible when compared to changing a simulation specification – or worse still, a simulation already in progress.

Inasmuch as it is inadvisable to undertake a quantitative assessment without a corresponding Qualitative Assessment, it is generally inadvisable to proceed to implementation on the basis of a Qualitative Assessment alone. This is because of the disadvantages associated (particularly with stand-alone) Qualitative Assessment i.e.

- ❑ Tendency for assessment to be subjective as opposed to objective;
- ❑ Because it's usually takes the form of debate/discussion, it is possible that
 - particularly in an hierarchical Terminal Airspace design team, the Qualitative Assessment could reflect the most 'authoritarian view' (which may not necessarily be the 'best'); or
 - that the scope of solutions suggested by members of the Terminal Airspace design team could be limited to 'pre-determined' solutions (which may be

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inefficient in that they resolve the perceived as opposed to the real problem).

- ❑ Because the value of 'qualitative' assessment is often doubted (for lack of numerical 'proof'), its 'findings' may be dismissed or ignored. (Note, however, that this effect can be mitigated by providing clear rationales substantiated with simulations.)
- ❑ Business Plans normally require justifiable, accountable figures on cost benefit analysis.

2.4 SUMMARY

This chapter has sought to explain the difference between quantitative and Qualitative Assessment, particularly in the validation phase. It has stressed that these two forms of assessment complement each other.

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CHAPTER 3

- AIRSPACE MODELLING -

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ATTACHMENTS

D.3-1: Sample Scenario Identification Sheet: Airspace Modelling

Terminal Airspace Design Guidelines - Part D**3.1 PURPOSE OF AIRSPACE MODELLING**

This chapter discusses Airspace Modelling as a Validation method. As with all other validation methods, it is seldom used in isolation to validate a Terminal Airspace design, but tends to be one of several validation methods used to validate a design.

The extensive development of simulation tools has meant that it is quite unusual to find a 'stand-alone' airspace modeller i.e. one whose functionalities are 'limited' to those described below. Most often, airspace modeller functionality is likely to be included amongst those of a fast-time simulator. This means that calculation of basic sector loads and the visualisation of these are part of the FTS package. Nevertheless, it is useful to provide a general overview of Airspace Modellers, and for designers to be aware that the material in this chapter should be considered complementary to that contained in the chapter discussing Fast-Time Simulation (see Chapter 4).

3.2 PRINCIPLES

Airspace modelling tools can be considered as "scaled down" version of Fast Time Simulators. Their main usage is to create a crude representation of the routes and airspace structures (sectors) together and their interaction with a selected traffic sample. The tool generate simplified 4D trajectories (position + time) for the aircraft according with the flights plans described in the Traffic Sample (with its Rules) in a particular Airspace Organisation (with its Rules). This process is called traffic assignment. These trajectories are used together with the airspace blocks to calculate a series of statistical data as: sector loading, route segment loading, conflicts, etc. Some more advanced airspace modelling tools can derive more refined data with regard to the workload and sector capacity.

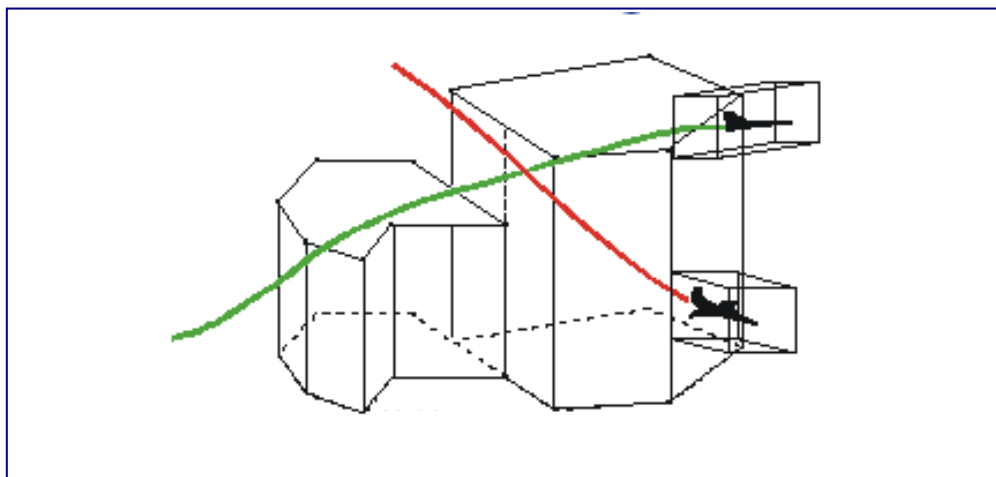


Figure 3 - 1: Simplified Airspace Organisation on an Airspace Modeller

Usually the airspace modelling tool consists of a series of software modules which are used according to the designer need:

- ❑ graphical tools - used to define the Airspace Organisation for visualisation in 2D or 3D;
- ❑ trajectory manipulation tools -used to process the traffic sample (route assignment, time distribution, 4D trajectory generation, etc);
- ❑ data analysing & processing tools (traffic distribution queries, sector loading, conflicts evaluation, etc);

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3.3 ADVANTAGES & LIMITATIONS**3.3.1 AIRSPACE MODELLING ADVANTAGES**

- ❑ unlimited scope and great flexibility
- ❑ simple to assess various alternatives
- ❑ easy Scenario adaptation and generation of Test Cases
- ❑ easy to create and assess "what if" Test Cases
- ❑ easy to test large number of traffic samples
- ❑ can use data derived from real traffic and ATC environment

3.3.2 AIRSPACE MODELLING DISADVANTAGES

- ❑ crude representation of real environment
- ❑ can provide only high level statistical data
- ❑ cannot replicate tactical controller interventions
- ❑ basic aircraft performance
- ❑ simplified trajectories
- ❑ no representation of meteorological conditions
- ❑ results accuracy depends heavily on the assessor ability and experience
- ❑ high degree of subjectivity
- ❑ difficult to involve users

3.4 SETTING SIMULATION OBJECTIVES

Because of the theoretical nature of this method, the simulation objectives should be achieved by analysing statistical recorded data such as: capacity, sector and segment load, workload, number of conflicts, etc.

The design team should take consideration of the following principles when setting up the simulation objectives. Objectives should -:

- ❑ be high level
- ❑ address specific issues
- ❑ be measurable

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3.5 PREPARATION**3.5.1 PREPARING SCENARIOS****3.5.1.1 Airspace Modelling**

The first step in assessment and validation process is to build a adequate model of the analysed situation i.e. Base Case or Test Case from the Reference or Conceptually developed Scenario, with regard to the tools used for evaluation. These models approximate the Airspace Organisation, and their degree of realism depends of the capabilities of the simulation tool used. The airspace design team should work in close co-operation with the simulation team/experts in order to ensure that the representation of the airspace design in the simulated environment is accurate enough and adequate for the purpose of this assessment/validation phase.

3.5.1.2 Aircraft profiles

The airspace modelling tools generally use simplified aircraft trajectories, called aircraft profiles. Those profiles are usually extracted from more complex data collections such as traffic samples recorded from real life operations.

For the Base Case it is recommended to use as much as possible a real traffic sample (radar data recordings, flight plan system recordings, CFMU database, etc) as a basis for extracting aircraft profiles. A good traffic sample should be representative of the real operation, preferable an average day traffic sample, with normal operation and traffic distribution. It is preferably to use 24h (or longer) traffic samples (if it is feasible with respect to the simulation objectives). The use of short interval samples bears the risk to be non-representative for daily operation or to miss significant events.

For Test Cases, the aircraft profiles should be developed according to the simulation objectives. It is very important to ensure that the traffic distribution (origin/destination, route assignment, hourly/daily distribution, runway in use) is realistic, e.g. it is similar to reality. Whilst for the Base Case it is generally easy to set up a realistic traffic sample, for the Test Case it can be very difficult to forecast the traffic distribution, particularly in the situation when new runway/airports are tested or major changes in the traffic demand are expected. In these conditions, it is recommended to develop more options so as to cover the most probable possibilities.

3.6 DATA ANALYSIS

After the Test Cases have been prepared, which means that the routes, holds and airspace structures are defined and the traffic sample is assigned, data can be extracted by running a series of queries.

The output from airspace modelling includes a large amount of data which can be clustered into several groups:

- ❑ Generic statistical data
 - sector load
 - routes/segments load
 - point load
- ❑ ATC related data
 - workload
 - conflicts

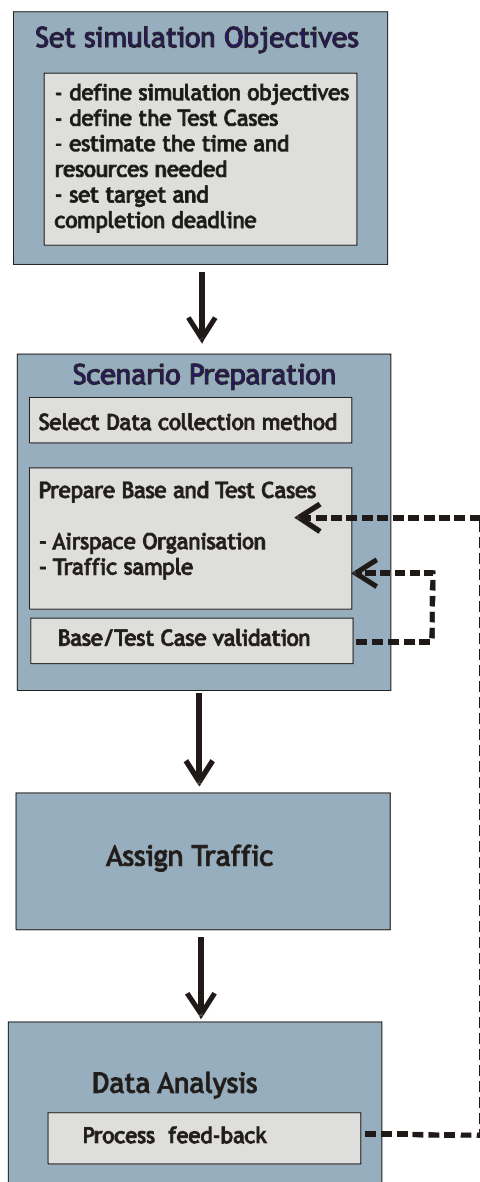
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□ aircraft data related to flight profile e.g.

- flight time
- flight distance

Those data can be used directly for initial estimation or can be processed using various tool and produce more refined result in form of statistical data, charts and graphs. Such data can provide valuable statistical information, but to assess the performance of the various Test Cases, all figures should be filtered and qualitatively assessed.

3.7 SUMMARY OVERVIEW



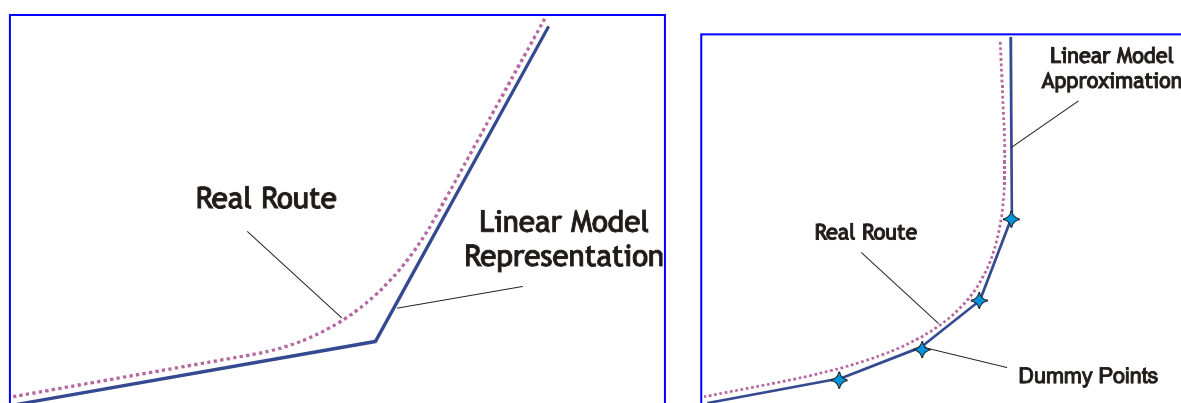
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Terminal Airspace Design Guidelines - Part D**Attachment D.3.1****Airspace Modelling*****Routes, holds and sectors modelling***

The first step in airspace modelling is to translate the design developed by the team into a simplified, computer based representation i.e. the Airspace Organisation and Traffic Sample.

