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iFly

Safety, Complexity and Responsibility based design and validation of highly automated Air Traffic Management

Specific Targeted Research Projects (STREP)

Thematic Priority 1.3.1.4.g Aeronautics and Space

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Abstract

This report presents the results of the analysis performed for the Cost-Benefit Analysis (CBA) assessment of the Autonomous Aircraft Advanced (A^3) Concept of Operations (ConOps). A scenario-based CBA approach is used to overcome problems associated with the lack of data for estimating relevant cost and benefit variables, i.e., forward/retro-fit cost, Air Navigation Service Providers (ANSPs) implementation costs, Air Traffic Flow Management (ATFM) en-route delay reduction, flight Inefficiency reduction, ANSPs charges reduction, and ANSPs staff cost reduction. The proposed CBA analysis approach involves building a wide range of alternative scenarios for the Airlines and ANSPs in which the B/C ratio and a subset of uncertain variables are fixed while the remaining uncertain variables are calculated on the basis of achieving the predetermined B/C ratio. Combined Airlines-ANSPs scenarios were also developed and analyzed in which the % reduction of ANSPs en-route charges for the Airlines was considered as a function of the ANSPS en-route staff cost. This report describes the steps of the scenario-based CBA approach, presents the analysis scenarios that have been developed, and provides the results from the application of the CBA approach to Airlines and ANSPs analysis scenarios. The analysis results for the airlines indicate that A^3 ConOps can be economically viable even under the worst case scenario where the forward-fit cost reaches its highest value while the expected ATFM delay reduction and flight inefficiency reduction take their lowest possible values. Moreover, the CBA for the ANSPs indicated that A^3 ConOps may contribute to the substantial reduction of the en-route service cost. The findings of the CBA seem encouraging for developing A^3 ConOps to its next maturity stage from the perspective of both the Airlines and the ANSPs economic implications.

1 Introduction

1.1 iFLY Project

The iFLY project aims to define and assess a self-separation ATM ConOps (Autonomous Aircraft Advanced Concept of Operations- A^3 ConOps) in which the separation task is solely performed by the flight crew within a given airspace, labelled as self-separation airspace [1]. The objective of iFLY project was to develop an ATM design for en-route traffic aiming to manage a three to six times increase in current air traffic levels, taking advantage of autonomous aircraft operations. The A^3 ConOps was developed following a two design cycles approach. The outcome of the first design cycle was a baseline A^3 ConOps developed based on the current "state of the art" in aeronautics research. The first design cycle is followed by an assessment cycle which aimed at assessing the A^3 ConOps impacts is human factors, safety, and economy.

The work in WP6 aimed at the assessment of the economic impacts of A^3 ConOps issued through the first design cycle. The results of the assessment cycle provide input for the second design cycle which aims to refine A^3 ConOps and specify operational, technological and performance requirements for its implementation in SESAR-based ATM.

1.2 Objective of iFLY Work Package 6

The transition from the managed airspace to the self-separation airspace as described in the A^3 ConOps document [1], signifies major changes in the role and responsibilities of the ATM stakeholders, the ATM technologies and systems used, and the operations performed during the en-route phase of a flight. An essential prerequisite before the full scale development and implementation of the proposed ATM ConOps is the assessment of its institutional implications and economic viability. Thus, the objective of WP6 was twofold, first to identify the institutional implications of implementing A^3 ConOps and second to validate its economic feasibility [2]. The work in WP6 was organized to the following sub-WPs: i) WP6.1 Development of a methodological framework for cost-Benefit analysis, ii) WP6.2 Institutional and Organizational analysis for the implementation of the autonomous aircraft operations, iii) WP6.3 Data collection for cost-Benefit analysis, iv) WP6.4 Cost Benefit analysis and results assessment. This report presents the results of the data analysis for the assessment of the economic viability of A^3 ConOps performed within WP6.4.

1.3 WP6.4 Cost-benefit analysis and results assessment

The objective of WP6.4 is to specify and analyse the results from the application of the proposed CBA to the stakeholders directly affected by the A^3 ConOps (i.e., Airlines and Air Navigation Service Providers). A major feature of the economic assessment of A^3 ConOps in terms of CBA is that the current version of the A^3 ConOps [1] is at E-OCVM phase V1 [3], and thus a number of implementation issues have not been fully specified. This feature implies the existence of an inherent difficulty in obtaining valid estimates for the operational improvements and/or costs arising from the implementation of A^3 ConOps. In this context, a CBA approach is proposed where the economic viability of A^3 ConOps is assessed through the application of CBA to a series of analysis scenarios involving alternative values for the uncertain cost and benefit metrics. This report aims to provide a description of the process of applying the proposed CBA approach for the Airlines and the ANPS, illustrate the A^3 ConOps analysis capabilities offered to the decision maker, and the present the results from its application to specific analysis scenarios. The analysis results presented in this report aim at identifying operational performance targets for the potential ATM operational improvements of A^3 ConOps and the stakeholders' investment and operating costs in order to achieve predetermined levels of return on investment for the Airlines and ANSPs. However, the focus of the analysis results presented is on scenarios where conservative operational improvements are assumed for the Airlines and ANSPs. Deliverable D6.4 enhances interim report D6.4i which aimed to present indicative analysis scenarios for assessing the economic impacts of A^3 ConOps and provide preliminary results from the application of the proposed CBA.

1.4 Organisation of this report

The remainder of this report consists of five sections and four Appendices. Section 2 provides an overview of the data collection process and the corresponding scenario-based analysis approach. Section 3 presents an overview of the analysis scenarios for the Airlines and the associated CBA results. Section 4 provides the corresponding analysis scenarios for the ANSPs and presents the relevant CBA results. Section 5 provides an overview of the combined analysis scenarios and the associated CBA results. Section 6 provides concluding remarks and future steps. Appendices I & II provide an overview of the data used in applying the CBA for the Airlines and the ANSPs respectively. Appendices III and IV provide the entire set of data analysis results from the Airlines and ANSPs CBA respectively.

2 Overview of the CBA Approach for Assessing A^3 ConOps

The costs and benefits in the proposed analysis measure additional expenses and the cost savings/avoidance resulting from the potential implementation of the A^3 ConOps ATM system considering the SESAR enhanced ATM system as the baseline system. The data collection process for assessing the costs and benefits induced by A^3 ConOps to Airlines and ANSPs involves the identification of input values for the following categories of variables [4],[5]: i) Global variables which are not considered as either costs or benefits but they are used as input metrics in calculating various cost and benefit variables, (e.g. air traffic growth, discount rate), ii) Time variables which refer to various periods or milestones of the A^3 ConOps implementation (e.g., Start year of the analysis, Pre-implementation period of A^3, Implementation period of A^3), iii) Baseline variables which refer to performance measures of ATM under the baseline scenario throughout the time horizon of the analysis (e.g., annual baseline en-route ATFM delay, annual baseline Flight Inefficiency), iv) Cost and Benefit variables, which refer to various cost elements (e.g., forward-fit cost per aircraft) and cost savings (e.g., Reduction of ANSPs charges) respectively. More detailed analysis on this categorization (based on EMOSIA [5]) may be found in iFLY Deliverable D6.1 [4] while a complete list of CBA variables for the Airlines and ANSPs is presented in Appendices I and II respectively.

Various information sources were used in selecting data for estimating the variables involved in the CBA for the Airlines and ANSPs. However, limited data availability for estimating the following cost and benefit variables was encountered [6]:

- % Reduction of the en-route ATFM delay,
- % reduction of the Horizontal and Vertical Flight Inefficiency (or % Horizontal Efficiency Gain),
- % Reduction of the Vertical Flight Inefficiency (or % Vertical Flight Efficiency Gain)
- % Reduction of the en-route ANSPs charges,
- Retro-fit and forward-fit costs for the Airlines,
- % reduction of the en-route ANSPs staff and operating (non-staff)cost,
- ANSPs one-off implementation cost.

Given that no measured data were available for the above stated variables, experts were asked to provide judgments. A template was developed to collect experts judgments required for estimating the corresponding cost and benefit variables [6]. The task of completing this template was assigned to organizations participating in WP6.3. Only data regarding the ANSPs one-off implementation cost were obtained through this process. However, the relevant estimates referred only to a single organization (AENA) and not the entire body of ANSPs in Europe.

Limited description of the specifications regarding the proposed A^3 operations hindered the provision of estimates regarding the potential improvements in ATFM delays and flight inefficiency and the reduction of the operating cost for the ANSPs. Moreover, issues associated with the provision of proprietary industrial data made it difficult for the corresponding partners to provide estimates for the avionics costs (forward-fit and retro-fit costs). Given the above stated limitations, a typical application of the CBA for either the Airlines or the ANSPs would yield results associated with high uncertainty, which would provide no credible findings regarding the cost-effectiveness of the A^3 ConOps for either category of organizations. Thus the focus of the analysis was placed on examining the relationship between the potential operational improvements with the expected costs that yield predetermined B/C values.

This target is achieved through the application of a scenario-based CBA for assessing the A^3 ConOps impacts. The proposed analysis framework involves the application of CBA to a series of analysis scenarios built on the basis of combining various valid alternative values for uncertain variables associated with the costs and benefits of A^3 ConOps.

Thus, given a specified B/C ratio and a combination of values for the cost (or benefit) uncertain variables, reverse CBA calculations are performed in order to determine the corresponding values of the benefit (or cost) variables for which the targeted B/C ratio is achieved. The expected outcome of this type of analysis is to determine the operational improvements and cost scenarios for which a predetermined economic performance can be achieved. The remainder of this report presents the process of applying the proposed CBA approach and the results from its application for assessing the economic implications to the Airlines and ANSPs within specific analysis scenarios.

3 Airlines Analysis

This section presents the process of applying the proposed CBA approach for the Airlines, the emerging analysis scenarios, and the associated results.

3.1 Airlines Analysis Scenarios

Performing a scenario-based application of the CBA involves building a wide range of alternative scenarios in which the B/C ratio and only a subset of uncertain variables are fixed while the remaining uncertain variables are calculated on the basis of achieving the predetermined B/C ratio. In particular, for any given B/C value, a bundle of analysis scenarios are built in which combinations of valid values for the uncertain variables yielding the targeted B/C value are determined.

For the airlines CBA where one uncertain cost variable and four uncertain benefit variables have been identified, this type of analysis may be used in two alternative but equivalent ways: i) identifying the upper bound of the forward-fit/retro-fit cost variables for given values of the benefits variables in order to achieve the predetermined B/C value, and ii) identifying the combinations of values for the benefits variables (% ANSPs En-route Charges Reduction, % Horizontal Flight Efficiency Gain, % Vertical Flight Efficiency Gain, % ATFM en-route Delay reduction) given a forward-fit and retro-fit cost value for which the predefined B/C ratio is achieved. In this study, the latter type of analysis is selected since it leads to manageable number of analysis scenarios.

