CNS/ATM cost/benefit analysis for Spain

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The global Communications, Navigation and Surveillance/Air Traffic Management (CNS/ATM) systems concept, was endorsed by the ICAO Tenth Air Navigation Conference in september 1991. Besides the evident technological benefits of the new systems, support for this endorsement was supplied by a broad economic study which indicated that, on a global basis, the benefits from the new systems greatly exceeded the costs of implementing them.

The Conference recognized that, although the implementation of the FANS (CNS/ATM systems) concept was cost-effective on a global basis, more information was needed with regard its implications on regional and individual State levels. To that end, the Conference developed **recommendation 6/1**, which specifies that **States, individually, perform their own cost-effectiveness and/or cost/benefit analyses to determine how they would be affected by the implementation of the new systems.**

In accordance with such recommendation, *Aena* (Aeropuertos Espah such recommendation,cost-effectiveness and/or cost/benefit analyses to determine how they would be affected by the implementation of the new systemsh regard its implications on regional and individual State levels. To that end, the Confementation technological alternatives for the purpose of helping to decide which is best.

The analysis, performed in ten months by a team made up of personnel from the Directorate of Systems and Facilities of Aena and from the consulting firm Arthur Andersen, was completed in June 1996. The **final report** and the **executive summary** have been both edited in both Spanish and English.

Methodology

In this way, and following the guidelines and methodology of the **Net Present Value (NPV)** contained in ICAO Circular 257-AT/106 **("Economics of satellite-based air navigation services")**, the analysis was performed by comparing the so called **"project case"** and the so called **"base case"**, both in terms of costs and benefits, for a period of 20 years.

Figure 1 in ***ATC Magazine*** nº 11, article titled ***"CNS/ATM systems cost/benefit analysis"*** shows the general methodology applied in the analysis.

The **base case** includes the investments, maintenance and operating costs, training costs, and others, which would be incurred in the next twenty years if the new CNS/ATM systems (FANS concept) were not implemented and current classic technology continued to be used.

The **project case** includes the investments, maintenance and operating costs, trainig costs and others, which would be incurred in the next twenty years to implement the new CNS/ATM systems (FANS concept). These costs correspond to both advanced CNS/ATM systems and current classic technology systems, independently they remain in the definitive scenario or they are simply used for transition.

The **project case** also includes benefits that from efficiencies such as more direct flight paths, improved flight profiles, and reduction of delays, the **project case** brings over against the **base case**.

There are substantial annual expenditures (SACTA, etc.) which are common to both **project case** and **base case** during the whole analysis period, and therefore have been excluded from the costs of both cases. These expenditures would be incurred irrespective of whether CNS/ATM **(project case)** is implemented or the current classic technology continued to be used **(base case)**.

The **Net Present Value (NPV)** is calculated in the following manner:

First, the **net benefit**, by year, is calculated for each of the 20 years of the analysis period.

The **net benefit** (N) for a particular year is calculated as follows:

N = benefit minus cost = (Bp) - (Cp-Cb)

Where:

Bp = Benefit of the **project case** over against the **base case**, for that year.

(Cp - Cb) = Cost of the **project case** over against the **base case**, for that year.

In order to take into account the fact that one dollar now is more valuable than one dollar in the future (inflation), it is necessary to express the **net benefit** for each future year in terms of its equivalent in the base year (first year of the analysis). This is achieved by a discounting process which puts all the **net benefits** generated in each of the 20 years of the analysis on a comparable basis.

The Net Present Value (NPV) for the **project case** is then given by the algebraic sum of all the 20 **net benefits** (some of which might be negative). A residual value is also added to this sum to account for the value of the depreciated assets in place at the end of the analysis period.

Base case and project case costs

Data regarding equipment costs, operating and maintenance costs, and purchase of services were obtained from the following sources:

— *Aena* provided costs related to ground-based classic technology equipment.

— 85 manufactures provided information related to other equipments.

— National and international experts from various organizations such as ICAO, FAA, INMARSAT, IBERIA, British Telecom, SITA, ARINC, etc., were consulted for opinions on estimated prices of certain types of equipment and purchase of services.

— Cost information from other analyses and studies were also used.

Project case scenarios

Since the CNS/ATM systems concept offers different alternatives in respect of type of equipment that can be used to perform the various CNS/ATM functions, twelve alternative technological scenarios habe been considered within the **project case**. The differences among such scenarios are related exclusively to ground/air communications and surveillance, being equal in navigation and ATM.