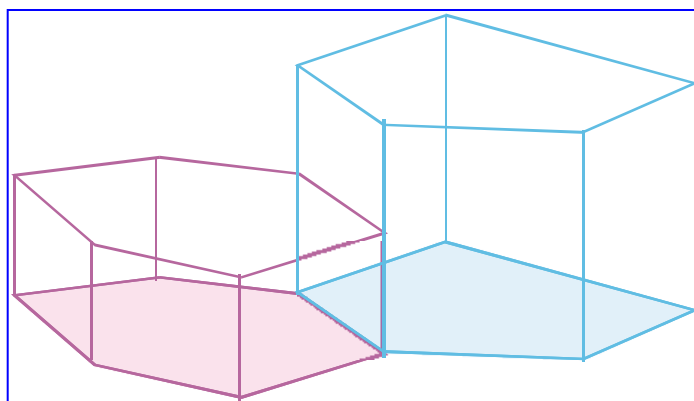
In most of the cases, routes are described as a 2D network of linear segments. These segments could have associated proprieties such as orientation (eastbound/westbound/bi-directional), type (arrival/departure/cruise), etc.



These modelling tools usually do not use curved segments and aircraft models have no turn capabilities. However, in order to describe more accurately the SIDs and STARs, the curved segments of the procedures can be approximated by linear segments.

Similar methods can be used to describe (approximate) the holds. However, the airspace modelling has a very limited application in holds evaluation, due to the limitation of the aircraft model and because the tactical interventions of the ATC normally cannot be described by the tool.

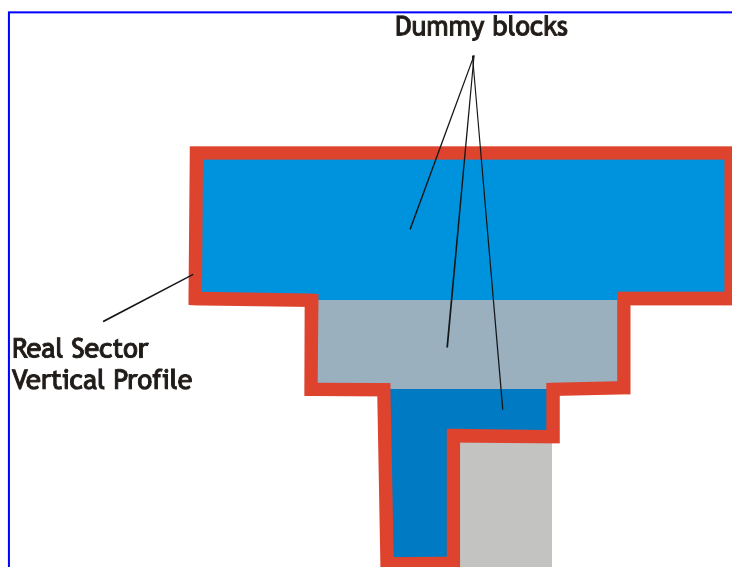
The sectors are represented as airspace blocks defined by their horizontal shape and height.



The horizontal shape of the sectors is described by closed polygons; in the situations when the horizontal shape of the sectors is defined by curves segments these can be approximated by linear segments (as for the routes).

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In the situations where the sector has a complex vertical shape it is necessary to "decompose" it in basic geometric blocks (dummy airspace blocks) which will be linked together for analysis purposes.



After the modelling is complete, the designer should check that the sector configuration is depicted correctly and that there are no "gaps" between the sectors at their common boundaries (in the horizontal and the vertical planes).

CHAPTER 4

- FAST-TIME SIMULATION -

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4.1 PURPOSE OF FAST-TIME SIMULATION (FTS)

As a methodology, Fast-Time simulation is a valuable and frequently used way of validating a proposed design and it may also be used as a way of demonstrating that the safety objectives have been met.

Very often, designers use fast-time simulation as a first step in the validation process i.e. prior to real-time simulation, but also it might be the only step used to validate the concept. Because fast-time simulation is less demanding than real-time simulation in term of human resources, this is often a preferred method for improving the proposed design, identifying flaws in the design concept, and/or preparing the path to real-time simulation or direct implementation.

4.2 PRINCIPLES

As with all simulation tools, Airspace Organisation and Traffic Sample need to be defined for the simulated environment using specific computer language and conventions. To simplify the explanation which follows, various parameters of the Airspace Organisation and Traffic Sample are discussed under separate headings.

4.2.1 ROUTES

Usually, **any route** in a FTS is defined by linear segments between points. The aircraft model follows the planned turns in the route according to the aircraft performance defined in the aircraft performance database used by the Traffic Sample. Because FTS flight trajectories are computer generated models, all aircraft naturally follow, *with maximum accuracy*, the planned flight trajectory unless, deviations are specifically programmed into the trajectory.

Additionally, routes in the FTS have associated vertical constraints used to model a realistic behaviour of the aircraft in the vertical dimension (These are types of Rules in the Traffic Sample). These constraints could be generally applicable to all aircraft or defined on a flight-by-flight basis. For their part, tactical manoeuvres (e.g. radar vectors) are replicated by the creation of a set of fictional routes which are designed to overlap the tactical allocated paths.

Some simulators can use imported real-radar data and the extracted trajectories can be used in simulation.

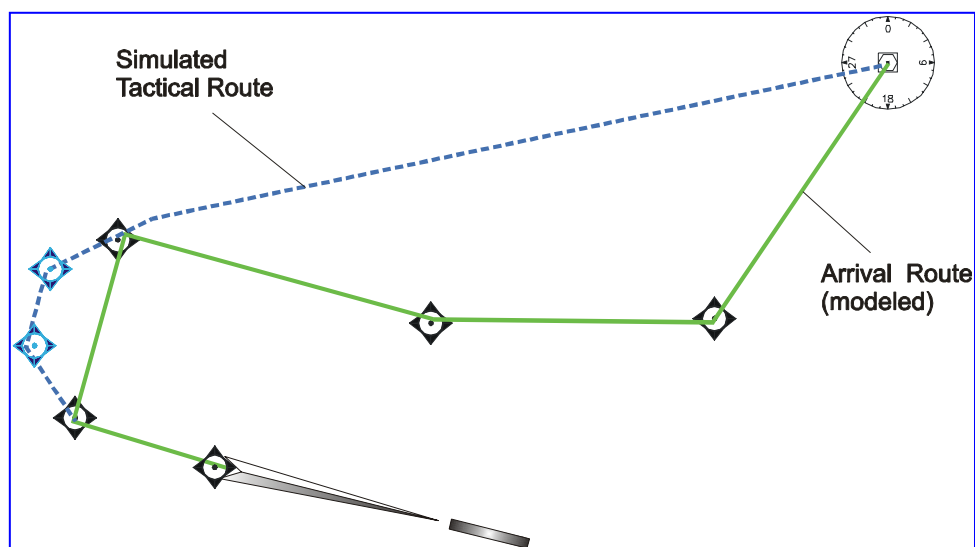


Figure 4 - 1: Sample FTS Route definition

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4.2.2 TERMINAL AIRSPACE STRUCTURES AND SECTORS

The same logic is applicable to the airspace modelling of Terminal Airspace Structures and ATC Sectors: the airspace is represented by blocks defined by a horizontal shape and height. In this respect, functional sectors are difficult to model. A way around is to define fictional blocks of airspace for each functional sector and assign the specific controller task to each one.

4.2.3 RULES

In a FTS the behaviour of aircraft is dictated by a series of rules which are generally defined for some or all Test Cases or specifically for each block of airspace, route segment or waypoint. Without these rules, the simulated aircraft will fly their optimum profiles according to their flight plan which seldom reflects real life operation.

Rules are used by the simulator engine to mimic pilots and ATC actions, such as:

- ❑ tactical routes assignment
- ❑ vertical manoeuvres
- ❑ conflict detection and conflict solving
- ❑ sequencing and metering

The Rules are based on data emerging from the following sources:

- ❑ LoAs
- ❑ Route Availability Document restrictions
- ❑ SID/STARs vertical profiles
- ❑ speed restrictions
- ❑ operational practices

4.2.4 HOW IT WORKS

The simulator engine generates 4D trajectories (position + time) for each aircraft based upon flight plan information and rules stated in the Test Cases. The system checks each trajectory for certain predefined events. Examples of such predefined events may include conflicts (remembering that defining the parameters of what constitutes a conflict might need to be written into the rules – see para. 4.2.5), level changes, routes changes, sector entry or exit. When such an event is detected, the system increments the defined counters and trigger tasks parameters linked to the event. For example, if the system detects that an aircraft has crossed a sector border, it will increase by one the number of aircraft counted in that specific sector and will trigger as active the tasks assigned to the controllers (such as hand-over, transfer of communication, identification, etc).

In the simulator model, controller actions are described by **task**. These tasks are basic ATC actions, which are triggered by specific events and have a time value associated with it. This value is the time required in real life for the controller to fulfil the specific action.

The simulator adds the values of the task parameter for a given Test Case and the result value gives an indication of controller workload. Usually, a controller is considered not to be overloaded if this figure does not exceed 70% of the total time of the Test Case.

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The precision of workload indication is higher when the ATC *modus operandi* is better known and formalised, e.g. it could be described by basic task with clearly identified trigger events and well determined time parameters.

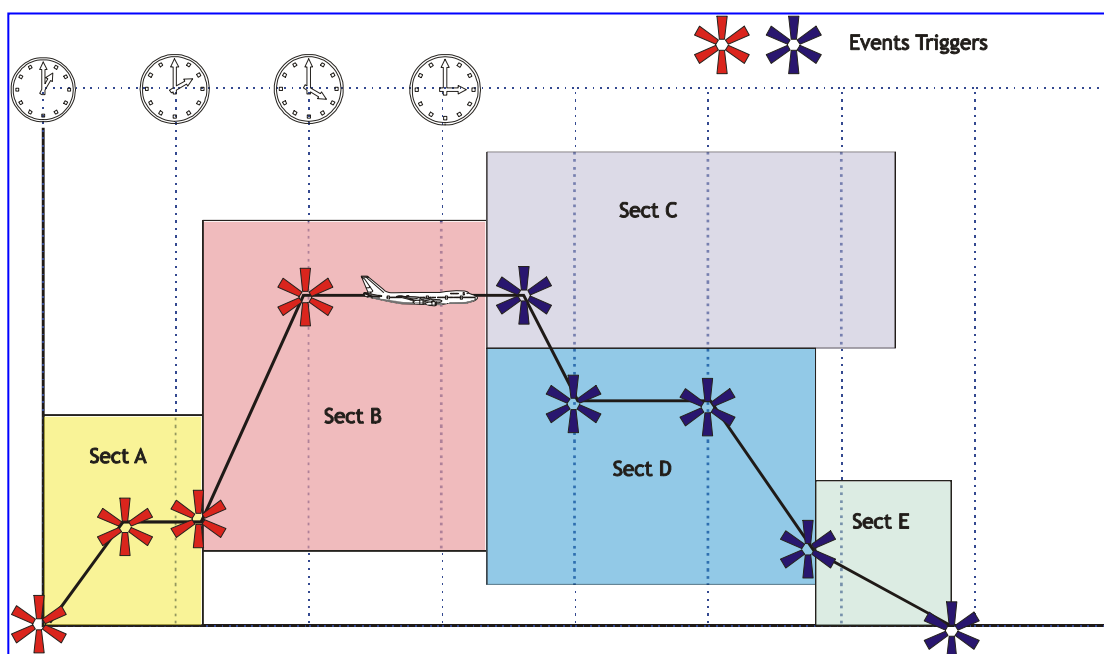


Figure 4 - 2: Event Triggers in FTS

4.2.5 CONFLICT DETECTION AND RESOLUTION

Based on values used in each sector for vertical and horizontal separation the simulator builds around each aircraft a protected volume (which can be assimilated usually with a cylinder). The system will detect a conflict when one aircraft's protected volume touches or intersects another aircraft's protected volume.

Because the FTS is based only on mathematical calculation the careful setting of the separation value is of paramount importance for the accuracy of the modelling. For example if the separation value is set for 2.999 Nm for aircraft flying on parallel routes spaced at 3 Nm the system will record no conflict, but if the separation is set at 3 Nm all the aircraft on those routes will be in conflict for the simulator.