The scenarios are built on the basis of only one uncertain variable, the forward-fit cost. The retro-fit cost is assumed proportional to the forward-fit cost and it is calculated as a function of the forward-fit cost value. The ratio of the retrofit over the forward-fit cost is taken equal to 2 as indicated in SESAR CBA study [7]. The analysis results involve various alternative combinations of values for the benefit variables and forward-fit cost. This type of results may illustrate the relationship between the cost and benefits variables under various economic performance levels. More concrete assessment results regarding the economic viability of A^3 ConOps, may be concluded only under considering assumptions regarding the expected level of the forward-fit cost or any of the benefit variables. Thus for instance, if a decision maker obtains a specific estimate or requires a desired upper bound for the forward-fit cost and assumes specific levels for operational improvement under the ATFM delay and (horizontal and vertical) flight inefficiency reduction, then he/she may calculate the corresponding value required for the % en-route ANSPs charges reduction which may lead to a predetermined B/C. Depending on the possibility of achieving the emerging ANSPs charges reduction (which is equivalent to the possibility of achieving the corresponding reduction of the ANSPs en-route staff cost) the decision maker may conclude on the viability of the A^3 ConOps. The analysis presented in this report provides such conclusions only for extreme hypothetical scenarios (pessimistic vs. optimistic) since the current maturity level of A^3 ConOps does not allow for making more specific assumptions regarding the forward fit costs or the uncertain benefit variables.

In particular, the proposed scenario-based CBA for the Airlines involves the identification of the combinations of values for the uncertain benefit variables (*Horizontal Efficiency Gain (%), Vertical Efficiency Gain (%)*, the *Incremental Delay Reduction,* and the *% Reduction of ANSPs en-route charges*) under various levels of the forward-fit cost for which the A^3 ConOps impacts yield a predetermined B/C. The proposed analysis is applied for various B/C ratio values above unity (e.g., 1, 1.1,.., 2). The expected outcome from applying the CBA in the alternative analysis scenarios is to specify an envelope of cost and benefit variables values under which A^3 ConOps implementation achieves a specified level of economic performance from the Airlines perspective.

Figure 1 provides a flow chart that illustrates the process followed for applying the proposed scenario based approach for the Airlines. Details regarding the proposed methodological framework used and the cost and benefit variables involved in the application of CBA for the airlines can be found in Deliverable D6.1 [4]. For the readers' convenience, Table 1 below presents the uncertain variables associated to the Airlines CBA and the relevant ranges of possible values used for building the analysis scenarios.

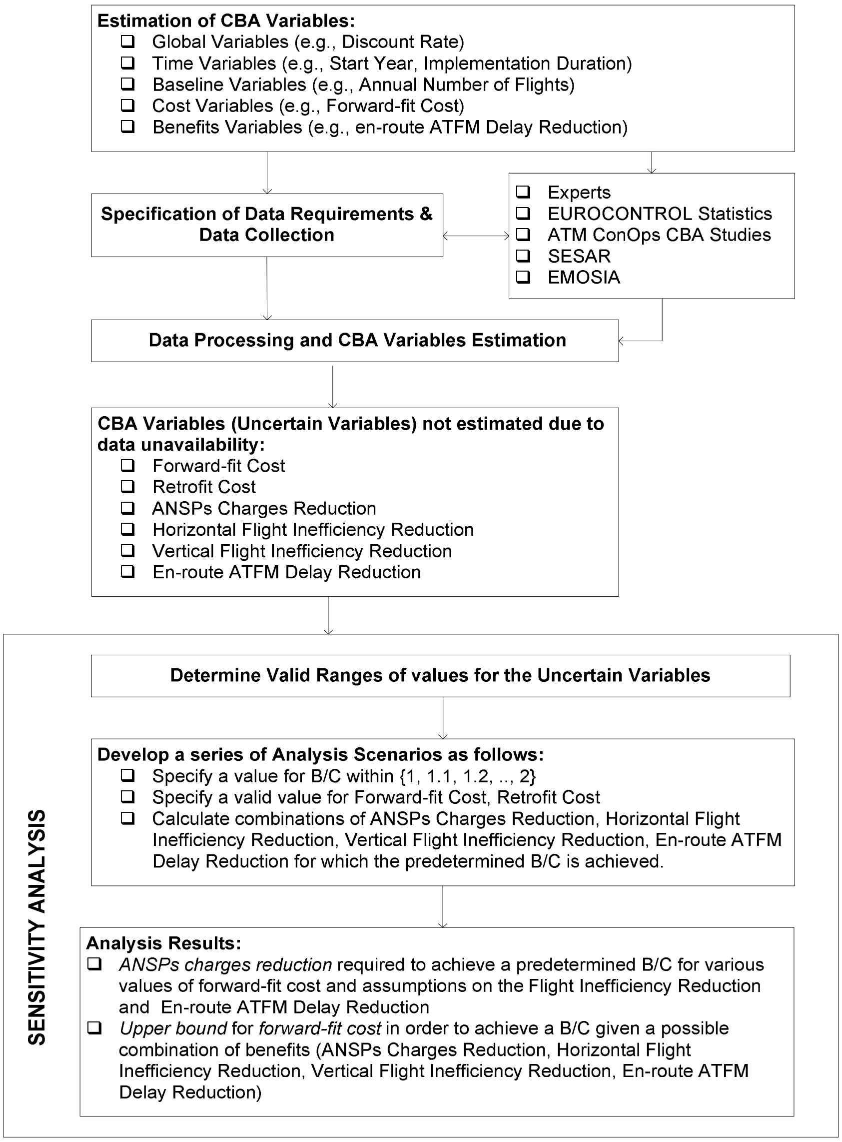

Figure 1. Overview of the process followed for applying the proposed scenario-based CBA approach for the Airlines.

Uncertain Variable	Definition	Range of Values
Forward-Fit Cost	The equipage considered in the cost estimation does not include systems which are essential in A^3 ConOps but also covered in SESAR ATM Master Plan. Based on the current version of the A^3 ConOps, the forward-fit cost refers to the cost of acquiring and installing advanced Airborne Separation Assistance System (ASAS) applications for detecting and resolving conflicts within self-separation airspace.	Lower bound equal to 24576 €/aircraft (in 2010 prices). This value was taken from ASSTAR ("Advanced Safe Separation Technologies and Algorithms") project and refers to the cost of ASAS application for Self-Separation-Free Flight Track in oceanic airspace. It is assumed that a more advanced ASAS application will be required for A^3 ConOps. The upper bound for this variable was taken equal to the triple of the lower bound (i.e., 73728 €/aircraft) which was considered by experts in avionics technologies (participating in this WP) as a reasonable bound.
(%) Reduction of ANSPs en-route charges	This is the percentage reduction of the ANSPs en-route charges. In 2007 the en-route ANSPs charges were 6122 M€. This value is considered as a baseline for this analysis.	It is assumed that the maximum proportional reduction of the en-route ANSPs charges is equal to the maximum possible proportional reduction of the en-route ATM/CNS (Air Traffic Management / Communications, Navigation and Surveillance) cost if ATC staff cost is entirely vanished. Based on ATM Cost-Effectiveness (ACE) 2008 Benchmarking Report, the en-route ATC cost is 3617 M€ accounting for 62.1% of the entire en-route ATM/CNS cost (which is 5822 M€). Thus the maximum proportional reduction is 62.1%. Note however, that this value may not be a tight upper bound since the possibility of vanishing the en-route staff cost in its entirety is marginal. However on the other hand it is not possible to specify a tighter bound given that significant details regarding the implementation of A^3 ConOps (including the degree of involvement of ANSPs in managing Self-Separation Airspace) have not been specified.
Horizontal Efficiency Gain (%)	This is the percentage reduction of baseline horizontal flight inefficiency. According to the 2009 Performance Review Report (PRR 2009), the horizontal flight inefficiency is equal to 3.9% (i.e., the flight distance actually flown in 2008 exceeds the direct route distance on average by 3.9%). Thus, a 10% horizontal efficiency gain corresponds to reducing the flight inefficiency to 3.51% .	The range of values for this variable ranges from 0% up to 100%. However given that the percentage of reduction directly attributed to A^3 ConOps may be disputable (according to the judgment of experts participating in this WP), only conservative levels of Horizontal Efficiency Gain are taken into account. In particular the range of values of this variable considered for creating the analysis scenarios was [0%,20%].
Vertical Efficiency Gain (%)	This is the percentage reduction of the additional fuel consumed per flight due to the deviation of the actual vertical flight profile from the optimum trajectory. Based on the Performance Review Report for 2009, the additional flight fuel consumption was 25 kg/flight [8].	This variable may take values from 0 up to 100%.
En-route ATFM Delay Reduction (%)	This is the percentage reduction of the en-route ATFM delay per flight. In 2007 the delay was 1.9 min per flight.	No specific range of values could be determined for this variable. However given that the percentage of reduction directly attributed to A^3 ConOps may be disputable (according to the judgment of experts participating in this WP), only conservative levels of ATFM delay reduction are taken into account. In particular the range of values of this variable considered for creating the analysis scenarios was [0%, 10%].

Table 1. Overview of the uncertain benefit variables involved in the Airlines CBA

The creation of the analysis scenarios is performed based on the following methodological steps:

1. Determination of the B/C ratio alternative values. The objective of this step is to specify the alternative valid values of the B/C ratio expressing the airlines economic expectations from investing on A^3 ConOps. Since there is no interest to consider scenarios in which costs overrun benefits, the analysis scenarios will involve alternative values of B/C above unity. In this analysis the upper limit for B/C is set equal to 2, i.e., the expected benefits cash flows will be twice the total costs related cash flows within the analysis time horizon. The range of the values of B/C used in this analysis is {1, 1.1, 1.2, 1.3, 1.5, 2}. Special emphasis is given to exploring scenarios with B/C 1 , 1.1, 1.2 and 1.3. For scenarios with B/C value equal to 1, the analysis results may indicate the boundary limits on the values of benefits variables for various levels of forward-fit cost beyond which the airlines investment on A^3 ConOps are not covered by the expected benefits cash flows. On the other hand for B/C equal to 1.1, 1.2, and 1.3 reflect conservative expectations regarding the expected economic performance of A^3 ConOps. However, higher values (i.e., 1.5 and 2) are also taken into consideration in order to investigate the benefits required from the implementation of A^3 ConOps for achieving high economic performance targets.
2. Determination of the range of valid values for the forward-fit and retro-fit costs. In the data collection process, lower bounds on the forward-fit and retro-fit costs were determined (see Table A-6 in Appendix I). The ratio of the retro-fit over the forward-fit cost values is assumed (as indicated by experts in avionics technologies participating in this WP) equal to the corresponding ratio (retro-fit / forward-fit) calculated for the SESAR CBA [7](equal to 2). Thus, it suffices to specify a range of valid values only for the forward-fit cost. Assuming the lowest value for the forward-fit cost equal to the relevant cost estimated in ASSTAR project [9] (see Table A-6 in Appendix I), i.e., 24576 €/aircraft (in 2010 prices), any relevant analysis scenario should use values higher than this lower bound. The upper bound for the forward-fit cost is set equal to the triple of its lower bound (i.e., 200% increase). This upper bound was assessed as reasonable by experts in avionics participating in this WP.
3. Calculation of the benefits for which the fixed B/C is achieved. An issue arises in this step since the aggregated benefits includes the benefits arising from the % Reduction of ATFM delays, the % Gains in Vertical Flight Inefficiency, the % Gains in Horizontal Flight Path Inefficiency and the expected % reduction of the ANSPs charges. Thus, for each level of cost, the objective of the proposed analysis is to identify the alternative combinations of the benefits variables values for which the fixed B/C ratio is achieved. In addition to the calculation the combinations of benefits, the corresponding Internal Rate of Return (IRR) is also calculated in order to indicate the rate of return of the proposed investment for the Airlines under the specific benefits outcome.