The ground/air communications alternatives which make the differences among these twelve scenarios are VDL voice+data and AMSS voice+data. In surveillance, the alternatives are MSSR, Mode S radar, and ADS based either on VDL or AMSS. Navigation, common to all scenarios, is based on satellite systems augmented by EGNOS (WAAS), which will allow for CAT I approaches. LAAS and MLS are the alternatives for CAT II/III approaches. ATM, also common to the twelve scenarios selected, is based on the current air traffic control system called SACTA, augmented mainly by automated and expert ATC systems which will support CPDLC (controler-pilot data link communications) and perform part of the current controller's routine work. This reduction in his workload will allow the controller to manage a higher number of aircraft and therefore increase ATC capacity. The most important element of the on-board ATM is RNAV equipment, which will support closer and more direct routes.

In all project case scenarios, VOR, DME, NDB and ILS, are assumed to be progressively withdrawn; primary radar replaced by ADS in most cases, and the number of secondary radars minimized. Voice communications are progressively replaced by data communications.

The Annex includes a brief description of Scenarios I and VI.

In the area in yellow of **Scenario I** *(see map in the Annex)*, air/ground data communications and digitized voice are supported by means of VDL with redundant configuration. Surveillance double coverage is achived by combining single MSSR coverage with single ADS coverage supported by VDL.

In the area in blue of **Scenario I**, air/ground data communications and digitized voice, and ADS, are provided by means of AMSS with redundant configuration to those aircraft equipped with SATCOM. The carriage of SATCOM equipment is not mandatory.

In the area in yellow of **Scenario VI** *(see map in the Annex)* air/ground data communications and digitized voice are supported by means of VDL with non-redundant configuration. AMSS provides communications redundancy to VDL and communications service in the blind areas of VDL. Surveillance double coverage is achived by combining single ADS coverage supported by VDL with single ADS coverage supported by AMSS.

In the area in blue of **Scenario VI**, data communications, digitized voice, and ADS, are supported by means of AMSS with redundant configuration.

In the whole area (yellow+blue) of **Scenario VI**, the carriage of SATCOM equipment is mandatory.

All the **project case** secenarios defined in the analysis should be as realistic as possible and therefore have been developed taking into account a range of international and regional policies and strategies which will significantly affect both the type of equipment required (mainly avionics) and the rate of transition. The type of avionics required for aircraft flying international routes to/from Spain will not depend only on national equipment requirements but also on the requirements of other States and regions to/from which aircraft fly.

The main strategies and policies taken into account in the developement of the project case scenarios were:

— ICAO global co-ordinated plan for transition to the CNS/ATM systems.

— Eurocontrol satellite CNS strategy.

— North Atlantic CNS/ATM strategy.

— GNSS policies (GPS, GLONASS, EGNOS, WAAS etc.).

— WGS-84 implementation plan.

— Eurocontrol standard for area navigation (RNAV) in the ECAC area.

— Special european regional air navigation meeting (Vienna, September 1994).
— Strategy for the initial implementation of Mode S enhanced surveillance in the core area.

Project case efficiency benefits

The improvements in navigation, communications and surveillance, and air-traffic management expected from CNS/ATM implementation will generate benefits related to both **flight efficiencies** and **reduced delays**. For aircraft operators, these improvements will generate savings in fuel and other aircraft operating costs. For the passengers, will reduce travel time. Passangers and freight shippers will, in principle, be the ultimate recipients of at least a significant part of the aircraft operators benefits, assuming such a part is passed on to them as a reduction in fares and rates that they pay.

It should be noted that the efficiency benefits of the **project cases** have been calculated for a maximum number of aircraft equal to the maximum number that the **base case** could accommodate.

Although is evident that the **project cases** could manage more aircraft than the **base case**, the possible benefits deriving from this extra number of aircraft have not been quantified. The reason is that the validity and significance of these benefits is questionable, because in the **base case**, once the maximum number of aircraft that the ATS system is able to accomodate has been reached, the growing passenger demand could continue to be satisfied by replacing existing aircraft with greater-capacity aircraft. The benefits for operators coming from such replacements, neither quantified in the **base case**, would be counteracted by the benefits derived from the explotation of such extra number of aircraft that the **project cases** could manage, at least for the 20-year period considered in the analysis.

It should be noted also that it has been assumed that all the twelve scenarios selected provide the same amount of benefits from flight efficiencies and delay reductions. Obviously some scenarios have slight advantages over against others from the operational standpoint (for example: better coverage at low altitudes or in mountainous areas, better redundancy levels, lower data link transit delays, etc.) or even from an institutional standpoint, which should be taken into consideration in deciding between scenarios with a similar cost/benefit ratio.