After detecting a conflict, the simulator can handle the situation in two different ways:

- ❑ the conflict is recorded and the trajectories of the involved aircraft are not affected
- ❑ the simulator tries to "solve" the conflict by altering the trajectories of the involved aircraft at the appropriate moments. The way the simulator modifies the trajectories is dictated by the conflict solving rules, which should be set up before hand.

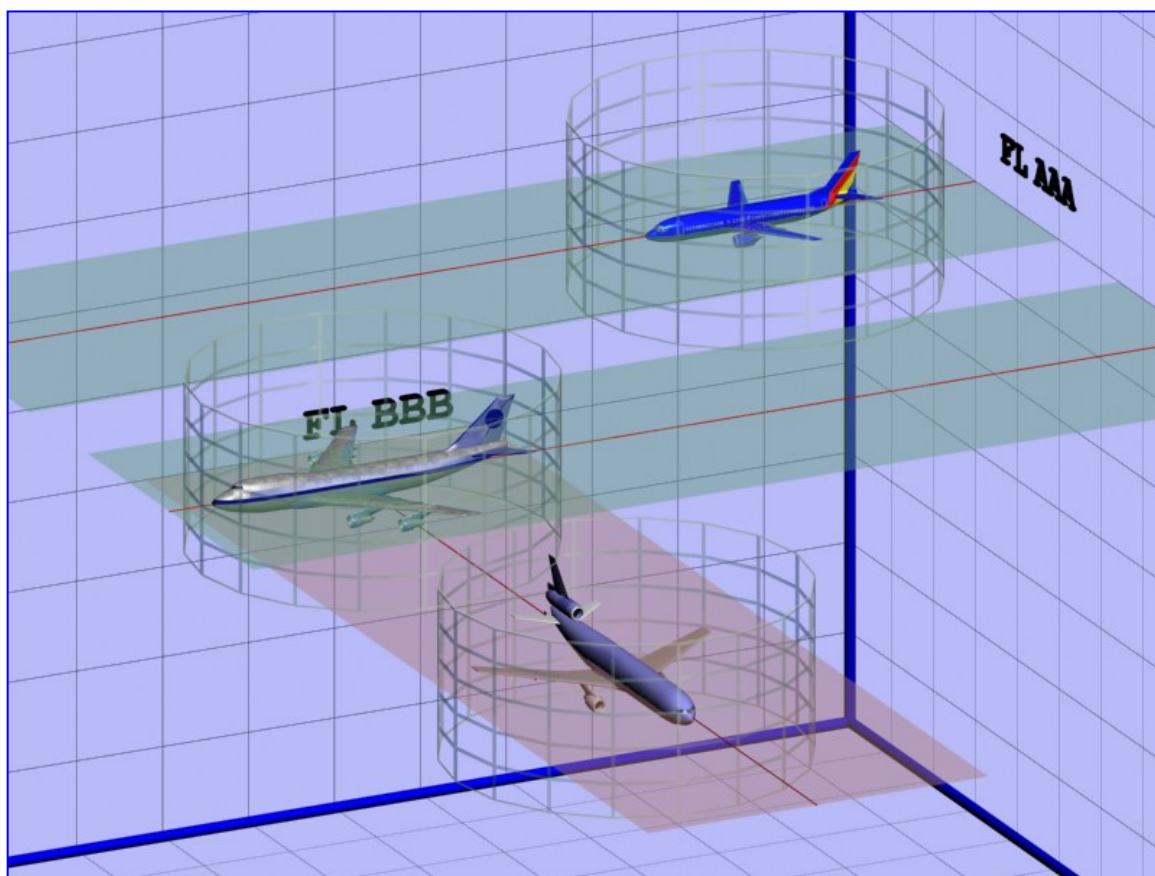
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Figure 4 - 3: Airspace Protected Volumes

4.3 ADVANTAGES & LIMITATIONS

4.3.1 FAST TIME SIMULATION ADVANTAGES

- ❑ one of the most frequently used methods for sector capacity assessments
- ❑ gives opportunity to collect quality data
- ❑ relatively unlimited scope and great flexibility
- ❑ relatively simple to assess various alternatives
- ❑ relatively easy Test Case adaptation
- ❑ relatively easy to test large number of traffic samples
- ❑ can use real traffic and environment data
- ❑ good acceptance of the results
- ❑ can evaluate the achievement of the TLS (Target Level of Safety)
- ❑ can inform safety case development

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4.3.2 FAST TIME SIMULATION DISADVANTAGES

- ❑ simplified model of “real” operation
- ❑ can provide only statistical data
- ❑ cannot replicate tactical controller interventions
- ❑ quality of results depends heavily on the accuracy of the model
- ❑ limited aircraft performance and simplified aircraft behaviour
- ❑ low representation of meteorological conditions
- ❑ difficult to involve users

4.4 SETTING FAST TIME SIMULATION OBJECTIVES

Because of the theoretical nature of this method, the simulation objectives should be achieved by analysing statistical recorded data such as: capacity, sector and segment load, workload, number of conflicts, etc.

The design team should take consideration of the following principles when setting up the simulation objectives. Objectives should :

- ❑ be specific and limited
- ❑ be measurable
- ❑ not aim to test too many things in one simulation

After deciding on the simulation objectives the design team should complete the following actions:

- ❑ define the Base and Test Cases in general terms and ascertain their feasibility.
- ❑ decide on the number of assessments required
- ❑ estimate the time and resources needed
- ❑ set target and the completion deadline

4.5 PREPARATION**4.5.1 ESTABLISH DATA COLLECTION METHOD**

Prior to Test Case definition it is necessary to decide which parameters and performance indicators will be used to assess the simulation and what method will be used to collect the required data.

The output from a fast-time simulation includes a large amount of data which can be clustered into several groups:

- ❑ generic statistical data
 - sector load
 - routes/segments load
 - point load
 - airport/runway acceptance rate
 - airport/runway departure rate

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- ❑ ATC action related data
 - workload
 - conflicts
- ❑ aircraft related data
 - flight time
 - flight distance
 - delays
 - fuel consumption

4.5.2 PREPARING TEST CASES**4.5.2.1 Set up routes, holds and sectors**

As explained in the para. 4.2, the representation of the routes, holds and sectors inside the simulator is subtly different from the one depicted on the drawing board of the design team.

The design team should ensure that for each Test Case the translation between the real airspace (existing or the new designs) and simulation Test Case airspace is done accurately.

4.5.2.2 Traffic sample

For the Base Case it is recommended to use as much as possible a real traffic sample (radar data recordings, flight plan system recordings, CFMU database, etc). A good traffic sample should be representative for the real operation, preferable an average day traffic sample, with normal operation and traffic distribution. It is preferably to use 24h (or longer) traffic samples (if it is feasible with respect to the simulation objectives). The use of short interval samples bears the risk of being non-representative for daily operation or of missing significant events.

4.5.2.3 Set up ATC Task parameters

The appreciation of the ATC workload and sector capacity evaluation is based on the assessment of the required time for the controllers to complete specified tasks. Air traffic controllers' actions in real life are described in the simulation environment by various tasks. These tasks are basic actions which are triggered by specific events and have a time value associated with it (the nominal time required to the controller to perform that specific action).

The accuracy of the FTS result is directly related to how well the real life ATC actions (ATC *modus operandi*) can be described in a formalised way within the simulator protocols and of the accuracy of time values associated with the tasks.

The modalities to determine the task and their associated time values are:

- ❑ expert judgement based on experience
- ❑ operational controller interviews
- ❑ real life data collection (by observing and timing real life operations)

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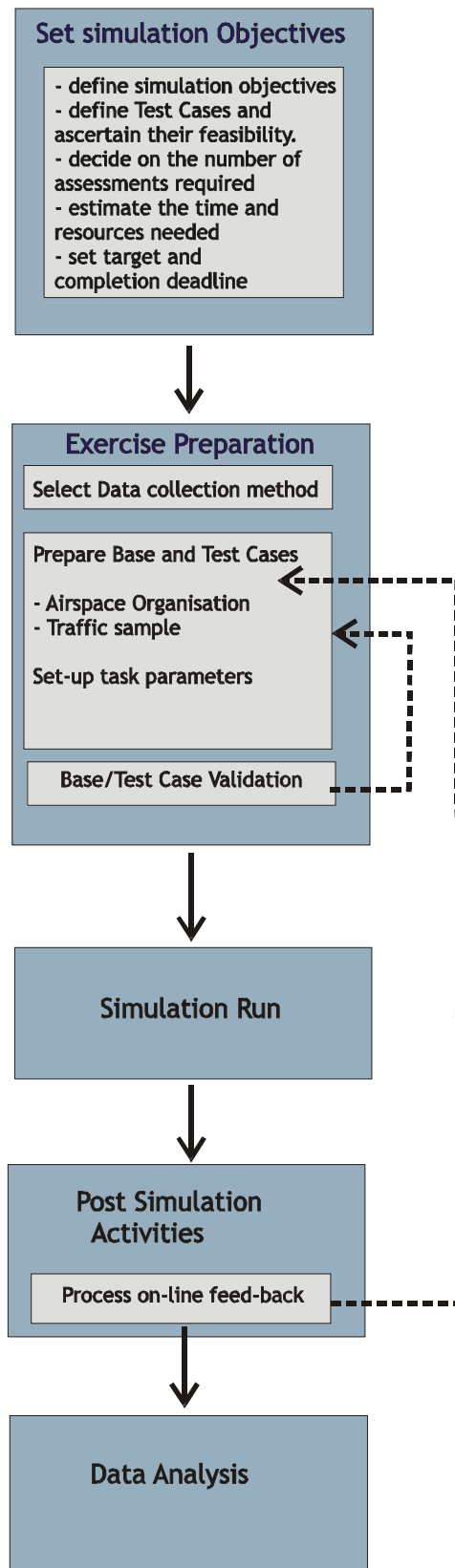
4.6 DATA ANALYSIS

After running the FTS a large amount of data is collected:

- ❑ Airport movements/delays.
- ❑ Sector movements/workloads
- ❑ Global Flight Data Record - 4D Position data
- ❑ Events logs (conflicts, sector changes, level changes, etc)
- ❑ Message File (Records terminations, errors reports, etc)

This data can be used directly for initial estimation or can be processed using various tool and produce more refined result in form of statistical data, charts and graphs.

The statistical data collected by FTS does not constitute a final product by itself. In order to have a realistic view of the performances of Test Cases assessed, all data resulted from FTS should be subjected to a qualitative assessment by ATC experts. The acceptance or rejection of one particular airspace design cannot be based only on the numerical data resulting from FTS without considering the ATC perspective on that particular case.

Terminal Airspace Design Guidelines - Part D**4.7 SUMMARY OVERVIEW**

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CHAPTER 5

- REAL-TIME SIMULATION –

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Terminal Airspace Design Guidelines - Part D**5.1 PURPOSE OF REAL-TIME SIMULATION (RTS)**

As a methodology, Real-Time simulation is used in the later stages of the validation of a proposed design and it may also be used as a way of demonstrating that both the safety objectives and operational objectives have been met.

Often, the real-time simulation is used as a final check of the design and as the preparatory step for the implementation. This method is used mainly because it provides live feedback from the operational air traffic controller and for its potential high degree of realism.