Table 2 presents the list of analysis scenarios with fixed cost and B/C ratio taking values in $\{1, 1.1, 1.2, 1.3, 1.5, 2\}$. The total number of scenarios considered equals to 30.

Scenario ID	B/C Ratio	Forward-Fit Cost	Retro-Fit Cost
AIR-(1)-1	1	24576	49152
AIR-(1)-2	1	36864	73728
AIR-(1)-3	1	49152	98304
AIR-(1)-4	1	61440	122880
AIR-(1)-5	1	73728	147456
AIR-(1.1)-1	1.1	24576	49152
AIR-(1.1)-2	1.1	36864	73728
AIR-(1.1)-3	1.1	49152	98304
AIR-(1.1)-4	1.1	61440	122880
AIR-(1.1)-5	1.1	73728	147456
AIR-(1.2)-1	1.2	24576	49152
AIR-(1.2)-2	1.2	36864	73728
AIR-(1.2)-3	1.2	49152	98304
AIR-(1.2)-4	1.2	61440	122880
AIR-(1.2)-5	1.2	73728	147456
AIR-(1.3)-1	1.3	24576	49152
AIR-(1.3)-2	1.3	36864	73728
AIR-(1.3)-3	1.3	49152	98304
AIR-(1.3)-4	1.3	61440	122880
AIR-(1.3)-5	1.3	73728	147456
AIR-(1.5)-1	1.5	24576	49152
AIR-(1.5)-2	1.5	36864	73728
AIR-(1.5)-3	1.5	49152	98304
AIR-(1.5)-4	1.5	61440	122880
AIR-(1.5)-5	1.5	73728	147456
AIR-(2)-1	2	24576	49152
AIR-(2)-2	2	30720	61440
AIR-(2)-3	2	36864	73728
AIR-(2)-4	2	43008	86016
AIR-(2)-5	2	49152	98304

Table 2. Analysis scenarios of the CBA for Airlines.

The process of calculating the corresponding benefits under each of the above analysis scenarios, involves the determination of the combinations of the % Reduction of ATFM delays (denoted by p_1), the % Gains in Horizontal Flight Inefficiency (denoted by p_2), the % Gains in Vertical Flight Inefficiency (denoted by p_3)and the expected % reduction of the ANSP charges (denoted by p_4) for which the B/C ratio of the specific scenario is achieved. The EMOSIA spreadsheet for the Airlines is used in order to perform the calculations required for identifying the above mentioned combinations of benefits. In particular, the EMOSIA spreadsheet for the airlines (available at the EUROCONTROL site [10]) have been reformulated in order to comply with the cost and benefit variables used for the CBA assessment of A^3 ConOps. The values (presented in the Tables of Appendix I) for any CBA variable considered fixed (non-uncertain) have been inserted in the appropriate cells of the spreadsheet. Running each of the above mentioned analysis scenarios involves: i) inserting the forward-fit and the retro-fit costs in the corresponding cell of the spreadsheet, and ii) identifying with a trial and error procedure the alternative combinations of benefits that yield the desired B/C. In order to facilitate this trial and error procedure, the boundary value for each benefit variable is identified by setting the remaining benefit variables equal to their lowest possible value. The lowest possible values for the required % Reduction of ATFM delays, % Gains in (reducing) Horizontal Flight Inefficiency, % Gains in (reducing) Vertical Flight Inefficiency are assumed to be equal to zero expressing the contingency that no improvement in the corresponding performance measures would be attributed to A^3 ConOps.

The corresponding lowest value considered for the % reduction of the ANSP charges should be above zero since under the A^3 ConOps, no ATC services will be provided to the airspace users flying within the self separation airspace. Thus, in any case the ANSPs charges are expected to be reduced. A 5% is arbitrarily[1] assumed as the minimum possible reduction of ANSPs charges. Based on the above assumptions, the following boundary values are identified for the uncertain benefit variables given a specified Forward fit value and the pre-determined B/C ratio:

i. The required % Reduction of ATFM delays (denoted by p_1^{max}) to reach the B/C ratio of the specific scenario given that the % Gains in Horizontal and Vertical Flight Inefficiency, and the expected % reduction of the ANSP charges is set equal to 5% (i.e., improvement is expected solely for the reduction of the ATFM delays).
ii. The value of the % Gains in (reducing) Horizontal Flight Inefficiency (expressed in percentage points and denoted by p_2^{max}) required for achieving the specific B/C ratio given that the % Reduction of ATFM delays, % Gains in (reducing) Vertical Flight Inefficiency and the % reduction of the ANSP charges are set to 5% (i.e. gains of flight inefficiency is the only improvement expected from A^3 ConOps)
iii. The value of the % Gains in (reducing) Vertical Flight Inefficiency (expressed in percentage points and denoted by p_3^{max}) required for achieving the specific B/C ratio given that the % Reduction of ATFM delays, % Gains in (reducing) Horizontal Flight Inefficiency and the % reduction of the ANSP charges are set to 5% (i.e. gains of flight inefficiency is the only improvement expected from A^3 ConOps)
iv. The value of the % reduction of the ANSP charges (denoted by p_4^{max}) required for achieving the specific B/C ratio given that the % Reduction of ATFM delays and the % Gains in Horizontal and Vertical Flight Inefficiency are set to 0 (i.e. the reduction of the ANSP charges is the only improvement expected from A^3 ConOps)

Given the above calculation of (p_1^{max}, p_2^{max}, p_3^{max}, p_4^{max}), the identification of the combinations of (p_1, p_2, p_3, p_4) for which the targeted B/C ratio is achieved may be computed by selecting one of (p_i^{max}) e.g., $p_1^{max}$and iteratively decreasing it by a predefined step (e.g.,0.5, depending on which variable has been selected) and then identify (through trial and error) at least one triple of (p_2, p_3, p_4) for which the targeted B/C ratio is achieved. However, this process may be significantly simplified given that the relationships between the % Reduction of ATFM en-route delays (denoted by p_1), the % Gains in Horizontal Flight Inefficiency (denoted by p_2), the % Gains in Vertical Flight Inefficiency (denoted by p_3), the % reduction of the ANSPs en-route charges (denoted by p_4) and Forward fit Cost (c_f) is linear. Thus, for instance the ANSPs Charges Reduction % (p_4) is given by formula (1) below.

$$p_4 \coloneqq a_0 + a_1 p_1 + a_2 p_2 + a_3 p_3 + a_f c_f \quad (1)$$

[1] The minimum possible % reduction of ANSPs en-route charges may take values that the decision maker/analyst finds reasonable.

Therefore, it suffices to calculate (through trial and error) only five vectors of $(p_1, p_2, p_3, p_4, c_f)$ achieving the predetermined B/C ratio in order to estimate the coefficients $(a_0, a_1, a_2, a_3, a_f)$ of formula (1). Thus, the calculation of the % ANSPs en-route charges reduction (p_4) in any of the airlines analysis scenarios may be performed by substituting to equation 1, the corresponding values of the remaining uncertain variables. The complexity of the calibration of equation 1 is equivalent to the complexity of solving a 5x5 system of linear equations.

In theory an infinite number of combinations of values for the uncertain benefit variables exist for given forward-fit cost and B/C. In the context of this analysis, only a representative set from these combinations are presented where conservative operational improvements are assumed with respect to Horizontal and Vertical Flight Efficiency Gain and en-route ATFM delay reduction. It should be pointed out that the proposed analysis approach allows for the consideration of different assumptions regarding the operational improvements leading to different results. Given the maturity level of A^3 ConOps no valid assumptions can be made for either the benefits or the forward fit costs, and thus the analysis results reported cover the scenarios where marginal or moderate reduction of the Horizontal Flight Efficiency Gain and en-route ATFM delay is assumed.

3.2 Results for the Airlines

This section provides the results from the application of the Airlines CBA for the analysis scenarios presented in the previous section. Each analysis scenario is identified by two major indicators: i) the value for the desired B/C, and ii) the value for the forward-fit cost associated with the A^3 ConOps. The expected outcome from each analysis scenario is the determination of alternative combinations of values for the uncertain benefit variables (Incremental Delay Reduction (%), Incremental Vertical Efficiency Gain (%), Incremental Horizontal Efficiency Gain (%), Savings from reduced ANSPs en-route charges) for which the corresponding total benefits divided by the total costs yield the targeted B/C. Given that no data are available for narrowing the range of potential values for the forward-fit cost or the benefit variables, the results from each analysis scenario relates to a wide set of combinations of benefits values. The objective of this section to illustrate the usability of the proposed A^3 ConOps CBA for a set of certain assumptions regarding the en-route ATFM Delay reduction and Horizontal Flight Efficiency Gains and the identification of the relevant conditions under which specific B/C values may be achieved through the A^3 ConOps changes.

The results presented in this section were derived from analysis scenarios with forward fit cost variable taking values in {€ 24576, € 36864, € 49152, € 61440, € 73728} which correspond to 0%, 50%, 100%, 150%, and 200% of the lower bound for that variable (i.e., € 24576). Moreover, the analysis scenarios under consideration correspond to B/C taking any of the following values 1, 1.1, 1.2, 1.5, and 2. A complete set of results may be found in Appendix III. The above B/C values cover a wide spectrum of desired economic performance ranging from marginal (B/C equal to 1), substantial (B/C equal to 1.1 &1.2) and high (B/C equal to 1.5, 2). It should be highlighted though that the A^3 ConOps CBA tool for the airlines may provide results for any other intermediate or higher value for the B/C.