Flight efficiencies

The improvements to be provided by CNS/ATM implementation will bring about a series of flight efficiencies such as more direct routes, shorter and more efficient approach and take-off maneuvers, improved climb and descent profiles, and a greater availability and exploitation of optimal flight levels. These efficiencies will generate economies in fuel costs and other aircraft operating costs, such as crew costs, which will depend on the level of reduction in flight time.

For the purpose of quantifying all these cost savings, which will mainly benefit aircraft operators, the percentage of aircraft equipped at any given time with the required avionics had to be estimated. Also estimated were the dates on which, both the new CNS/ATM systems, and the airspace structures and associated procedures needed to achive the above mentioned efficiencies, are suppossed to come into operation.

It has been estimated that the efficiencies will be based mainly on:

— Precision RNAV navigation, using EGNOS (WAAS), which will permit to implement the concept called "Reduced Lateral Route Spacing" (RLRS), and consequently a much more efficient direct route structure, characterized by the extensive use of closely spaced pairs of parallel airways running in opposite directions rather than two-way airways. The elimination of two-way airways will allow optimum climb and descent profiles, which will not be staggered since aircraft will not be limited by traffic in the opposite direction.

— The reduction in the controller's workload per aircraft, result of the progressive implementation of new automated functions which will,in turn, make extensive use of the air/ground data link and CPDLC messages. This reduced workload will make it possible for the controller to increasingly authorize more direct trajectories, especially in TMA during approach and take-off.

— Improved surveillance, based on ADS and its integration with radar, will make it possible to apply increasingly smaller minima separations, since greater levels of precision, availability, integrity, and continuity of service will be ensured.

It has been assumed that the dates on which the stated efficiencies will be shown will depend on the dates on which CNS/ATM systems will begin to operate in the airspace being considered. These dates will depend, in turn, on the characteristics of the selected project case scenario. There are several scenarios, but the element which distinguishes between them and conditions the schedule for implementation of flight efficiencies, is the data link, which may be either AMSS or VDL. The beginning and full obtainment dates for the efficiencies are as follows:

	START OF EFFICIENCIES	FULL EFFICIENCIES
AMSS SCENARIOS	2003	2006
VDL SCENARIOS	2003	2010

The main reason why the date of the start of efficiencies (2003) is the same for both AMSS and VDL scenarios, despite of the fact that AMSS avionics will begin to be implemented much earlier than VDL avionics, is that the efficiencies will not begin to be significant until EGNOS (WAAS) is available.

The reason why AMSS scenarios provide full obtainment of efficiencies before VDL scenarios is because AMSS data link will be implemented in all aircraft earlier than VDL.

The quantification of savings in time and fuel, derived from the flight efficiencies provided by **the project cases** over against the **base case**, has been a tough and complex task. The analysis shows that, once the new CNS/ATM systems have been fully implemented, the savings due to improved climb and descent profiles and due to a greater availability of optimal flight levels, would be for the Canary FIR 1.5% of the cost of the total fuel that would be consumed in the **base case** by all aircraft. For the peninsular FIRs as a whole would be 1.3%.

The savings due to more direct routes and shorter trajectories in TMA would be for the Canary FIR 2.7% of the total flight hours that would be flown in the **base case** by all aircraft. For the Peninsular FIRs as a whole would be 3.4%. Obviously flight hours savings mean fuel and crew costs savings.

Reduction in delays

When traffic volumes approach the theoretical traffic handling capacity of the airspace, the resultant congestion may cause delays in flights and disruptions to timetables. Unless capacity is increased, growth in demand would lead congestion and delays to scalate rapidly, with very serious consequences for aircraft operating costs and passenger traveling time. Furthermore, anacceptable delays will freeze demand, since passengers will opt for other more efficient means of transport. Reduced separation standars and improved airspace management made possible by the implementation of CNS/ATM will increase capacity and hence eliminate most of the congestion costs that might otherwise be incurred.

In order to estimate the benefits from reduced delays, it has been necessary to forcast the extent of the delays that would be expected year by year in the event that CNS/ATM systems are not implemented. The delay reduction benefits that has been taken into account are only those related to aircraft departing from Spanish airports. This benefits have been calculated separately for "domestic departures", constrained by the capacity limitations of the Spanish ATS system, and for "international departures", constrained mainly by the capacity limitations of the European ATS system.

For the purpose of estimating the benefits from reduced delays, it has been assumed that the increase in theoretical capacity over the **base case**, consequence of CNS/ATM systems implementation, will take place from 2002 through 2015, and will be a 50%. It has been estimated that, if CNS/ATM systems are not implemented, the growing delays will make domestic traffic (nº of flights) freeze from the year 2008, and the international traffic from 2003. The average cost per hour of delay has been assumed to be between US$ 1,223 and US$ 1,408, depending on aircraft type.