5.2 PRINCIPLES

The Real Time Simulator tries to replicate as accurately as possible the real working environment of involved air traffic controllers. The main components of a RTS platform are:

- ❑ simulator engine
- ❑ active controller positions
- ❑ pseudo pilots and feeder sectors
- ❑ data recording system

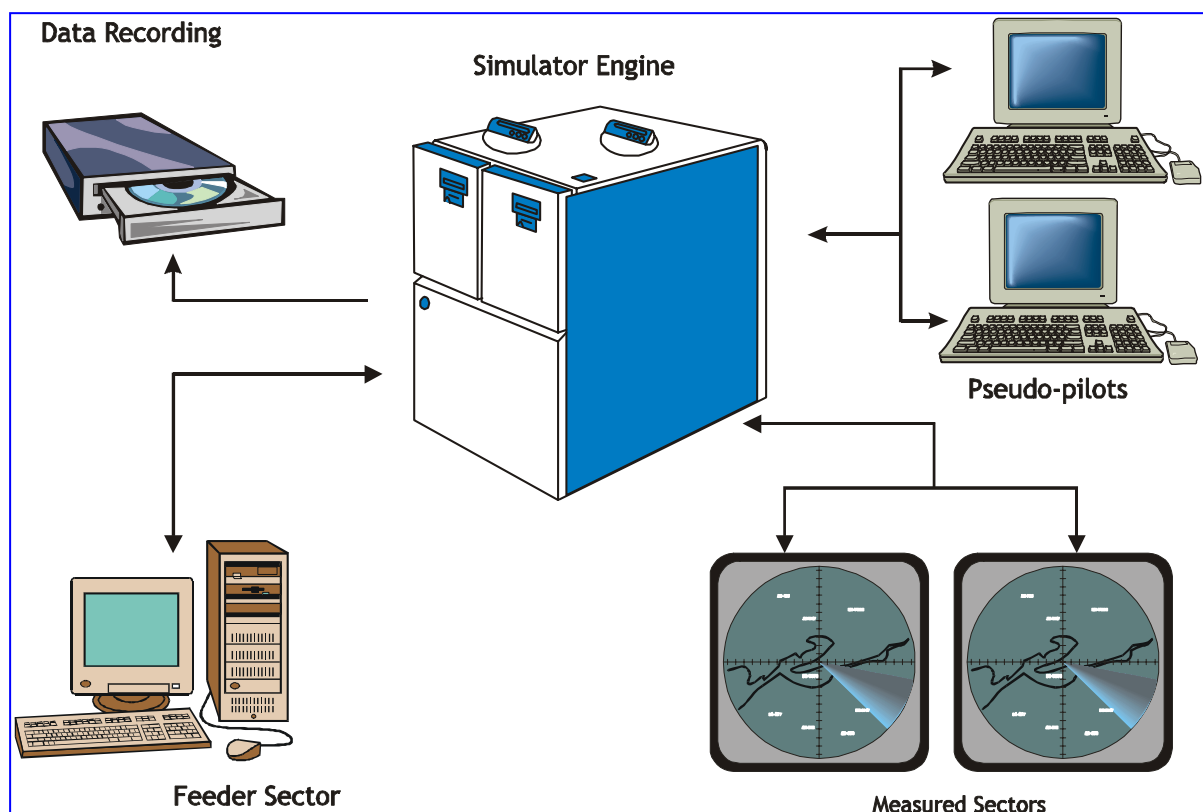


Figure 5 - 1: Components of an RTS Platform

The simulator engine process the flight plans and the inputs from the pseudo pilots and controllers and provide all positions with the relevant data as do real RDP (Radar Data Processing System) and FDP (Flight Data Processing System) systems.

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5.3 ADVANTAGES & LIMITATIONS**5.3.1 REAL TIME SIMULATION ADVANTAGES**

- ❑ closest simulation method to the live ATC trials which can be used to assess and validate simulation objectives
- ❑ gives opportunity to collect high quality quantitative and qualitative data
- ❑ feed-back from controllers, based on operational experience (further qualitative assessment)
- ❑ feed-back from pseudo-pilots (depending on their expertise and simulation conditions)
- ❑ can indicate and assess human factor related issues (further qualitative and quantitative assessment)
- ❑ automatic data collection (for quantitative assessment)
- ❑ unlimited scope and greater flexibility compared to the live trials (further qualitative assessment)
- ❑ no risk to the live operation
- ❑ allow testing of contingency procedures and hazard analysis (qualitative and quantitative assessment)
- ❑ simple to assess various alternatives
- ❑ on-line feed-back and scenario adaptation (qualitative assessment)
- ❑ can use real traffic and environment data (quantitative input)
- ❑ good acceptance of the results by the controllers (wide scope qualitative assessment)
- ❑ can be part of a safety case

5.3.2 REAL TIME SIMULATION DISADVANTAGES

- ❑ sterile environment: limited HMI (Human Machine Interface) capabilities, artificial RT, limited radar performance
- ❑ limited aircraft performance and simplified aircraft behaviour
- ❑ not realistic aircraft behaviour due to pseudo-pilots without, or with limited, aviation experience
- ❑ pseudo-pilots cannot replicate real crews performance
- ❑ low representation of meteorological conditions
- ❑ human factor related drawbacks:
 - controller mind-set
 - exercise/scenario learning curve
 - subjectivity of assessment (mainly with regard to workload)
 - macho attitude
- ❑ controllers feed-back clouded by historic experience
- ❑ cost and time demanding
- ❑ potentially resource intensive
- ❑ difficulties related to the operational controllers availability for simulation

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- ❑ difficult to involve users directly

5.4 SETTING REAL TIME SIMULATION OBJECTIVES

Because of the great flexibility and potential accuracy of this method the range of the possible simulation objective is extremely large (from capacity and feasibility evaluation to sophisticated human factor and safety measurements). For this reason, the design team should take consideration of the following principles when setting up the simulation objectives. The objectives should -:

- ❑ be specific and limited
- ❑ be measurable and realistic
- ❑ not aim to test too many things in one simulation

After deciding on the simulation objectives the design and simulation teams should complete the following actions:

- ❑ define the scenario in general terms and ascertain their feasibility.
- ❑ decide on the number of assessments required
- ❑ estimate the time and resources needed
- ❑ set target and the completion deadline

5.5 REAL TIME SIMULATION PREPARATION

5.5.1 DATA COLLECTION METHOD

After setting up objectives the design team should decide which parameters should be analysed in order to achieve the simulation objectives. There are two types of data collection methods available for the real-time simulation:

- ❑ manual data collection (debriefing, questionnaires, survey)
- ❑ automatic data collection (recordings and statistics of RT, radar tracks, controllers and pseudo-pilots inputs, etc)

Usually, both methods are used in conjunction and the comparison of the results is very useful in order to eliminate biases. Simulation teams should be aware that a real time simulation could generate vast amount of information and if recording and storage are not issue, the processing of this data could be a long, laborious and work intensive process. Based on the simulation objectives, the team should decide which data are needed for evaluation/recording. The amount required should be kept within practical limits and available time.

5.5.2 EXERCISE PREPARATION

The real simulation consists of a Base Case and a series of Test Cases. Each case contains:

- ❑ Airspace Organisation and Traffic Sample
- ❑ ATC environment
- ❑ scripts

The number of Test Cases is directly determined by the simulation objectives: complex and ambitious simulation objectives require a large number of variable Airspace Organisations or Traffic Samples, a great number of Test Scenarios will be required to achieve these objectives.

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The Simulation team leader should take into consideration that each Test Case should be run multiple times and the controllers should change their position on each run in order to eliminate as much as possible the biases and to obtain reliable results.

5.5.2.1 Traffic sample preparation

General assumption regarding the traffic samples used in RTS:

- ❑ aircraft entering in the measured sector are free of conflict
- ❑ all aircraft exiting the measured sectors are accepted without restriction by the receiving sectors (if complying with LoAs)
- ❑ all the measured sector should be loaded evenly (if practicable, without affecting the credibility of the Traffic Sample)
- ❑ a traffic build up period should be provided at the beginning of each exercise

For the Reference Traffic Sample, real data (e.g. RDP/FDP recordings) can be used; however in most of cases this data will require manipulation in order to fulfil the above assumptions.

For the Test Cases, the Traffic Samples should be re-aligned to reflect the modification foreseen in each exercise for:

- ❑ the route scheme (new routes, new runways, etc)
- ❑ traffic level (increase of traffic, change of the distribution of traffic, etc)
- ❑ aircraft performance/equipment

In order to reduce the cost and time required for traffic sample preparation it is recommended to use in real time simulation the traffic samples tested before in Fast Time Simulation process.

5.5.2.2 Simulation ATC environment preparation

The simulation environment is defined by:

- ❑ The Airspace Organisation and its Rules, with particular attention paid to the configuration of Feed and Measured Sectors.
- ❑ HMI configuration (establish availability of safety nets, automated tools, etc)

The Base Case environment should reflect as much as possible the existing situation as regards the Airspace Organisation and its Rules.

5.5.2.3 Exercise validation

Prior to running the Real Time Simulation a recommended step is to verify the correctness of the exercises. The main checkpoints could be:

- ❑ traffic sample:
 - appropriate traffic distribution for measured sectors
 - traffic pattern is according to specification (time and geographic)
 - the sector sequence is correct
 - aircraft are free of conflict when entering in the measured sector – in accordance with inter-sector agreements
- ❑ ATC environment:

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- the HMI is according to the specification
- the sectors are displayed correct on HMI
 - the sectors are connected correctly
 - the RT links are correct
- ❑ Data collection
 - Confirm if data collection tools are in place and are recording the desired data

5.6 TRAINING

The training phase is very important in order to achieve the simulation objectives. Training is undertaken by both controllers and pseudo-pilots, and could involve:

- ❑ training documentation (maps, procedures, rules, CBT, etc)
- ❑ briefings
- ❑ training session

Training goals include -

- ❑ to present the simulation objectives
- ❑ to make the participants familiar with:
 - simulation assumptions
 - simulated airspace organisation
 - traffic in the Traffic Sample
 - rules and specific procedures
- ❑ to make participants familiar with the simulation platform

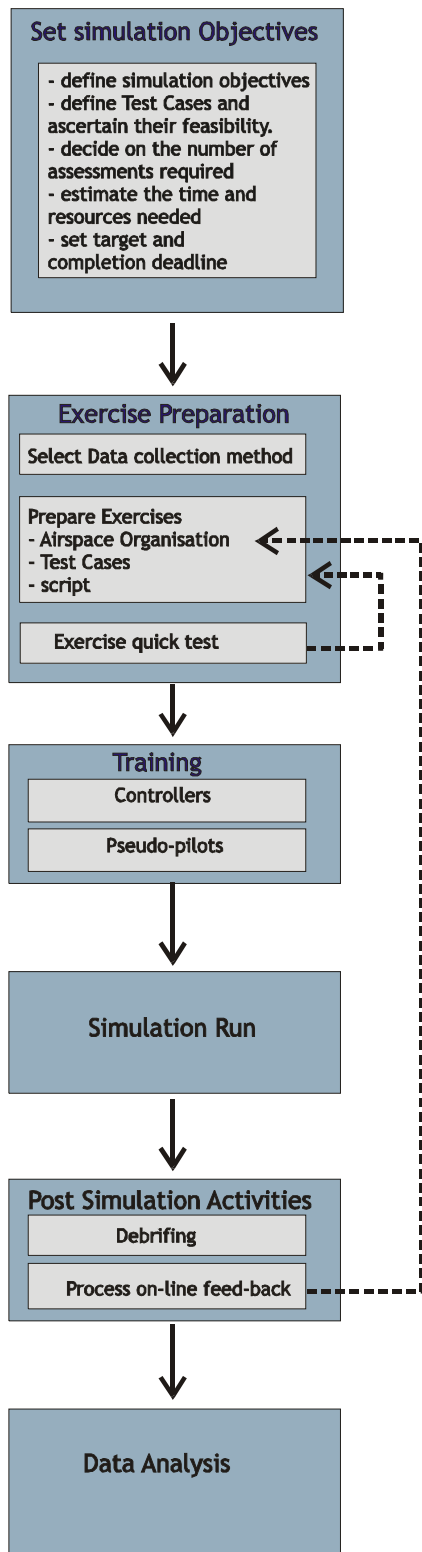
When human factor related issues are to be analysed by RTS, part of the simulation objectives may not be revealed to the participant controllers in order not to affect the accuracy of the results.

5.7 DATA ANALYSIS

After running the RTS a large amount of data is collected:

- ❑ automatic collected data (recordings and statistics of RT, radar tracks, controllers and pseudo-pilots inputs, etc)
- ❑ questionnaires and debriefings
- ❑ direct feed-back collected during the simulation

The analysis and interpretation of the data collected by RTS can be a resource intensive and complex process. Depending on the simulation complexity, a multi-disciplinary team may be required to analyse the data: ATC experts, simulation experts, data analysts and human-factor specialists.

Terminal Airspace Design Guidelines - Part D**5.8 SUMMARY OVERVIEW**

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CHAPTER 6

- LIVE ATC TRIALS -

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6.1 PURPOSE OF LIVE ATC TRIALS

Live ATC Trials are probably the least used validation method. Generally, this is because it is perceived as carrying the highest risks despite providing what is probably the highest degree of realism. When used, Live Trials tend to be aimed at assessing a very specific factor such as a SID or STAR, a new Terminal Area Procedure or a new Sector design with a very limited traffic sample.