Concerning the expected operational improvements as expressed by the four uncertain benefit variables mentioned above, experts within the iFLY consortium indicated that the potential implications of A[3] ConOps on *ATFM Delay and Horizontal Inefficiency Gain* depend on other factors apart from the A[3] ConOps and thus the share of A[3] ConOps changes to any improvement in the above two measures *may* be disputable. On the other hand it can be argued that the *Savings from reduced ANSPs en-route charges and Incremental Vertical Efficiency Gain* are direct implications from the implementation of the A[3] ConOps. Based on the above, the results presented in this report refer to analysis scenarios assuming low or moderate improvements for the *Incremental Delay Reduction* (up to 10%) and *Incremental Horizontal Efficiency Gain* (up to 20%). For any combination of values for the benefit variables *Incremental Delay Reduction* and *Incremental Horizontal Efficiency Gain* the entire set of combinations of values for *Savings from reduced ANSPs en-route charges and Incremental Vertical Efficiency Gain* yielding a ratio of total benefits over total cost equal to the corresponding B/C can be determined. Figures 2-7 present the results from the analysis scenarios under consideration. Each of the plotted points in any of the graphs presented in Figures 2-7, represents a pair of values of forward fit cost and the corresponding ANSPs charges reduction % required for achieving the predetermined B/C for pre-specified values for the ATFM delay reduction %, the Horizontal Flight Inefficiency Reduction %, and the Vertical Flight Efficiency Gain. The formulas (2)-(7) presented below express the relationship between the ANSPs charges (dependent variable) with the remaining benefits variables and the forward for cost for B/C of 1, 1.1, 1.2, 1.3, 1.5 and 2 respectively. Each of the formulas (2)-(7) emerged from the calibration of formula (1) for each of the above B/C values considered.

$$p_4 \coloneqq 0.352 - 1.013p_1 - 1.583p_2 - 0.006p_3 + 3.05 \cdot 10^{-6}c_f \quad (2)$$

$$p_4 \coloneqq 0.388 - 1.004p_1 - 1.583p_2 - 0.006p_3 + 3.35 \cdot 10^{-6}c_f \quad (3)$$

$$p_4 \coloneqq 0.423 - 1.014p_1 - 1.583p_2 - 0.006p_3 + 3.66 \cdot 10^{-6}c_f \quad (4)$$

$$p_4 \coloneqq 0.458 - 1.014p_1 - 1.583p_2 - 0.006p_3 + 3.96 \cdot 10^{-6}c_f \quad (5)$$

$$p_4 \coloneqq 0.528 - 1.014p_1 - 1.583p_2 - 0.006p_3 + 4.57 \cdot 10^{-6}c_f \quad (6)$$

$$p_4 \coloneqq 0.705 - 1.014p_1 - 1.583p_2 - 0.006p_3 + 6.09 \cdot 10^{-6}c_f \quad (7)$$

It should be highlighted that the impact of the Vertical Flight Efficiency Gain variable to the en-route ANSPs charges is marginal. Thus, each of the points plotted in the graphs of Figures 2-7 correspond to the average value of ANSPs en-route charges reduction for the corresponding values of Forward-fit Cost, en-route ATFM delay reduction and Horizontal Flight Efficiency Gain, over the following values of the Vertical Flight Efficiency Gain: 0%, 50% and 100%. All pairs of values of forward fit cost and the corresponding ANSPs charges reduction % calculated for given values of the ATFM delay reduction % and the Horizontal Flight Inefficiency Reduction % are marked with the same symbol, e.g., a diamond for ATFM Delay Reduction % equal to 0% and Horizontal Flight Inefficiency reduction % equal to 0%, a square for ATFM Delay Reduction % equal to 0% and Horizontal Flight Inefficiency reduction % equal to 10%, etc. In order to clarify the calculations performed for specifying each of the points plotted in the graphs 2-7, a numerical example of specifying the coordinates of the first (from the left) diamond point of graph 2 is presented. In general, each point plotted in the graph of Figure 2 is specified by two coordinates: i) the forward fit cost, and ii) the corresponding average value of % ANSPs en-route charges reduction required for 0%, 50% and 100% Vertical Flight Inefficiency Reduction. For the first diamond point the forward fit cost is equal to €24576 per aircraft, while the average % ANSPs en-route charges reduction is equal to 27.1%. In addition any of the diamond points correspond to 0% ATFM delay reduction and 0% Horizontal Flight Inefficiency Reduction. Using the Airlines CBA spreadsheet it was calculated that the ANSPs en-route charges reduction required in order to achieve a B/C equal to 1 (the graph in Figure 2 presents the results from the analysis scenarios with B/C equal to 1) for 0% Vertical Flight Inefficiency Reduction equals to 27.3%, for 50% equals to 27.1% and for 100% equals to 26.9 %. The average of these three values calculated for the % Vertical Flight Inefficiency Reduction is equal to 27.3%. Table **3** below provides the input values used for the calculation of the corresponding values of the % en-routes charges reduction.

Category of Variables	Variable	Input Value
	Discount Rate	8%
Time Variables	*This Year*	2010
	Benefit Start Year	2026
	Benefit End Year	2035
	Final Year	2035
	Implementation Duration	8 years
	Start Year	2013
	Pre-Impl. Start year	2013
	Pre-Imp duration	10 years
Baseline Variables	*Aircraft BL number*	16759 (2009)
	Aircraft Growth Rate (annual)	3%
	Annual Retirement Rate	2%
	BL Annual Flights	10.1 (2009)
	Average Flight Duration (min)	106
	BL Delay per flight TS	1,9 min
	S1 Horizontal BL Flight Path Inefficiency % (TS)	3.7%
	Vertical Flight Inefficiency	0.6% (of the jet fuel consumed per flight)
	Jet Fuel Price	655 €/mt
Cost Variables	*Forward-fit Cost*	€24576 (2010)
	Overall Annual Operating Cost	70.53 M€
	Airlines One-off Implementation cost (Training)	3.86 B€
	Total Pre-Implemention Cost	5.85 M€
Benefit Variables	*Cost per unpredictable Delay Minute*	89.76 €/min
	Cost per flight minute	69.77 €/min
	Incremental Efficiency Gain (%)	0%
	Incremental Delay Reduction	0%

Table 3. Input values for calculating the required reduction of ANSPs en-route charges for a given scenario.

The entire set of results are provided in Tables of Appendix III at the end of this report.

Under the assumption that the en-route ANSPs charges reduction due to the reduction of the en-route staff cost reduction corresponds to 62% of the total en-route ANSPs charges (see Appendix I), the maximum percentage reduction of the en-route ANSPs charges should not exceed 62%. In addition the relevant Internal Rate of Return (IRR) is clearly indicated in each graph.

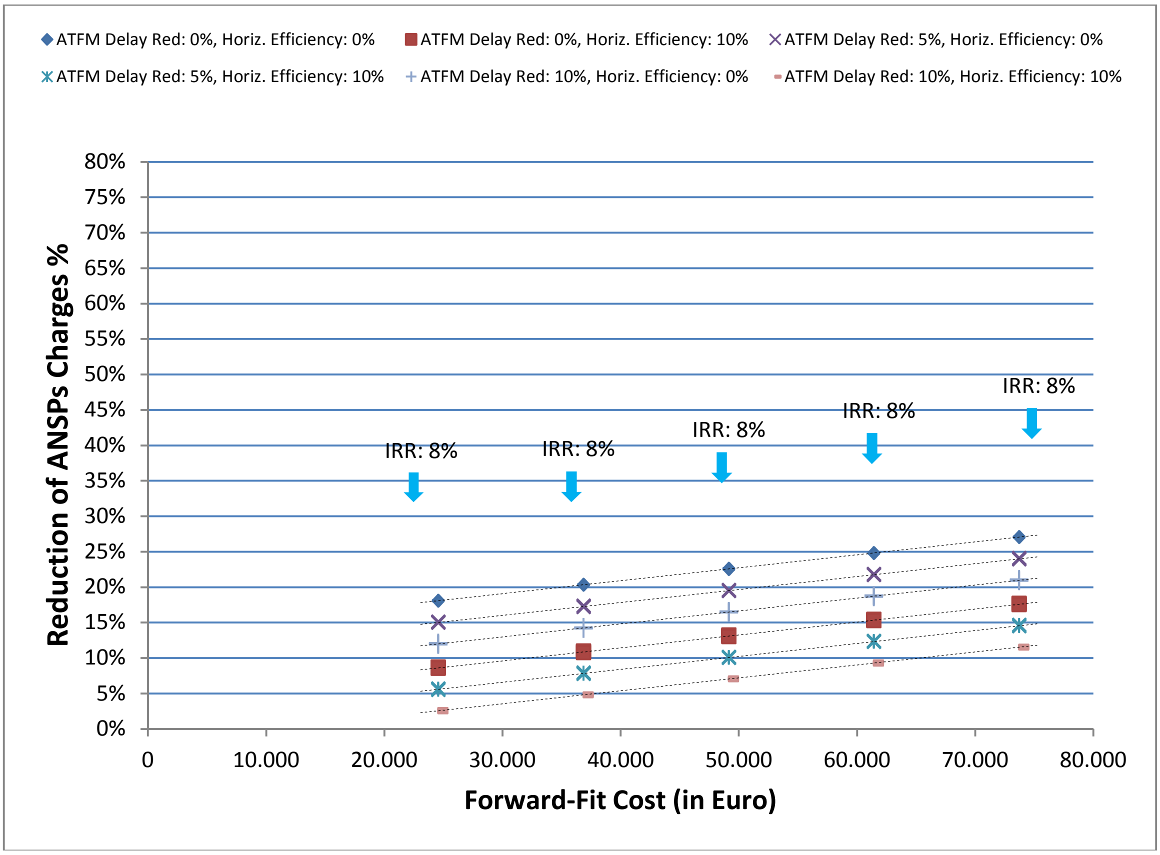

Figure 2. ANSPs charges reduction (%) relation to forward-fit cost for B/C equal to 1**.**