Time savings for passengers

CNS/ATM improvements, which will allow more direct flight trajectories, and will reduce airspace congestion delays, will reduce also the passenger's flight time. If passengers value these time savings, they will represent an additional benefit provided by CNS/ATM systems.

The savings will depend on aircraft size, average number of seats for each type of aircraft, load factors considered, and value of passenger time per hour.

The value of passenger time is, in practice, extremely difficult to quantify and will depend on passengers perceptions and trip purpose (leisure or bussiness).

Since its validity is sometimes questioned and ultimately depends on passengers willingness to pay for it, this benefit has not been included in the calculation of the **CNS/ATM net benefit**, nevertheless, it has been calculated for information purposes, taking into account the flight hours saved, and assuming an aproximate cost of US$ 25 per hour (value obtained from the high speed train cost/benefit analysis for Spain).

Intangible benefits

There are benefits, called intangible, that can not be quantified in an analysis. They frequently fall into the categories of safety, efficiency, environmental, productivity, and socio-economic. The lack of adequate data, and the many variables involved, frequently makes it impossible to adequately estimate de dollar value of these benefits. However, they can be indentified , described and their effects highlighted. Among the intangible benefits identified in the analysis are the following:

* Improvement in controller's working conditions

The **final report** says: *"The new CNS/ATM systems will improve the working conditions of controllers and lead to decreased stress, higher air-traffic safety and lengthening of controller's professional lives"*

* Environmental benefits

The **final report** says: *"Shorter trajectories in TMA, the use of more direct routes, improved flight profiles and optimum cruising levels, benefits derived from the new CNS/ATM systems, will generate fuel savigns which will, in turn, reduce emissions of polluting gases in the atmosphere, and possibly noise".*

Results of the analysis

The results show that all the twelve alternatives analyzed are profitable at countrywide level, both from the ATS service provider and aircraft operators perspectives, and of course, from the passengers perspective.

The table of *(figure 2)* presents a summary of the results, in thousands of dollars, for both ATS service provider and aircraft operators. Note that the benefits from passengers travel time reductions have not been included in the **TOTAL**, since, as said before, its validity is sometimes questioned; however, these benefits have been meassured and presented within the results.

Although the investment and operational costs of the **project case** are in all scenarios superior to those of the **base case**, the benefits from flight efficiencies and delay reductions make results be positive in all **project case** scenarios.

Since there are no great differences in the profitability of the scenarios, sensitivity analysis takes on special significance. This is so because a small variation in the value of certain variables, such as the cost per kilobit of satellite communications, could affect the profit-based ranking of the scenarios. For example, if that cost were of 0.4$ intead of 0.5$, scenario VI, one of the most robust, and where double surveillance coverage is provided by ADS/VDL and ADS/AMSS and where satellite provides redundancy communications to VDL and communications service in the blind areas of VDL, would be as profitable as scenario I.

Many assumptions and judgments had to be made about future traffic levels, equipment costs and pricing policies, and about the speed and success of the transition process. Even though a sensitivity analysis has been carried out to account for a certain divergence from the assumed values, it is evident that the cost/benefit analysis should be updated as time goes by and those values are better known.

Is important to stress that it has not been the goal of the cost/benefit analysis to reach a final conclusion on what is the best possible alternative, since for that, apart from the economical, it will be also necessary to take into account institutional and political issues. This analysis and its results should be regarded as guidance to help in finding the best possible alternative, help analysts to perform more detailed calculations on these matters, and finally help in planning the CNS/ATM implementation.

The Annex includes the results breakdown of **Scenario I**, which provides the best total results from the ATS service provider and aircraft operators standpoint. A results breakdown of **Scenario VI** is also provided.

These results breakdowns show, in thousands of dollars, *project case costs (A), base case costs (B), benefit due flight efficiencies (C), benefit due to reduction of delays (D), net benefit of CNS/ATM (B+C+D-A), and value of passengers time savings.*

Glossary of terms and abbreviations

ADLP
Airborne data link processor

ADS
Automatic dependent surveillance

AMSS
Aeronautical Mobile Satellite Service

ATS
Air traffic services

B-RNAV
Basic RNAV

CPDLC
Controller-pilot data link communications

EGNOS
European geostationary navigation overlay service

FANS
Future air navigation systems

ILS
Instrument landing system

LAAS
Local area augmentation system

MLS
Microwave landing system

MMR
Multimode receiver

MSSR
Monopulse secondary surveillance radar

P-RNAV
Precision RNAV

RNAV
Area navigation

SACTA
Automated ATC system

TDMA
Time division multiple access

VDL
VHF data link

VHF
Very high frequency

WAAS
Wide area augmentation system