6.2 PRINCIPLES

Live trials take place and are part of real-time air traffic operations using new/re-designed procedures (routes, airspace, etc) for a selected number of participants, in restricted condition and under a close supervision.

6.3 ADVANTAGES & LIMITATIONS**6.3.1 LIVE TRIALS ADVANTAGES**

- ☐ it is the most accurate validation method
- ☐ real data are collected
- ☐ gather feed-back from all users
- ☐ good acceptance of the results by the users

6.3.2 LIVE TRIALS LIMITATION

- ☐ safety implication
- ☐ very detailed required
- ☐ limited scope
- ☐ limited flexibility

6.4 SETTING OBJECTIVES

In this particular case the objectives are directly linked to the feasibility of the design implementation and they should follow the next principles:

- ☐ objectives should be specific
- ☐ objectives should be measurable
- ☐ a clear deadline should be set for the completion of trials

6.5 PREPARATION OF LIVE TRIALS**6.5.1 PREPARE DATA COLLECTION**

Data collection method available for live trials:

- ☐ debriefings, questionnaires, interviews
- ☐ data recorded by ground systems (noise monitoring system records, radar tracks records, RT records, etc)
- ☐ data recorded by airborne systems (flight recorders, etc)

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6.5.2 PREPARATION OF LIVE TRIALS

Because live trials take place and are part of live operations, the preparatory phase is very important if objectives are to be achieved without compromising required levels of safety.

The preparation phase should involve all the participants and specific tasks and safety responsibility should be acknowledged by each of them.

- National Regulator:
 - establish legal framework (liabilities, certification, other legal aspects)
 - safety related issues
- ATM Service provider
 - design routes and airspace
 - develop operational procedures
 - develop fall back and contingency procedures
 - prepare the ATM system
 - test procedures in simulators
 - develop training material
 - ensure regulatory approval
- Users (aircraft operators, general aviation, military. etc)
 - develop operational procedures
 - develop fall back and contingency procedures
 - prepare/update airborne systems
 - test procedures in simulators
 - develop training material
 - ensure regulatory approval
- Other participants (airport authorities, civil organisation, etc)
 - develop specific procedures
 - prepare participants

6.5.3 NOTIFY LIVE TRIALS PARTICIPANTS

- **Who:**
 - ATC staff (operational + support)
 - neighbouring ATC units
 - ATC support units
 - users (aircraft operators, general aviation, etc)
 - airport authorities
 - military authorities

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□ How:

- aeronautical publications
- NOTAMs
- workshops & briefings

6.6 TRAINING PARTICIPANTS

Because live trials are part of live operations, the proper training and preparation of all participants is crucial. The training phase should be geared to ensuring that all participants -

- know the simulation objectives
- are familiar with the new procedures
- know their responsibilities
- know the trials' programme
- know the contingency procedures

The training can be achieved by:

- seminars and workshops
- individual training (documentation, CBTs – computer based training)
- training sessions in simulators (for pilots and ATC controllers)

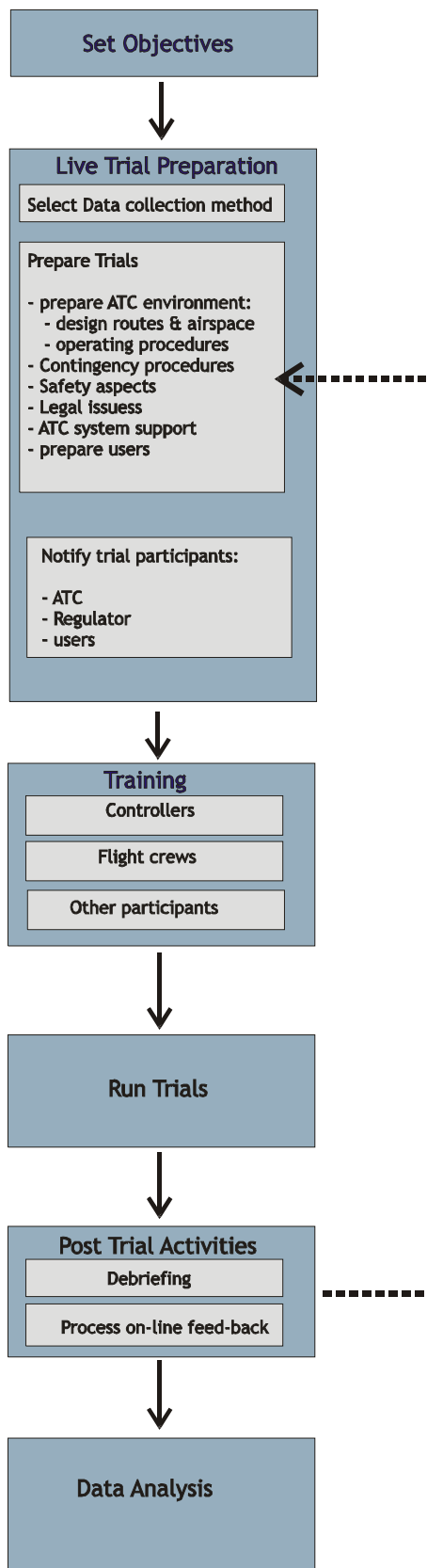
6.7 DATA ANALYSIS

Data from live trials is gathered from various sources:

- automatic collected data from ground & airborne sources (radar data recordings, noise monitoring, performance monitoring, flight recorder data, etc)
- questionnaires and debriefings from all participants
- direct feed-back collected during the trials

All data should be analysed, balanced, filtered and collated in order to obtain a full picture of the operations.

The data collection process could be lengthy and some intermediate data processing and analysis could occur. A multi-disciplinary team can be set up to monitor the trials and to analyse the resulting data. This multi-disciplinary team can be made up of ATC experts, pilots, aerodrome operation experts, safety experts, data analysts and human-factor specialists.

Terminal Airspace Design Guidelines - Part D**6.8 SUMMARY OVERVIEW**

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CHAPTER 7

– FLIGHT SIMULATION –

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7.1 INTRODUCTION

Full flight simulators are renowned for their superior realism and accuracy in reproducing all of the operational characteristics of a specific aircraft type. Normal and abnormal situations, including all of the environmental conditions encountered in actual flight, can be precisely simulated. The use of simulators has increased due to advances in technology and the significant cost savings provided by flight simulation training, compared with real flight time. Today's commercial flight simulators are so sophisticated that pilots proficient on one aircraft type can be completely trained on the simulator for a new type before ever flying the aircraft itself.

7.2 WHAT IS A FLIGHT SIMULATOR?

The main elements of a flight simulator are the cockpit, motion system, visual system, computer, and instructor/operator station. The cockpit provides a suitable environment for the crew in terms of the location, appearance, and feel of controls and displays. All modern simulators are mounted on a hydraulically operated motion platform, capable of imparting to the crew the impression of aircraft movement, adding to the fidelity of the observed response to flight control inputs and external disturbances. Motion cues are particularly important in critical handling tasks, and during instrument flight. The visual system presents the view seen by the pilot of the external visual scene. Advanced technology is needed to achieve representative scene details over a large field of view. The computer must process in real time the mathematical models which represent the aircraft, its systems, and the operating environment. It receives signals from the cockpit, and provides inputs to the other elements in the simulation.

7.3 USES

In addition to the training of pilots in flying the aircraft, flight simulation has an invaluable role to play in other aeronautical areas, such as research, accident investigation, aircraft design and development, operational analysis, and other activities such as space flight. Research areas include new concepts, new systems, flying qualities, and human factors. Most aircraft manufacturers use research simulators as an integral part of aircraft design, development and clearance. Major aeronautical projects would now be impractical without the extensive use of flight simulation, on both cost and safety grounds.

7.3.1 SPECIFIC VS. GENERIC

The current pilot shortage is likely to last some time and there will be a continual need for pilots to move up from small piston aircraft via turboprop commuters to jets. The transition from propeller aircraft to jets may be aided significantly by the use of generic simulators. The basic cockpit layout will need to be fixed in hardware terms, but some variation in performance and handling qualities could be possible by the use of different software. In this way the implications of large speed ranges, the ability to think more quickly and the very different handling qualities at high altitudes and lower speeds can be taught and demonstrated cost-effectively. If this potential requirement is accommodated, then the knock-on effect for ATM and airspace evaluation would be beneficial.

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7.3.2 SPECIFIC AIRSPACE PROJECT USE

A significant amount of the planning task for Terminal Airspace Design can be achieved by the other assessment methods shown in this section and flight simulators, the primary use of which is for the training of pilots, were not originally designed to play a role in ATM evaluations per se.

However, there are several areas in which the use of a flight simulator can assist in the successful completion of Terminal Airspace projects. One example is in the achievement of credibility. In addition to the well known noise and emission effects on operations on and around runways, whether in existence or planned, environmental issues are now influencing the positioning of routes (and their associated altitude) within the whole of Terminal Airspace at an increasing number of locations throughout ECAC.

Of course, environmental matters are paramount in the importance of many interested parties such as local residents' associations, environmental lobby groups, airport management to name but a few. It has become clear that it can be very difficult to convince these bodies that their environmental concerns have been addressed fully by the use of mathematical models and/or fast-time simulations.

This is where the flight simulator comes into its own. Using representative aircraft (simulators), the various options for airspace can be extensively flown and data recorded, such as airframe configuration (which affects the noise produced by the aircraft), fuel burn, track miles flown, altitude and so on. Depending on the requirements of a project and how sophistication of the data which is gathered, the results can be fed into analysis software for such parameters as aircraft noise and emissions.

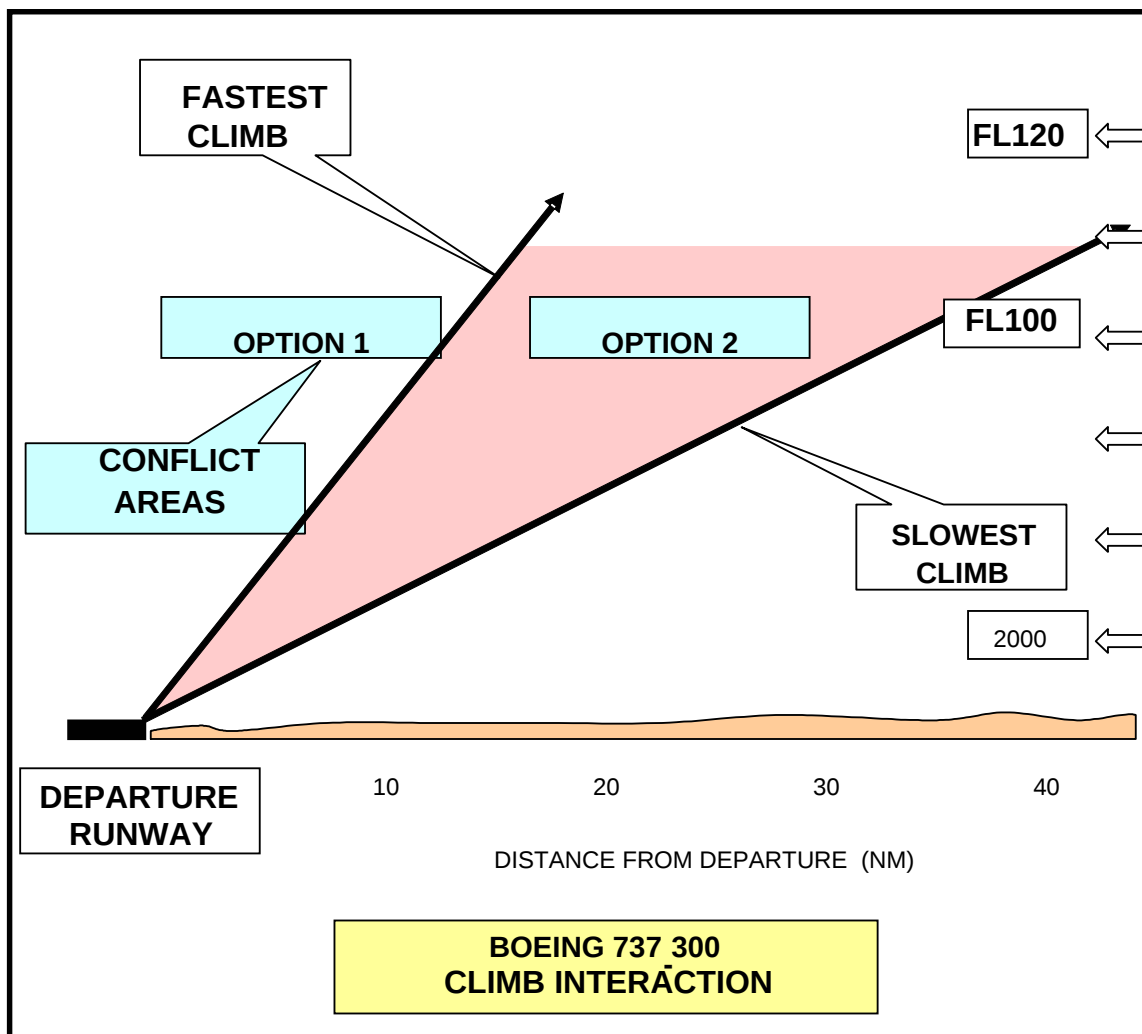
Apart from intensive, expensive live flight trials which are difficult to integrate with on-going operations, the use of the flight simulator is the closest to reality. The credibility factor is further enhanced if operational line pilots are used to fly the flight simulator. Once the data has been analysed, it can then be presented in the most appropriate way for the target audience.