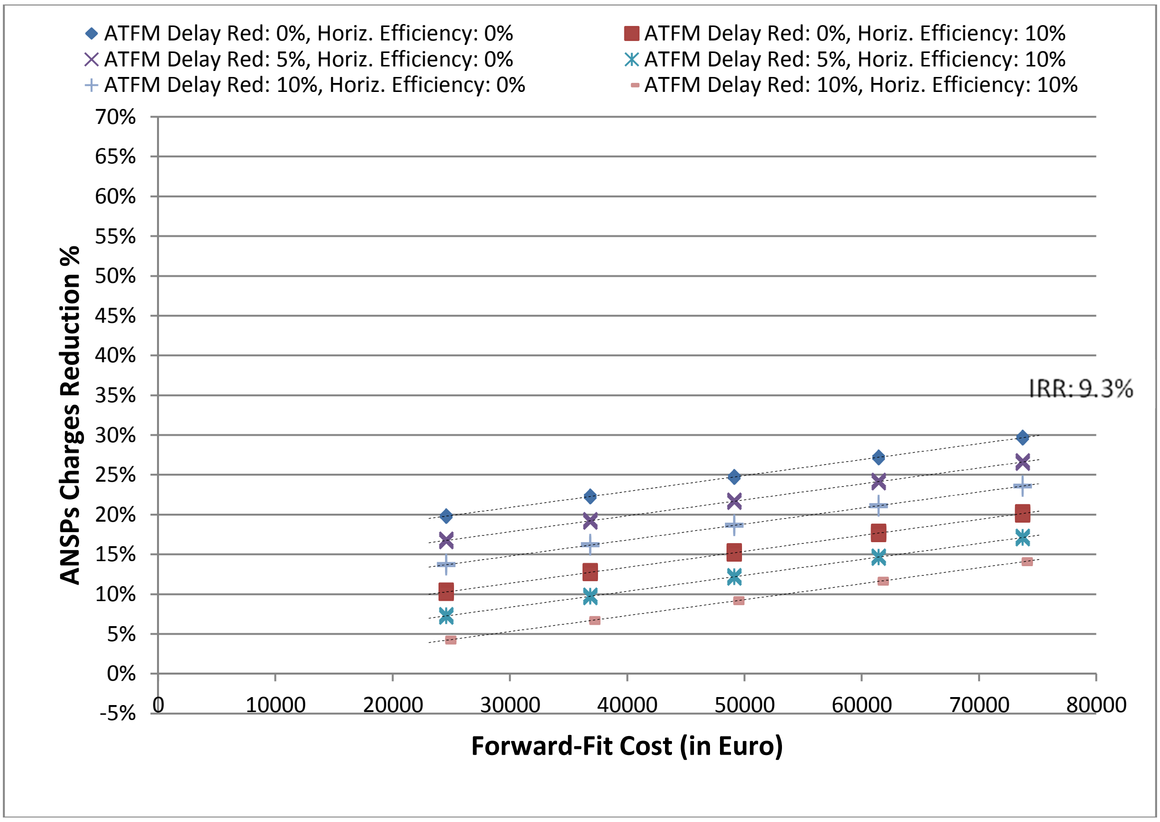

Figure 3. ANSPs charges reduction (%) relation to forward-fit cost for B/C equal to 1.1**.**

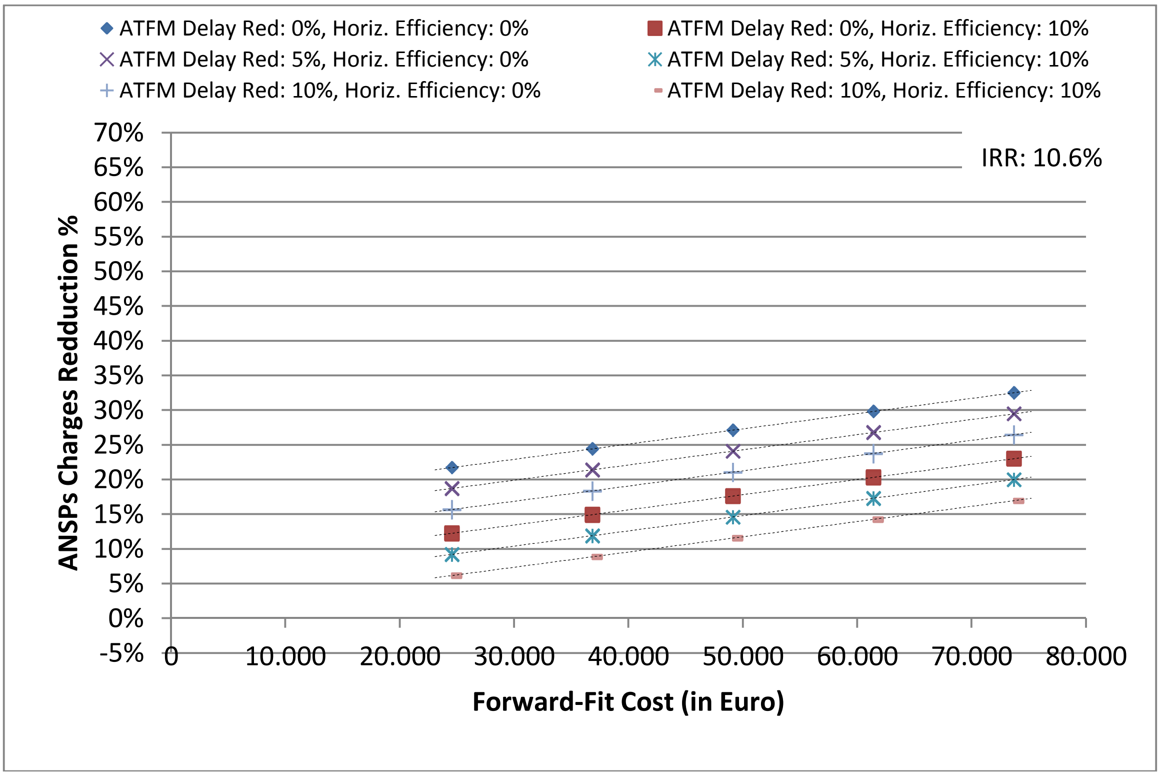

Figure 4. Graph of ANSPs charges reduction percentages vs. forward-fit cost values for various ATFM delay reduction and Horizontal Flight Inefficiency % values and for B/C equal to 1.2**.**

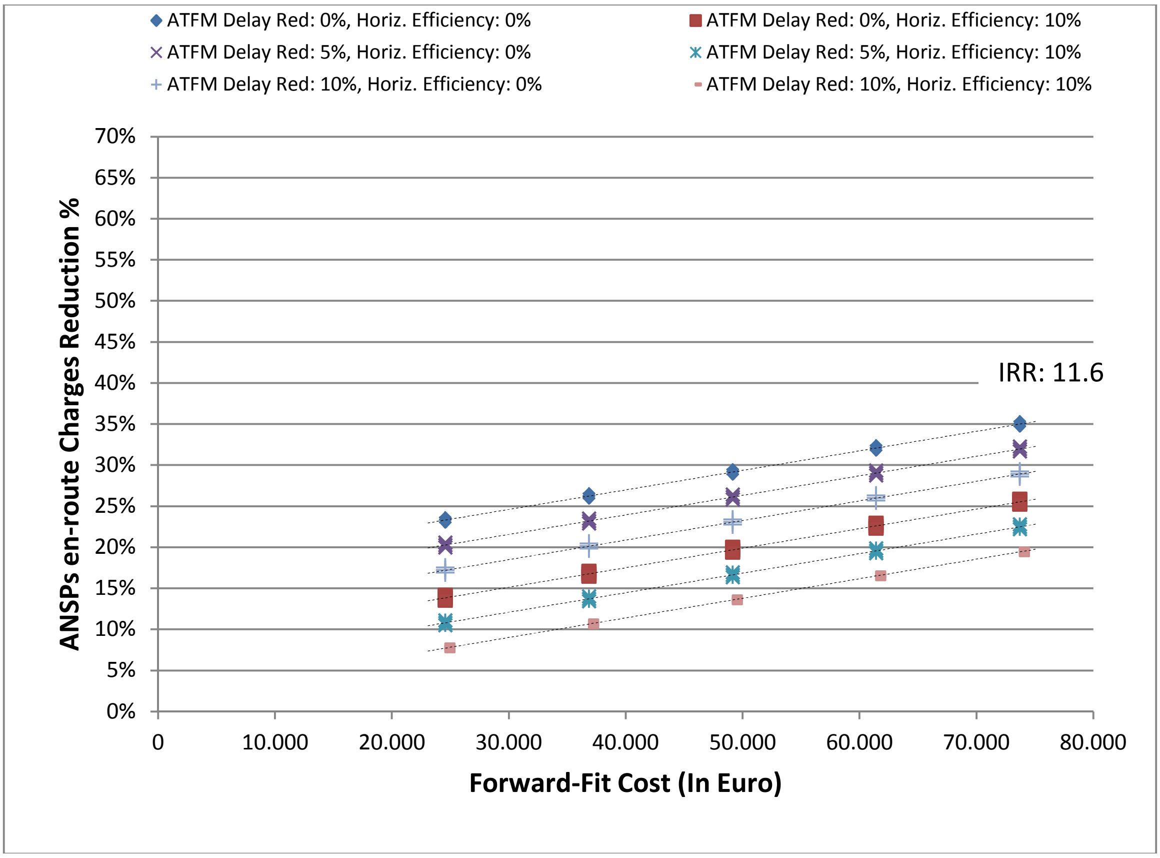

Figure 5. ANSPs charges reduction (%) relation to forward-fit cost for B/C equal to 1.3**.**

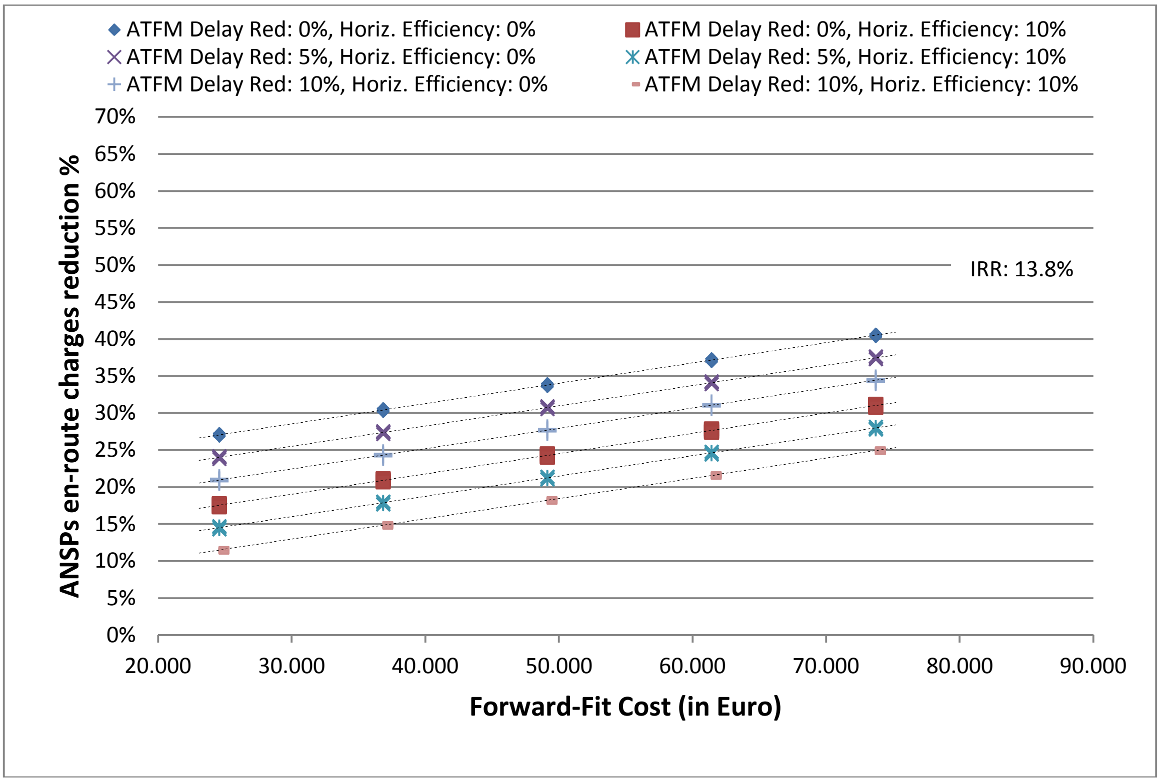

Figure 6. ANSPs charges reduction (%) relation to forward-fit cost for B/C equal to 1.5**.**

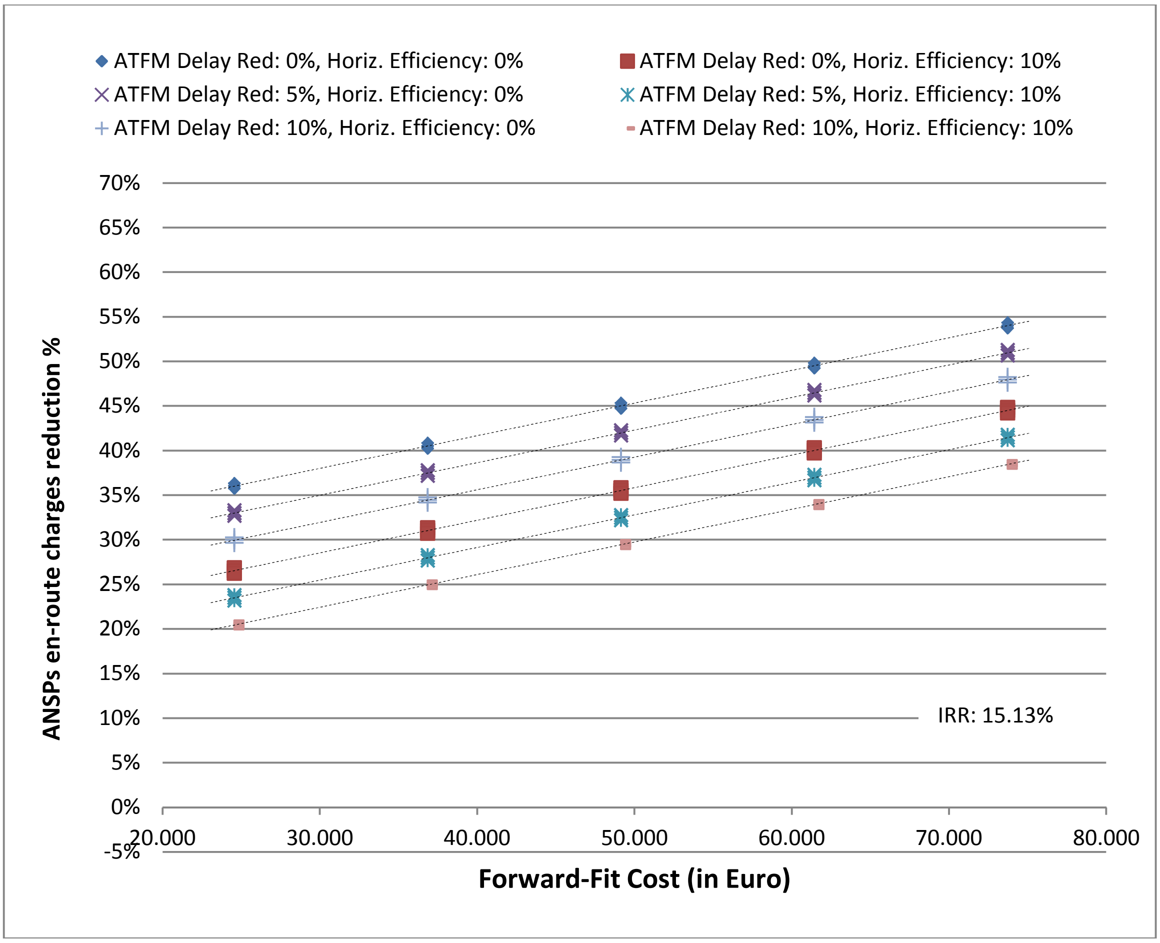

Figure 7. ANSPs charges reduction (%) relation to forward-fit cost for B/C equal to 2**.**

Based on the results presented in Figures 2-7 various remarks can be made with respect to the relationship between the forward-fit cost and the benefits variables under different B/C values. The ANSPs charges reduction % for a predetermined B/C equal to 1 ranges from 11.5% (for an optimistic case where the % Reduction of ATFM delay and the Horizontal Flight Inefficiency Reduction % are 10% while the forward-fit cost is €73728) up to 27.15% in the case of the most pessimistic case where the % Reduction of ATFM delay, the Horizontal Flight Inefficiency Reduction %, and the Vertical Flight Inefficiency Reduction% take their lowest value, i.e., 0% while the forward-fit cost takes its highest value, i.e., € 73728. If the forward fit cost takes moderate value i.e., € 49152, then in the worst case where no improvement takes place due to A^3 ConOps in horizontal or vertical flight inefficiency and ATFM delay, it was calculated though the use of the Airlines CBA tool (spreadsheet) that a 22.66% ANSPs charges reduction should occur for achieving balanced costs and benefits for the airlines (i.e., B/C equal to 1). In any case, all points plotted in the graph of Figure 2, lie under 62% level implying that the corresponding combinations of forward-fit cost, ANSPs charges, en-route ATFM delay reduction and Horizontal Flight Efficiency Gains are potentially feasible.

Similar remarks can be derived for any other value considered for ratio B/C. Thus, for B/C equal to 1.1 (i.e., when the business target is to yield benefits through A^3 ConOps that overrun the total costs by 10%), the ANSPs charges reduction % ranges from 14.27% in the optimistic case as described above (forward fit cost €73728, ATFM delay reduction 10%, Horizontal flight Inefficiency 10%, and Vertical Flight Inefficiency Reduction 50%) up to 29.65% for the most pessimistic case (forward fit cost €73728, ATFM delay reduction 0%, and Horizontal and Vertical flight Inefficiency 0%). On the other hand the forward fit costs takes the moderate value € 49152 then under the worst case (ATFM delay reduction 0%, Horizontal flight Inefficiency and Vertical Flight Inefficiency Reduction 0%) then a 24.92% reduction of the ANSPs charges is sufficient for achieving the predetermined economic performance target (B/C equal to 1.1).

For B/C equal to 1.2, the relevant economic performance target is to achieve benefits that overrun total costs by 20%. Under this target, the ANSPs charges reduction % ranges from 16.94% for the most optimistic case (forward fit cost €73728, ATFM delay reduction 10%, Horizontal Flight Inefficiency 10%, and Vertical Flight inefficiency Reduction 50%) up to 32.58% under the most pessimistic case (forward fit cost €73728, ATFM delay reduction 0%, and Horizontal and Vertical flight Inefficiency reduction 0%). If the forward fit cost takes a moderate value (€ 49152) then in the worst case scenario where ATFM delay reduction and Horizontal flight Inefficiency reduction equal to 0%, the minimum ANSPs charges reduction required to achieve the above economic target is 27.19%.

Examining the relationship among the forward fit cost and the benefit variables under a relatively high economic performance target where the B/C is equal to 1.5 (i.e., the benefits exceeding the costs by 50%) indicated that the ANSPs charges reduction % ranges from 24.93% to 40.71% for the most optimistic (forward fit cost €73728, ATFM delay reduction 10%, Horizontal Flight Inefficiency 10%, and Vertical Flight Inefficiency Reduction 50%) and most pessimistic (forward fit cost €73728, ATFM delay reduction 0%, and Horizontal and Vertical flight Inefficiency 0%) case respectively. For a moderate forward fit cost value (€ 49152), a 33.98% reduction of the ANSPs charges is required in the worst case scenario where the ATFM delay reduction, the Horizontal and Vertical flight Inefficiency reduction are equal to 0%, in order to achieve the above economic performance target.

In order to illustrate further the usability of the A^3 ConOps CBA method and its results, assume that simulation experiments for a more mature version of A^3 ConOps indicated that the proposed changes are expected to reduce Horizontal Flight Inefficiency by 7%, the Vertical Flight Inefficiency by 10%, and en-route ATFM delay by 2%. In addition assume that the expected reduction of ANSPs charges is expected to reach 20%. Given the above figures for the benefits, applying the Airlines CBA tool yields that for a B/C equal to 1.1, the forward fit cost should not exceed € 63000.

3.3 Summary of Results and Concluding Remarks

In summary, the potential viability of the A^3 ConOps from the perspective of the Airlines can be explored by assessing the CBA results for two scenarios encompassing a wide range of alternatives (i.e., a pessimistic and a fairly optimistic scenario). In both scenarios the total cost is the same corresponding to its worst case value emerging when the forward-fit cost takes its highest value, i.e., €73728. The most pessimistic scenario is defined when the expected benefit variables Horizontal Flight Efficiency Gain (%), Vertical Flight Efficiency Gain (%), en-route ATFM Delay Reduction (%) take their lowest possible values (i.e. 0%). On the other hand in the fairly optimistic scenario, the benefit variables take reasonable values (i.e., 10%, 50%, 10% respectively).

Table 4 below provides the costs and benefits calculated for the most pessimistic scenario with regards to benefits. Based on the assumptions of the most pessimistic scenario, the B/C ratio can obtain values greater than one (e.g., B/C=1.2) if the en-route charges will be reduced by at least 32.57% of the currently imposed en-route charges. While the present worth value of the total cost for this scenario is 3,257 M€ the corresponding en-route charges reduction yields savings of 3,905

M€. It should be pointed out that the required level of en-route charges reduction is approximately half of the maximum that can be potentially achieved (i.e., 62%).

Table 5 presents the costs and benefits calculated for a fairly optimistic scenario with regards to benefits. Based on the assumptions of the optimistic scenario the B/C ratio can obtain values greater than one (e.g., B/C=1.2) if the en-route charges will be reduced by at least 16.83% of the currently imposed en-route charges.

CBA Measures	B/C:	1.2	IRR:	10.6%	
	Break Even Year:	2029	NPV:	651 M€	
COSTS			BENEFITS		
Costs Indicators	Present Worth(2010)	Annual Worth (2018-2035)	Benefits Indicators	Present Worth(2010)	Annual Worth (2018-2035)
Total Forward-Fit Cost	421 M€	46.2 M€	*En-route Charges Savings*	3,905 M€	428,1 M€
Total Retrofit Cost	1,194 M€	130.9 M€	*Savings from ATFM en-route delay Reduction*		0
Training Cost	1,498 M€	164.2 M€	*Savings for Flight Efficiency Gains*	0	0
Maintenance Cost	138 M€	15.1 M€			
Pre-Imp. Cost	6 M€	0.66 M€			
Total Cost	**3,257 M€**	**357.1 M€**	**Total Benefits**	**3,905 M€**	**428.1 M€**

Table 4. Summary of the results for the most pessimistic (from the benefits perspective) scenario for the Airlines CBA.