EXAMPLE 1

Use of a flight simulator for airspace projects can range from simple to highly detailed. Example 1 describes a simple use. For this hypothetical project, it was necessary to assess which of the alternative arrival tracks (at FL100 - Option 1 and Option 2) had least effect on an uninterrupted climb of the most common aircraft at this particular location. Altitude measurements were to be taken at specific distances from the departure end of the runway. In order to carry out the measurements across the widest spread of weight and temperature conditions, the aircraft was first operated at maximum take-off weight in the highest ambient temperature experienced at the location in question. This produced the lowest climb rate. The second parameter measured was when the aircraft was very light and the temperature was very low – thus producing the best climb rate. This was repeated several times to ensure that the results were not anomalous and the data was inserted in Table 7 - 1. (The figures shown here are representative only).

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	LIGHT AND COLD	HOT AND HEAVY
5	4000 ft	2000 ft
10	6250 ft	3900 ft
15	FL100	5000 ft
20	Extrapolate	5800 ft
25		6250 ft
30		FL75
35		FL80
40		Extrapolate

Table 7 - 1: Rate of Climb data under different conditions**Figure 7 - 1: Diagrammatic representation of Table 7-1**

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By plotting the position of the two alternatives (Option 1 and Option 2) at the appropriate distances from the runway end, it can easily be seen that, whilst the climb profile range of the aircraft entirely encompasses Option 2, Option 1 is almost entirely outside the climb performance of the 737-300 used for the simulation. Therefore, from an aircraft point-of-view, selection of Option 1 as the arrival track would, in almost all circumstances, allow unrestricted climbs to be achieved by this aircraft type. Clearly, aircraft performance is not the only criterion to be assessed when selecting the route placement, but it is a valuable aid to the decision-making process.

EXAMPLE 2

A more complex assessment would group several of the measurement metrics together. In this example, the assessment includes altitude and time at a given point, track miles flown and fuel burn. One recent large-scale project required the use of both a medium category aircraft simulator (Boeing 737 type) and a heavy category (Boeing 747 type). Example 2 details an assessment of three different arrival profile proposals and Table 7 - 2 reflects the data gathering exercise for the Boeing 747 runs.

OPTION A	AFC	TP 1	END D/W	FAWP	LANDING	FUEL	TOTAL	TOTAL
		N57 35.0	N57 44.0	PT R074		BURN	FLIGHT	ROUTE
		E00155.0	E002 56.7	D11.9			TIME	LENGTH
	11000	11000				KGS	MINS/SECS	NM
	11000	11000	6295	3986				
FUEL	8020				7299	721		
ELAPSED TIME	0:00	6:09	14:07	17:15	21:02		21:02	
TRACK NM	0	35.1	76.4	90.3	102.3			102.3
OPTION B	AFC	RER	MELPO	FA	LANDING	FUEL	TOTAL	TOTAL
			PRMR134	PT R074		BURN	FLIGHT	ROUTE
			D10.0	D18.0			TIME	LENGTH
	11000	11000	9000	5000		KGS	MINS/SECS	NM
	11000	10977	9000	4984				
FUEL	8014				7195	819		
ELAPSED TIME	0:00	5:40	11:40	18:15	23:59		23:59	
TRACK NM	0	40.9	71.8	101.9	116.9			117
OPTION C	AFC	EM	DESC PT	FA	LANDING	FUEL	TOTAL	TOTAL
			PT R163	PT R074		BURN	FLIGHT	ROUTE
			D17.2	D12.0			TIME	LENGTH
	11000	11000				KGS	MINS/SECS	NM
	11000	11000	10605	3983				
FUEL	8028				7324	704		
ELAPSED TIME	0:00	5:24	8:55	15:20	19:40		19:40	
TRACK NM	0	39.3	58.6	87.5	99.5			99.5

Table 7 - 2: Grouped Measurement Metrics

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The data was then converted onto easy-to-read charts and the various parameters evaluated in turn. Chart 7 - 1 to Chart 7 - 3 show the presentation style used for this example.

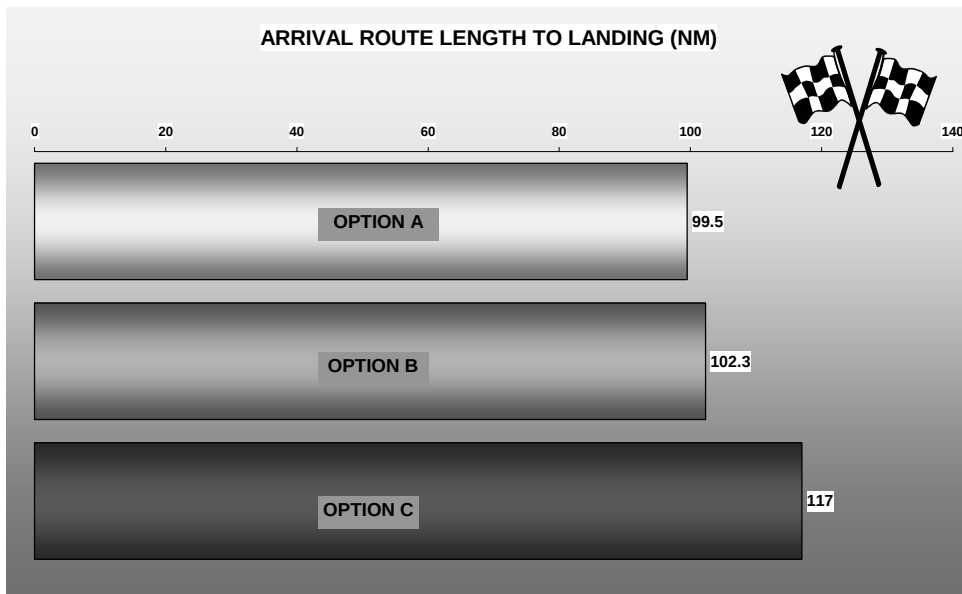


Chart 7 - 1

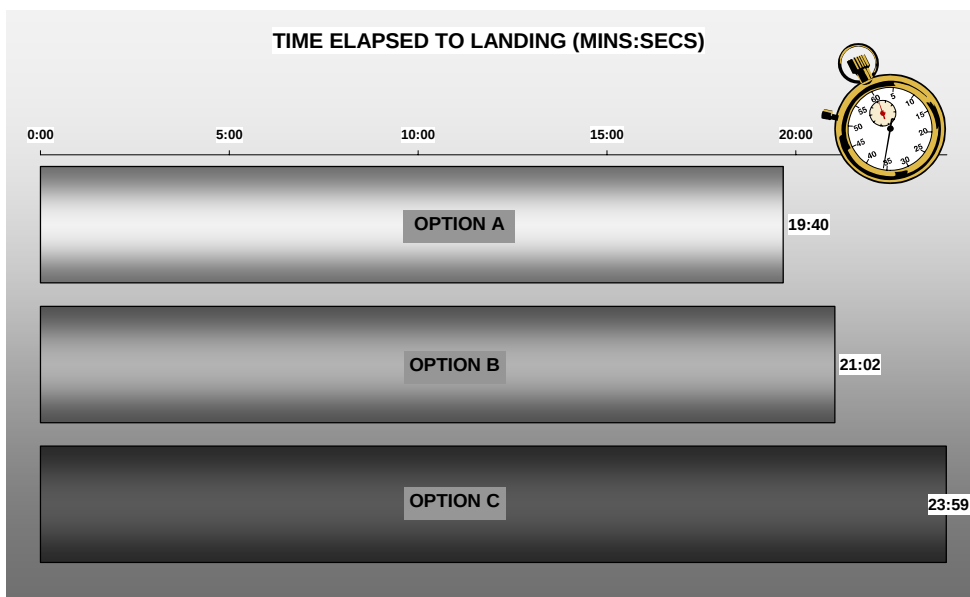
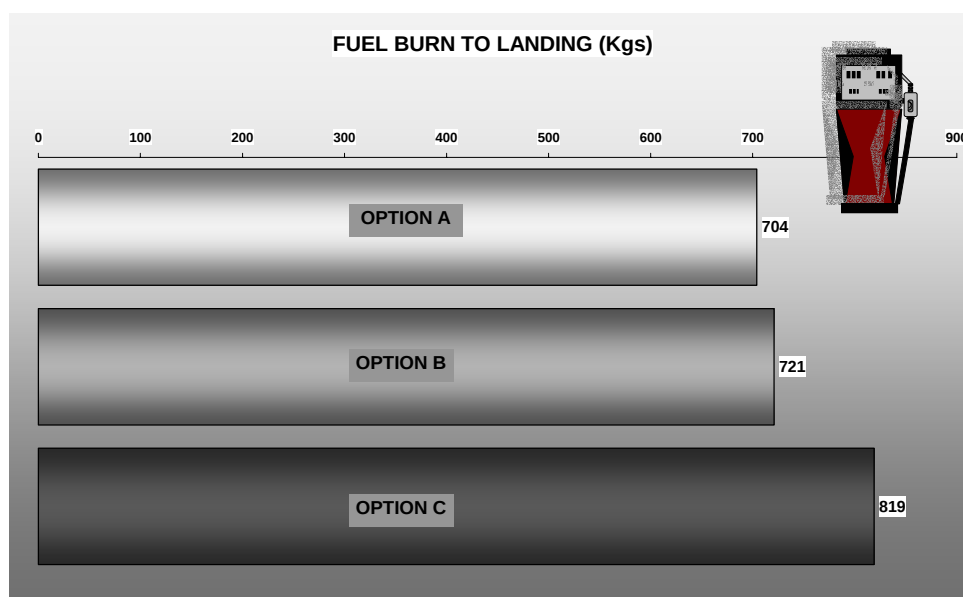


Chart 7 - 2

Terminal Airspace Design Guidelines - Part D*Chart 7 - 3***7.4 CONCLUSION**

Admittedly, the examples demonstrated here are far from the very sophisticated networks which can be constructed for large concept development, for example, linking ATC simulators with flight simulators to replicate a total ATM environment. Nonetheless the flight simulator can prove a useful tool in airspace projects – especially when trying to convince ‘the man-in-the-street’ that his/her concerns are being taken fully into account.

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CHAPTER 8

– ANALYTICAL TOOLS –

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8.1 INTRODUCTION

This Chapter provides an overview of three analytical/assessment tools viz. Collision Risk Modelling, Monte Carlo Simulations and Noise Modelling. Of these three, only Noise Modelling is the only tool which is likely to be used by the Terminal Airspace design team during the life-cycle of a Terminal Airspace project as envisaged in Part C. In contrast, Collision risk modelling (CRM) and Monte Carlo Simulations are tools used primarily by researchers/mathematicians/statisticians seeking to estimate and evaluate risk when, for example, new ATM concepts or IFR separation standards are being developed or when new technology is to be introduced into ATM system.

Given the scientific nature of these models, only a brief overview is given here. Nevertheless, these overviews are included with a view to making Terminal Airspace designers aware as to the existence and purpose of these analytical tools.

8.2 COLLISION RISK MODELLING¹

8.2.1 INTRODUCTION

In Part C, Chapter 3, discussions concerning Safety Criteria explained the difference between Absolute and Relative methods of evaluating safety in the context of requirements for ATS authorities to undertake safety assessment as per ICAO Annex 11. In Chapter 3, it was explained that safety can be evaluated using one of two methods viz. the Comparative method (by comparing a Reference System to a Proposed System) or the Absolute method (by comparing a Proposed system against an Absolute threshold. It also explained when it is necessary to evaluate (safety) against an absolute threshold.