CBA Measures	B/C:	1.2	IRR:	10.6%	
	Break Even Year:	2029	NPV:	653 M€	
COSTS			BENEFITS		
Costs Indicators	Present Worth(2010)	Annual Worth (2018-2035)	Benefits Indicators	Present Worth(2010)	Annual Worth (2018-2035)
Total Forward-Fit Cost	421 M€	46.2 M€	*En-route Charges Savings*	2,018 M€	221,2 M€
Total Retrofit Cost	1,194 M€	130.9 M€	*Savings from ATFM en-route delay Reduction*	729 M€	79.9 M€
Training Cost	1,498 M€	164.2 M€	*Savings for Flight Efficiency Gains*	1,160 M€	127,2 M€
Maintenance Cost	138 M€	15.1 M€			
Pre-Imp. Cost	6 M€	0.66 M€			
Total Cost	**3,257 M€**	**357.1 M€**	**Total Benefits**	**3,907 M€**	**428.3 M€**

Table 5. Summary of the results for an optimistic scenario (from the benefits perspective) for the Airlines CBA.

The interpretation of the analysis results presented above indicates that implementing A^3 ConOps under a conservative assumption for the reduction of the en-route ATFM delay and the Horizontal flight Inefficiency, may an economically viable investment for the Airlines. Even in the worst case scenarios considered in this analysis where benefits will result only from the reduction of the ANSPs charges, the required reduction of the charges is plausible. The above results imply that even if the forward-fit cost reaches the maximum value considered in this analysis then the benefits required in order to balance cost are not prohibitive. Moreover, the attainment of this goal may be achieved with several alternative combinations of benefits. This finding seems to be encouraging with regards to a potential implementation of A^3 ConOps from the perspective of the airlines. Definitely, the results provided above could be taken into account by the A^3 ConOps developers, the Airlines, and the ATM policy makers in drawing a strategy for further developing and implementing the proposed ConOps. The CBA results for the airlines suggest that it is economically viable to consider the development of the A^3 ConOps to the next maturity stage.

4 ANSPs Analysis Scenarios

4.1 ANSPs Analysis Scenarios

The application of the scenario-based CBA approach for the ANSPs involves the following uncertain variables: i) the ANSPs *one-off implementation cost* (i.e., transition cost for implementing A^3 ConOps and the corresponding training cost for adopting the new (or revised) tasks and operations), ii) the *annual % reduction of the en-route staff cost* and iii) the *annual % reduction of the non-staff operating cos*t. Thus, the application of the proposed analysis approach for the case of the ANSPs may be performed in two alternative (but equivalent) ways: i) calculating the en-route staff cost reduction and operating cost reduction for each combination of transition cost, training cost (i.e., ANSPs one-off implementation cost) and B/C ratio (or the Internal Rate of Return), ii) calculating the transition cost and training cost for each combination of the % reduction of en-route staff cost and the % reduction of operating non-staff cost and B/C ratio. However, valid ranges of potential values were specified only for the staff operating costs as indicated in Table 6. Thus, in the ANSPs CBA assessment, the latter direction of analysis was selected.

Each analysis scenario is identified by: i) a targeted B/C ratio, ii) the value for the *annual % reduction of the non-staff operating cos*t, and iii) the value of the *annual % reduction of the en-route staff cos*t. For each combination of the above quantities the ANSPs one-off implementation cost is calculated so that the ratio of the total benefits over the total cost is equal to the predetermined B/C value. A given triple of values for the B/C, the *annual % staff cost* reduction , and the annual % operating non-staff cost reduction specify unambiguously the maximum ANSPs *one-off implementation cost* for which the predetermined B/C is obtained. Assuming that the two constituents of the ANSPs one-off implementation cost (i.e., transition and training cost) are proportional and their ratio is equal to 6.3 (this is the ratio of the expected transition cost over the corresponding training cost for AENA, see Appendix II for more details), an estimate for each of these two costs may be calculated. The ranges of values for each of the above uncertain variables are presented in Table 6. The objective of the analysis results presented in this report is to examine the ANSPs one-off implementation cost that is allowed to be spent for A^3 ConOps under various levels of en-route staff cost and operating cost reduction so that predetermined economic performance targets (expressed in B/C values) are obtained. The economic performance levels considered in this analysis relate to marginal prevalence of benefits over costs (i.e., B/C equals 1), substantial prevalence (i.e., B/C equals 1.1 and 1.2) and high prevalence (i.e., B/C equals 1.5 and 2).

Uncertain Variable	Definition	Range of Values
Annual % reduction of the en-route staff cost	According to the A[3] ConOps no Air Traffic Control Services will be provided to aircraft flying within the Self-Separation Airspace (during the en-route phase of the flight). This ATM change implies that en-route staff cost of the ANSPs will be reduced (ATCOs in Area Control Centers and probably other supporting staff will be progressively reduced). Thus from the assumed implementation start year in 2018 until 2025, the staff cost is assumed to progressively be reduced. However, in this analysis the benefits within the implementation period are not taken into account. Any benefit considered in this analysis for ANSPs refers to 2025 onwards. This variable expresses the percentage en-route staff cost reduction on an annual basis. It should be mentioned that the actual reduction in euros is calculated by considering the 2008 en-route staff cost as a baseline value.	Based on the description of the A[3] ConOps and as indicated by experts (ISDEFE) participating in this WP, a non-zero reduction of the en-route staff cost is expected from the implementation of the proposed ATM changes. However, given that no indication could be provided as to the expected level of reduction, low values should also be included in the analysis. In this context, the lower bound for this variable was arbitrarily selected from the analysis team equal to 5%. On the other hand, the total vanishing of the en-route staff cost is the absolute upper bound although it cannot be verified that such an achievement is possible. In this context, the analysis team has selected 70% as an upper bound of this analysis (excluding too optimistic values).
Annual % reduction of the non-staff operating cost	This variable refers to the percentage annual reduction of the operating costs of ANSPs for offering Air Navigation Service Providers, including rentals, energy consumption, telecommunications, insurance, outsourced maintenance **[11]**	There is no indication regarding the upper or lower bounds for this variable. In this analysis a conservative scenario was used where it value does not exceed 5%.
ANSPs one-off implementation cost	The ANSPs *One-off Implementation Cost (M-Euro)* is the total investment of the ANSPs on one-off implementation activities, including the management of the transition process from the baseline ATM operational framework (SESAR inclusive) to the one proposed in the A[3] ConOps, and the training of the staff at the new operations. In particular, the cost of managing the transition involves the cost for the reorganization of ANSPs in order to implement the new procedures for the ANSPs ground support. The cost for training involves the ANSPs expenses for training the staff to use the new systems and implement the new procedures introduced by the A[3] ConOps. However, this estimate referred generally to transitions and not specifically for the transition implied by A[3] ConOps.	The cost estimates for the transition process that were provided (for AENA [12]) were: i) High: 1.2 M€, ii) Base:1 M€, iii) Low:0.9 M€ (in 2009 prices). The corresponding estimates for the training cost were: i) High:0,25 M€, ii) Base:0,2 M€, and iii) Low:0.18 M€ (in 2009 prices). The resulting aggregate cost estimates for the transition process are: i) High 12.4 M€, ii) Base 10.3 M€, and iii) Low 9.3 M€ (in 2009 prices). For the training cost: i) High: 2.12 M€, ii) Base: 1.7 M€, and iii) Low: 1.53 M€ (in 2009 prices). Thus, a lower bound that could be used is sum of the higher values in these two cost elements yielding the value of 15 M€.

Table 6. Overview of the uncertain benefit variables involved in the ANSPs CBA

The analysis scenarios are built and processed through the following process:

i. Determination of the B/C ratio alternative values. The objective of this step is to specify the alternative valid values of the B/C ratio expressing the ANSPs economic expectations from investing on A[3] ConOps. The lowest value of the B/C ratio is unity (i.e., $B/C \geq 1$) for which benefits and costs are balanced. Since there is no interest to consider scenarios in which costs overrun benefits, the alternative values considered for B/C were above unity. As mentioned above the range of values considered for B/C in this analysis is {1, 1.1, 1.2, 1.3, 1.5, 2}.
ii. Specify the valid ranges of values for the uncertain benefit variables: *annual % staff cost reduction*, and the *annual % operating non-staff cost reduction*.
    a. The *annual % staff cost reduction* is related to the gradual reduction of the ATC personnel due to the delegation of the separation task form ANSPs to the flight crew. For this

analysis the variable *annual % staff cost reduction* is assigned values from 0 to 70% as indicated in Table 6. The *% operating cost reduction* relates to any en-route non-staff cost of the ANSPs. The range of values for this variable lies between 0 to 5%, a rather conservative upper bound.

iii. Calculation of the ANSPs one-off implementation cost for which the targeted B/C ratio is achieved. The emerging ANSPs one-off implementation cost is split to transition and training cost under the assumed ratio 6.3/1. In addition the corresponding Internal Rate of return (IRR) is calculated in order to indicate the rate of return for the ANSPs emerging from the cost savings due to the A[3] ConOps operational and organizational changes in ATM.

Figure 8 below depicts the process followed for the application of the A[3] ConOps CBA for the ANSPs.