8.2.2 HOW IT WORKS

Collision Risk Modelling (CRM) is a useful way of assessing complex interactions in the ATM system and determining whether these interactions are safe. Its use is associated with the evaluation of a proposed system's risk against an absolute threshold (of maximum tolerable risk).

Viewed diagrammatically, the evaluation of risk against an absolute threshold can be depicted as follows:

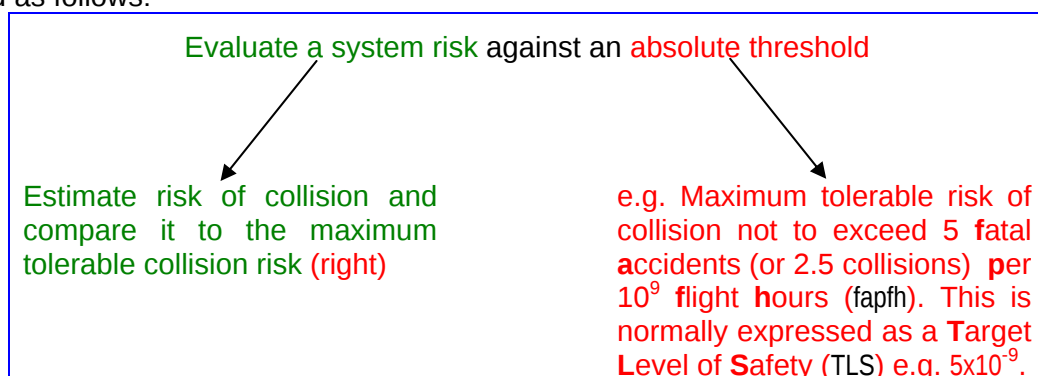


Figure 8 - 1: Risk Evaluation against an absolute threshold

The idea is that if the estimated risk is less than the maximum tolerable risk and can remain so during the anticipated lifetime of a proposed system, then the proposed system can be considered safe. In order to evaluate system risk against a threshold, ICAO has developed a

¹ Material in this section has been derived from [1] ICAO Doc. 9689 – *Manual on Airspace Planning Methodology for the Determination of Separation Minima* and [2] ICAO Doc. 9426, the *ATS Planning Manual*.

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process which is detailed in Doc. 9689 – *Manual on Airspace Planning Methodology for the Determination of Separation Minima*. This process envisages the following sequence of steps:

[i]	Define proposed system	e.g. airspace structure, proposed separation minima, complexity of airspace, airspace classification. COMM/NAV/SUR capability and their error rates, physical parameters of aircraft, aircraft navigation performance etc.
[ii]	Set evaluation criteria	e.g. Maximum tolerable risk of collision not to exceed 2.5 collisions or 5 fatal accidents per 10^{-9} flight hours.
[iii]	HAZID	i.e. Identification of all possible hazards, frequency estimation and consequence modelling (the last two provide overall risk estimates, below at [iv])
[iv]	Risk Estimation	is the result of frequency estimation and consequence modelling.
[v]	Risk Evaluation	is the process where by the estimated risk [iv] is compared to the evaluation criteria [ii]*. Risk evaluation involves the construction of mathematical models, which use detailed information about the system to estimate collision risk. i.e. collision risk model

**Note: If the calculated risk does not meet the evaluation criteria, then risk reduction measures are examined to see how risk can be reduced.*

Table 8 - 1: Evaluating System risk against a threshold

As regards [iii] in Table 8 - 1, it can be seen that CRM relies very heavily upon Cause-Consequence Modelling which effectively provides the basis for the Hazard identification process. Cause-Consequences modelling, which uses decision trees, operates on the assumption that truly independent variables contribute to occurrences and outcomes; i.e., independent events must occur to bring about an event. Cause-consequence analysis looks at the possible outcomes of these events by -

- Identifying the sources of the potential hazard.
- Identifying the events that could initiate such hazard occurring (fault trees).
- Establishing the possible sequence of events that could result from such occurrences (event trees).
- Quantifying - in probability and frequency terms - the likelihood of b) and c).
- Determining the overall risk by aggregating all the known quantified hazards.

Predictably, collision risk modelling (and therefore risk estimation and evaluation, [iii] and [iv] in Table 8-1), takes account of the following parameters -

- ❑ Exposure of one aircraft to another (with aircraft operating on parallel ATS routes, this refers to passing frequency);
- ❑ Navigation performance in the lateral, longitudinal and vertical plane;
- ❑ Effects of surveillance and communication (e.g. effectiveness of ATC capability to detect aircraft on conflicting. This effectiveness is determined by the efficiency of the surveillance and communication capability available to ATC).

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As can be seen, Collision Risk Modelling is not intended for direct use by the airspace designer as envisaged within the context of this document. Nevertheless, the ATC perspective and input is critical in the setting up of correct assumptions on which the CRM is based, and during the HAZID process.

8.2.3 USE OF COLLISION RISK MODELLING

CRM is frequently used to provide evidence for safety assessments. As explained in Chapter 3 of Part C, CRM – measurement against an absolute threshold – is only required when the proposed system does not bear sufficient resemblance to the reference system. This would be the case, for example, where RVSM is to be introduced (i.e. the 'reference' system is predicated conventional vertical separation minima, CVSM).

8.3 MONTE CARLO SIMULATIONS**8.3.1 INTRODUCTION**

Monte Carlo Simulations rely upon the use of random numbers and probability statistics to solve mathematical problems. Although these methods were originally developed for the Manhattan Project during World War II, they are now applied to a wide range of problems, including nuclear reactor design, econometrics, stellar evolution, stock market forecasting - .

8.3.2 HOW MONTE CARLO SIMULATIONS WORK

These simulations take their name from the capital of Monaco – a city whose main attractions include casinos. Roulette, dice and slot machines feature in these casinos, and each of these games provide entertainment by exploiting the random behaviour of the roulette wheel, dice or slot machine.

Similarly, Monte Carlo methods randomly select values to create scenarios of a problem. These values are taken from within a fixed range and selected to fit a probability distribution [e.g. bell curve, linear distribution, etc.]. This is like rolling a dice. The outcome is always within the range of 1 to 6 and it follows a linear distribution - there is an equal opportunity for any number to be the outcome.

In Monte Carlo simulations, the random selection process is repeated many times to create multiple scenarios. Each time a value is randomly selected, it forms one possible scenario and solution to the problem. Together, these scenarios give a range of possible solutions, some of which are more probable and some less probable.

When repeated for many scenarios [10,000 or more], the average solution will give an approximate answer to the problem. Accuracy of this answer can be improved by simulating more scenarios. In fact, the accuracy of a Monte Carlo simulation is proportional to the square root of the number of scenarios used.

8.3.3 USE OF MONTE CARLO SIMULATION

Monte Carlo simulation is advantageous because it is a "brute force" approach that is able to solve problems for which no other solutions exist. Unfortunately, this also means that it is computer intensive and best avoided if simpler solutions are possible. The most appropriate situation to use Monte Carlo methods is when other solutions are too complex or difficult to use.

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8.4 NOISE MODELLING**8.4.1 INTRODUCTION**

Noise Modelling is used to determine the noise distribution over a predetermined area as generated by a specific traffic pattern.

8.4.2 HOW NOISE MODELLING WORKS

Noise Modellers use an advanced form of fast-time simulator which are capable of calculating noise contours over a pre-defined area. These 'noise-modelling' functionalities are added to typical functionalities (such as a flight trajectory calculation) included in 'standard' fast-time simulators.

In order to generate the noise contours for each simulated aircraft in addition to the flight trajectories, the noise modeller determines (according to the aircraft model) the estimated speed and engine power setting/thrust. Based on these data and taking into account the terrain contours and other environmental conditions (time of the day, meteorological condition, etc), the simulator calculates the noise distribution and noise level at predetermined check points.

The accuracy of the results very much depends upon the realism of the aircraft models used by the simulator and on the model used for calculating noise distribution. Aircraft trajectories can be directly derived from recorded Radar data from real-live operations. Even so, modelling individual aircraft is difficult even when using advanced computational technologies. Movements are allocated to different aircraft 'types' and aircraft that are noise 'significant' (by virtue of their numbers or noise level) are represented individually by aircraft type, e.g. B747-400. Some 'types' are grouped together with those having similar noise characteristics. For each 'type', average profiles of height and speed against track distance are calculated from an analysis of radar data. These average profiles are subdivided into appropriate linear segments.

Average ground tracks for each route are calculated based on radar data. Accurate noise exposure estimation requires a realistic simulation of the lateral scatter of flight tracks actually observed in practice. This is done by creating additional tracks which are a number of standard deviations either side of the central average track. The standard deviations and the proportions of traffic allocated to each route are determined by analysis of the radar data.

8.4.3 USE OF NOISE MODELLING

Noise modelling has many analytical uses, such as assessing –

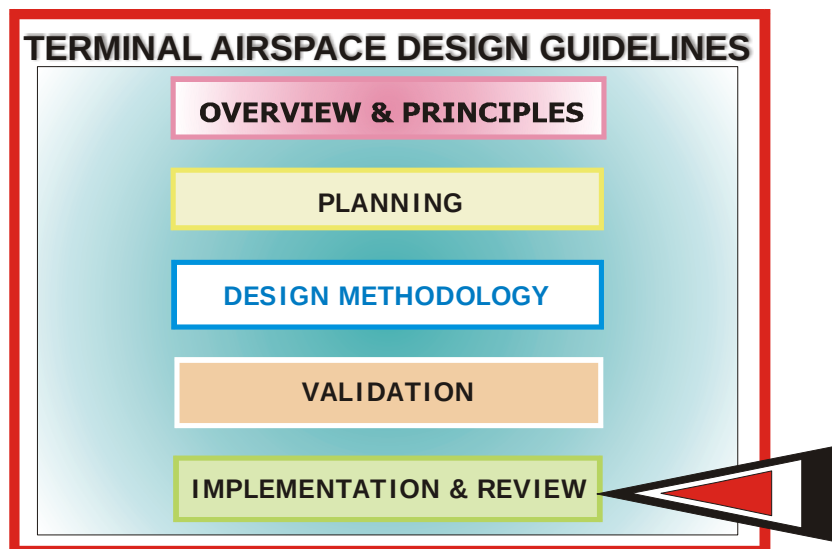
- ❑ changes in noise impact resulting from new or extended runways or their configuration,
- ❑ new traffic demand and fleet mix,
- ❑ revised Terminal routing and airspace structures and
- ❑ alternative flight profiles or modifications to other operational procedures.

Noise modelling outputs can include noise contours used in land-use compatibility studies, noise impacts by aircraft on individual flight tracks, and user-defined point analysis of noise impacts.

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PART E

IMPLEMENTATION & REVIEW



CHAPTER 1

– IMPLEMENTATION AND REVIEW –

Contents

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ATTACHMENTS

E.1-1: QUICK REFERENCE LIST FOR IMPLEMENTATION PLANNING

This Chapter constitutes the only chapter in Part E – and the conclusion of the Terminal Airspace Design guidelines. It provides an overview of Implementation and Review – which together mark the ‘end’ of a Terminal Airspace design project.

- ❑ Insufficient Implementation Planning
- ❑ Omission or overlooking of some critical factor.

For this reason, this chapter focuses on **Implementation Planning**: because it is the **planning for implementation** that makes successful implementation possible. It will be seen, that implementation planning includes **Review** and that Review is the final ‘full-stop’ in the post-implementation phase.

1.2 PLANNING FOR IMPLEMENTATION

The diagram illustrates the Design Thinking process as a continuous, iterative cycle. It is divided into four main phases, each represented by a colored box:

- Part B: PLANNING** (Yellow box)
- Part C: DESIGN METHODOLOGY** (Blue box)
- Part D: VALIDATION** (Orange box)
- Part E: IMPLEMENTATION & REVIEW** (Green box)

The process flow is as follows:

- PLANNING:** Starts with **Part B**. It leads to **IMPLEMENTATION CRITERIA (DECIDED DURING PROJECT PLANNING)**.
- DESIGN METHODOLOGY:** From **Part C**, it leads to **PRE-IMPLEMENTATION REVIEW**.
- VALIDATION:** From **Part D**, it leads to **IMPLEMENTATION PLANNING**.
- IMPLEMENTATION & REVIEW:** This phase contains a sub-cycle:
 - IMPLEMENTATION PLANNING** leads to **IMPLEMENTATION**.
 - IMPLEMENTATION** leads to **POST-IMPLEMENTATION REVIEW**.
 - POST-IMPLEMENTATION REVIEW** leads back to **IMPLEMENTATION CRITERIA**.
 - PRE-IMPLEMENTATION REVIEW** leads to a decision point: **GO** or **NO GO**.
 - GO** leads to **IMPLEMENTATION PLANNING**.
 - NO GO** leads back to **DESIGN METHODOLOGY**.

Large red curved arrows indicate the overall flow between the main phases: **PLAN** (from Part B to Part C), **DESIGN** (from Part C to Part D), **VALIDATE** (from Part D to Part E), and **IMPLEMENT** (from Part E back to Part B). The **IMPLEMENT** arrow is the largest and most prominent, indicating the final outcome of the cycle.

Figure 1 - 1: Overview of Planning for Implementation

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1.2.1 IMPLEMENTATION CRITERIA

It is usually during the validation process that it becomes evident whether the proposed design can be implemented. (This was alluded to in Chapter 1 of Part D). The decision to go ahead with implementation needs to be decided at a particular date in the life-cycle of a project.

The decision of whether to go, or not to go ahead with implementation is based on certain deciding factors i.e. **Implementation Criteria**, not the least of which are whether Safety and Performance Criteria have been satisfied (see Part C, Chapter 3). But there is more than satisfying Safety and Performance Criteria when deciding whether or not to go ahead with Implementation. Other factors can prevent a 'go' decision. For example –

- ❑ A change to the ATM system, needed to support the implementation, may prove impossible to realise despite careful identification of this enabler and a go-ahead being given by ATM systems engineers;

Or, For example -

- ❑ Dramatic political events which have nothing to do with the Terminal Airspace design and which could never have been foreseen when the Traffic Assumptions were chosen, could nullify the entire Terminal Airspace design project. This could occur, for example, if the entire design concept rested on the (traffic) assumption that 80% of the traffic would enter the Terminal Airspace from the west and unforeseen political events change the geographic distribution of traffic completely;
- ❑ Unforeseen change by lead operator concerning aircraft equipment upgrades causes collapse of the Business Case or, for example, Navigation assumptions.

It can therefore be said that it is the possibility of unexpected events that explain why it is necessary to fix a go/no-go date. (In 'purist' terms, the occurrence of a foreseeable event is not strictly an implementation issue but rather one of Project Planning which affects Implementation).

1.2.2 PRE-IMPLEMENTATION REVIEW

At this go/no go date, a **Pre-Implementation Review** is undertaken, the result of which decides the next project step. During the Pre-Implementation Review, the Terminal Airspace design project's progress is measured against the implementation criteria selected during the planning stage.

Examples of Criteria which a Terminal Airspace design team may have selected to determine whether to go ahead with implementation include:-

- ❑ Collapse of the main assumptions (see Part C, Chapter 4)
- ❑ Critical Enablers become void (see Part C, Chapter 4)
- ❑ Emergence of a project-critical constraint (see Part C, Chapter 4)
- ❑ Performance/Safety Criteria are not satisfied during or by the Validation or Safety Assessment process.
- ❑ No regulatory approval

1.2.2.1 'NO-GO' decision

Although it can be very discouraging to be confronted with a 'no-go' decision, it is essential that attempts should not be made to 'produce' a quick-fix' or work-around' so that implementation takes place at any cost. However difficult it might be *not* to proceed with implementation, a 'no-go' decision should be respected.

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As shown in Figure 1 - 1, and as suggested by the Criteria listed in the preceding paragraph, the route to be followed after a 'no-go' decision depends upon the reason for which the no-go decision was reached. In extreme cases, it may be necessary to scrap an entire project and return to the planning stage. In others, it might be appropriate to return to the selection of Assumptions, Constraints and Enablers as per Part C, Chapter 4. And it is also possible, that a new Validation exercises will have to be developed, or a new Safety Assessment completed. What-ever the route, the work needs to be organised and planned in a manner such as suggested in Part B.

1.3 'GO' DECISION – PLAN IMPLEMENTATION

If, on the other hand, all the implementation criteria are satisfied the Terminal Airspace design team needs to plan for implementation – not only as regards their 'own' airspace and ANSP but in co-operation with any affected parties which may include ANSPs in an adjacent State. To this end, a Quick Reference List for Implementation Planning is provided at **Attachment E. 1-1**. Whilst an attempt has been made to place the items in a logical sequence, it is recognised that the order of the items listed may vary, dependent on the nature of the Terminal Airspace design project, the extent/complexity of the changes and ANSP internal processes.

1.4 IMPLEMENTATION

With proper planning and organisation, the culmination of a Terminal Airspace design project is trouble-free Implementation. Nevertheless, the Terminal Airspace design team would be advised to –

- [i] Make members of the Terminal Airspace design team available in the operations hall on a 24-hour basis for at least two days before implementation, during implementation and for at least one week following implementation. This makes it possible for the Terminal Airspace design team to -
 - Monitor the implementation process;
 - Support the Centre supervisor/Approach Chief or Operational Manager should it become necessary to use redundancy or contingency procedures;
 - Provide support and information to operational controllers;
- [ii] Enable a log-keeping system for a period similar to that in [i] above, so that implementation-related difficulties may be noted and used in future project planning;

1.5 POST-IMPLEMENTATION REVIEW

It is evident that the Implementation and Review phase provides for Review on two occasions: once before and once after Implementation. Post-Implementation Review is concerned with monitoring and checking the effects of the implementation so as to ensure that unforeseen consequences do not arise. If they do, the Terminal Airspace design team should put mitigation measures (or redundancy procedures) in place as soon as possible.

As can be appreciated, the proper planning of a Terminal Airspace design project and robust Implementation planning is unlikely to necessitate drastic/radical action during the Post-Implementation Review phase. Nevertheless, this Review phase is important: it allows the Terminal Airspace design team to critically review the Implementation Scenario in a manner that is similar to the way in which the Critical Review of the Reference Scenario is undertaken during the Conceptual design phase. As such, the Quick Reference list at the end of Part C may serve as a basis for the development of a Post-Implementation Review Quick list.

Terminal Airspace Design Guidelines - Part D*Attachment E. 1-1***Quick Reference List for Implementation Planning**

IMPLEMENTATION QUICKLIST (ref. Part E)	
PROJECT NAME:	
TARGET IMPLEMENTATION DATE	
NO-GO DECISION – JUSTIFY	‘GO’ DECISION - JUSTIFY
	CONDITIONS:
SAFETY CRITERIA	
1.	Satisfied/Not-Satisfied
2.	Satisfied/Not-Satisfied
3.	Satisfied/Not-Satisfied
4.	Satisfied/Not-Satisfied
PERFORMANCE CRITERIA	
1.	Satisfied/Not-Satisfied
2.	Satisfied/Not-Satisfied
3.	Satisfied/Not-Satisfied
4.	Satisfied/Not-Satisfied
VALIDITY OF ASSUMPTIONS, CONSTRAINTS AND ENABLERS	
1. Assumptions ... a.	Valid/Invalid
2. Enablers ... a.	Valid/Invalid

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3. Constraints a.	Valid/Invalid
A. PROJECT REPORTS	
➤ Validation Report ➤ Safety Assessment and other Safety Documentation as per Safety Policy ➤ Environmental Report in accordance with State Policy.	➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding
B. PROCEDURES AND REGULATORY MATERIAL	
➤ Letters of Agreement ➤ National Regulations and Operating Procedures (including redundancy/contingency procedures) ➤ Local Regulations and Operating Procedures ➤ Register differences with ICAO in accordance with Article 38 of Chicago Convention, if applicable.	➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding
C. PUBLICATION	
➤ Design Terminal Routes in accordance with PANS-OPS criteria. ➤ Publish new SIDs/STARs in AIP in accordance with AIRAC system. ➤ Publish other relevant AIS material	➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding
D. PILOT AND CONTROLLER TRAINING	
➤ Training exercises ➤ Training Briefings ➤ Feedback questionnaires ➤ Analysis of feedback ➤ Briefings to Air Traffic Controllers ➤ Briefings to Pilots ➤ Pilot and ATC Awareness material (CBT/Fly-leafs etc.)	➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding ➤ Completed/Outstanding

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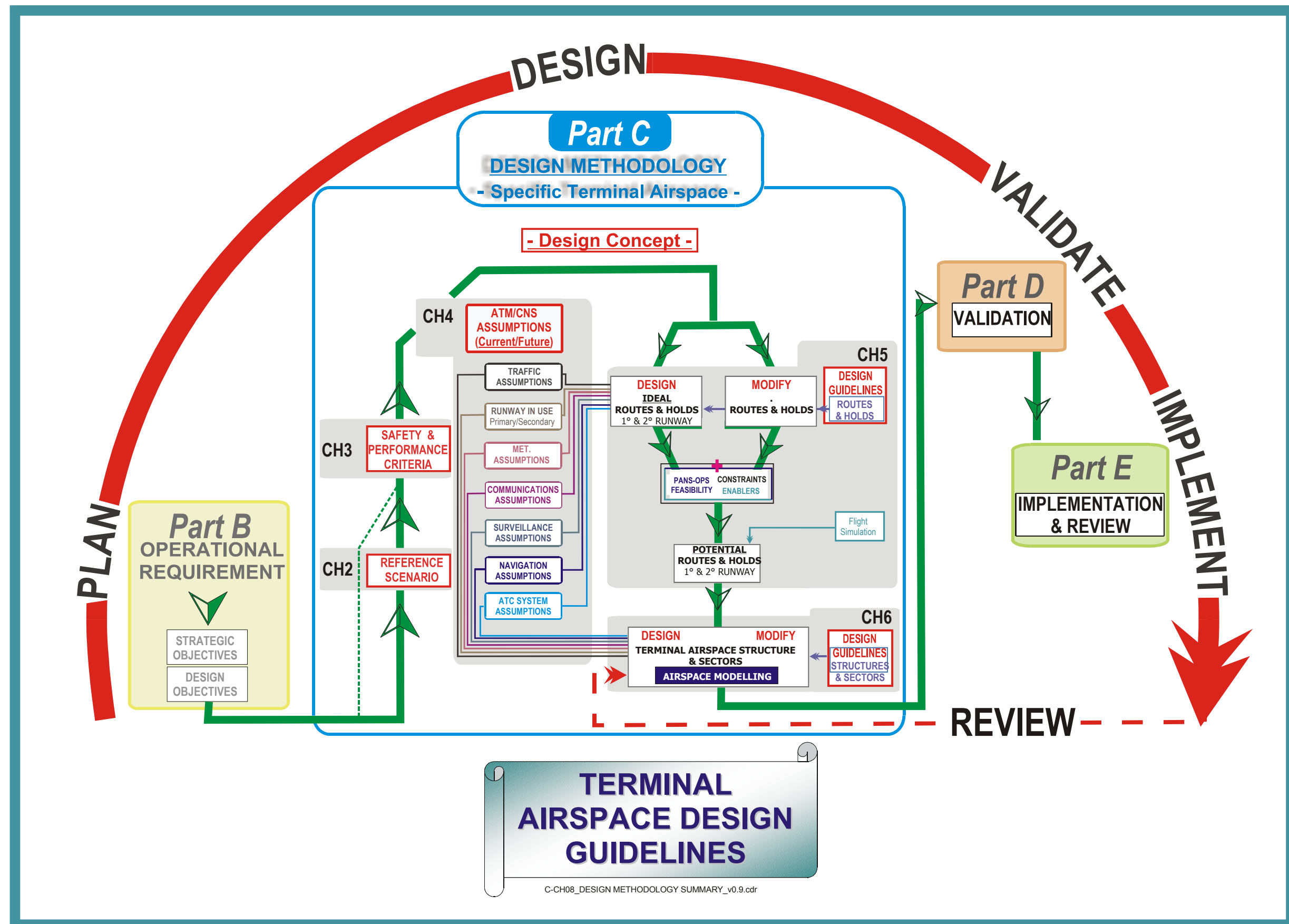
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APPENDICES

TERMINAL AIRSPACE DESIGN GUIDELINES

APPENDIX 2: DESIGN METHODOLOGY



APPENDIX 3: VALIDATION PROCESS