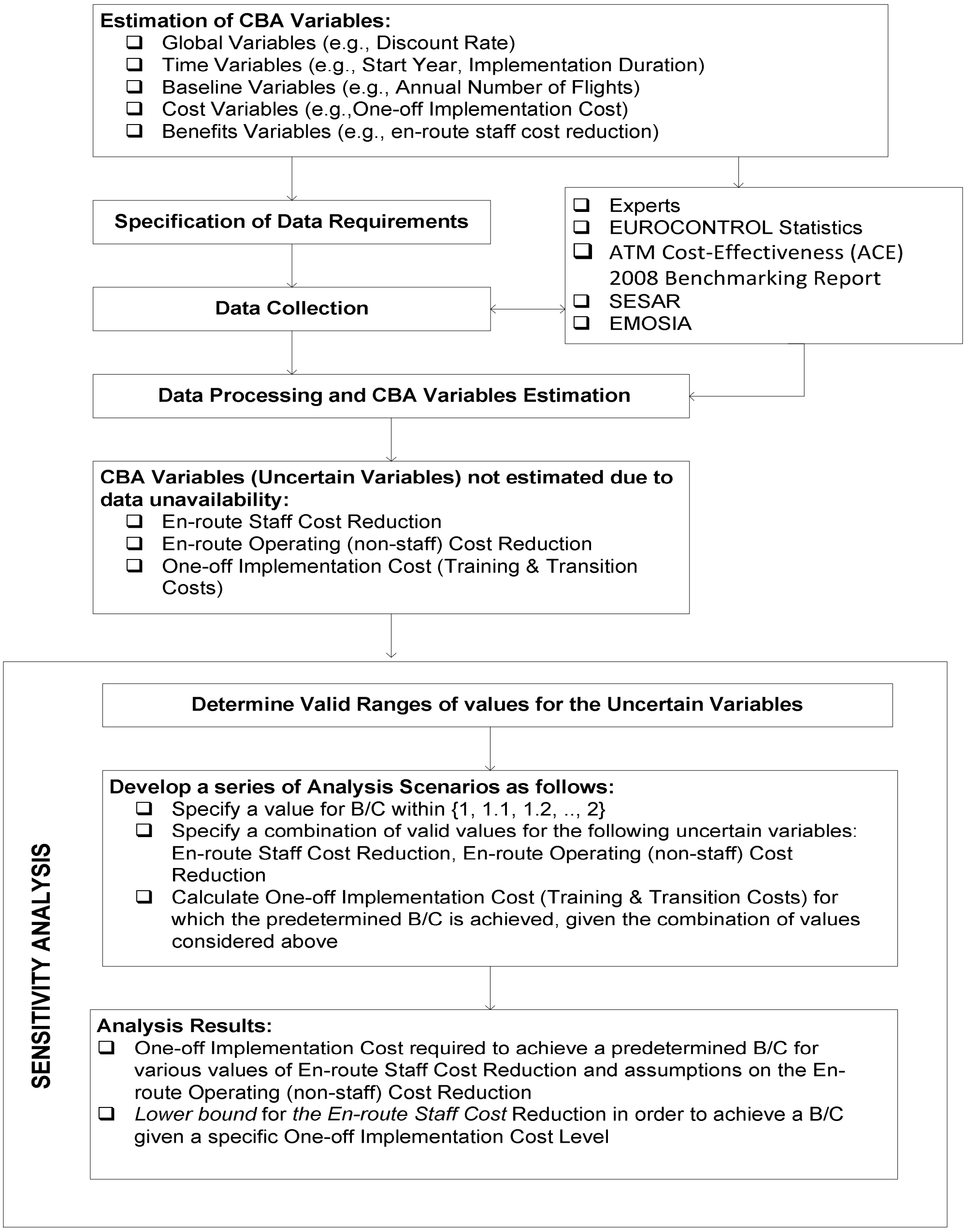

Figure 8. Flowchart presenting the process of applying the proposed Scenario-based CBA approach for the ANSPs.

Table 7 presents the list of analysis scenarios with B/C ratio equal to $\lambda_{(B/C)}$ (where $\lambda_{(B/C)} \epsilon \{1, 1.1, 1.2, 1.3, 1.5, 2\}$).

Scenario ID	B/C Ratio	% staff cost avoidance	% operating cost avoidance
ANSP-(1)-1	1	5	0
ANSP-(1)-2	1	10	0
…	…	…	…
ANSP-(1)-14	1	70	0
ANSP-(1)-15	1	5	5
ANSP-(1)-16	1	10	5
…	…	…	…
ANSP-(1)-28	1	70	5
ANSP-(1.1)-1	1.1	5	0
…	…	…	…
ANSP-(1.1)-14	1.1	70	0
ANSP-(1.1)-15	1.1	5	5
ANSP-(1.1)-16	1.1	10	5
…	…	…	…
ANSP-(1.1)-28	1.1	70	5
ANSP-(1.2)-1	1.2	5	0
ANSP-(1.2)-2	1.2	10	0
…	…	…	…
ANSP-(1.2)-14	1.2	70	0
ANSP-(1.2)-15	1.2	5	5
ANSP-(1.2)-16	1.2	10	5
…	…	…	…
ANSP-(1.2)-28	1.2	70	5
ANSP-(1.3)-1	1.3	5	0
ANSP-(1.3)-2	1.3	10	0
…	…	…	…
ANSP-(1.3)-14	1.3	70	0
ANSP-(1.3)-15	1.3	5	5
ANSP-(1.3)-16	1.3	10	5
…	…	…	…
ANSP-(1.3)-28	1.3	70	5
ANSP-(1.5)-1	1.5	5	0
ANSP-(1.5)-2	1.5	10	0
…	…	…	…
ANSP-(1.5)-14	1.5	70	0
ANSP-(1.5)-15	1.5	5	5
ANSP-(1.5)-16	1.5	10	5
…	…	…	…
ANSP-(1.5)-28	1.5	70	5
ANSP-(2)-1	2	5	0
ANSP-(2)-2	2	10	0
…	…	…	…
ANSP-(2)-14	2	70	0
ANSP-(2)-15	2	5	5
ANSP-(2)-16	2	10	5
…	…	…	…
ANSP-(2)-28	2	70	5

Table 7. Analysis scenarios of the CBA for ANSPS.

The EMOSIA spreadsheet for the ANSPs [13] is used in order to perform the calculations required for calculating the ANSPs one-off implementation cost (transition and training cost) that corresponds to each of the above mentioned analysis scenarios. The EMOSIA spreadsheet calculates various CBA measures (B/C, IRR) given the input values inserted by the user for cost and benefit variables. The relevant EMOSIA spreadsheet for the ANSPs were modified in order to adjust to the A^3 ConOps CBA variables. Analysis of the above mentioned scenarios involves inserting the % en-route staff cost and the % operating cost reduction in the corresponding cells of the spreadsheet, and specification of the corresponding ANSPs one-off implementation cost with a trial and error procedure (i.e., iteratively inserting various candidate values for the ANSPs one-off implementation cost in the appropriate cell of the spreadsheet, until the B/C calculated becomes equal to the targeted B/C value for the specific scenario). However, as in the Airlines case, this process may be significantly simplified given that the relationships between (p_1, p_2, p_3) where p_1 denotes the annual % of en-route staff cost reduction, p_2 is the annual % operating cost reduction, and p_3 is the ANSPs one-off implementation cost, is linear, expressed by the formula below:

$$p_3 \coloneqq b_0 + b_1 p_1 + b_2 p_2 \qquad (7)$$

Therefore, it suffices to calculate (through trial and error) only three vectors of (p_1, p_2, p_3) achieving the predetermined B/C ratio in order to estimate the coefficients (b_0, b_1, b_2) of formula (7). Thus, the calculation of the maximum ANSPs One-off Implementation Cost (p_3) in any of the ANSPs analysis scenarios may be performed by substituting to equation 7, the corresponding values of the remaining uncertain variables (i.e., p_2 and p_3).

4.2 Results for the ANSPs

The results from applying the CBA approach in any of the scenarios presented in section 4 involves the calculation of the ANSPs one-off implementation cost (transition and training cost) for a given combination of en-route staff cost reduction and operating cost (non-staff) reduction percentages under B/C values in the set {1, 1.1, 1.2, 1.3, 1.5, 2}. The graph in Figure 9 depicts the relation of the ANSPs one-off implementation cost with the en-route staff cost reduction % for the alternative B/C values under consideration under the assumption of a 0% reduction of the en-route operating cost. In addition, Figure 9 presents the IRR calculated for the points corresponding to 70% reduction of the ANSPs en-route staff cost In the same context the graph in Figure 10 depicts the corresponding relation of the ANSPs one-off implementation cost with the en-route staff cost reduction % for the alternative B/C values under consideration under the assumption of a 5% reduction of the en-route operating cost. Every point plotted in this type of graphs indicates the maximum one-implementation cost (y-coordinate of plotted point) for which under a given % staff cost reduction (x-coordinate of plotted point), a specific B/C value (denoted by the shape of the point) is achieved. The complete set of results is provided in Appendix IV.

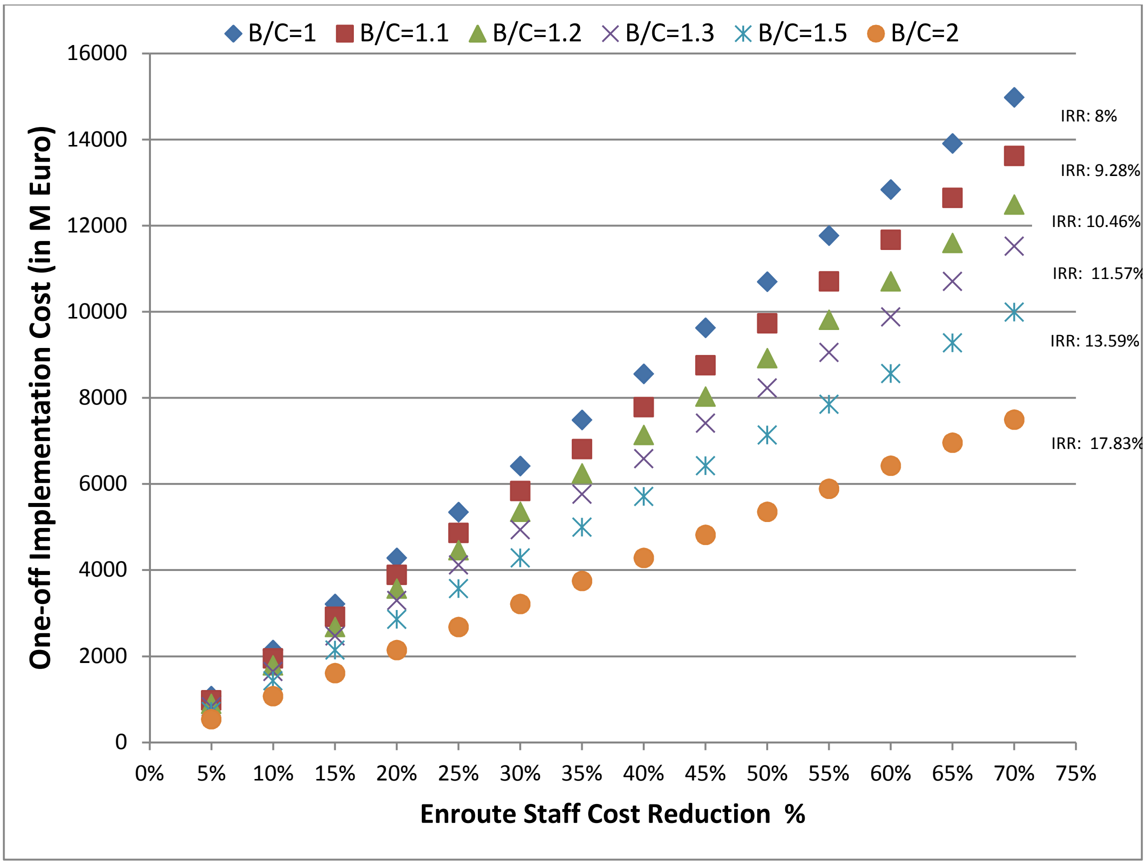

Figure 9. Relation between en-route staff cost reduction and ANSPs one-off implementation cost (under Operating Cost Reduction equal to 0%).

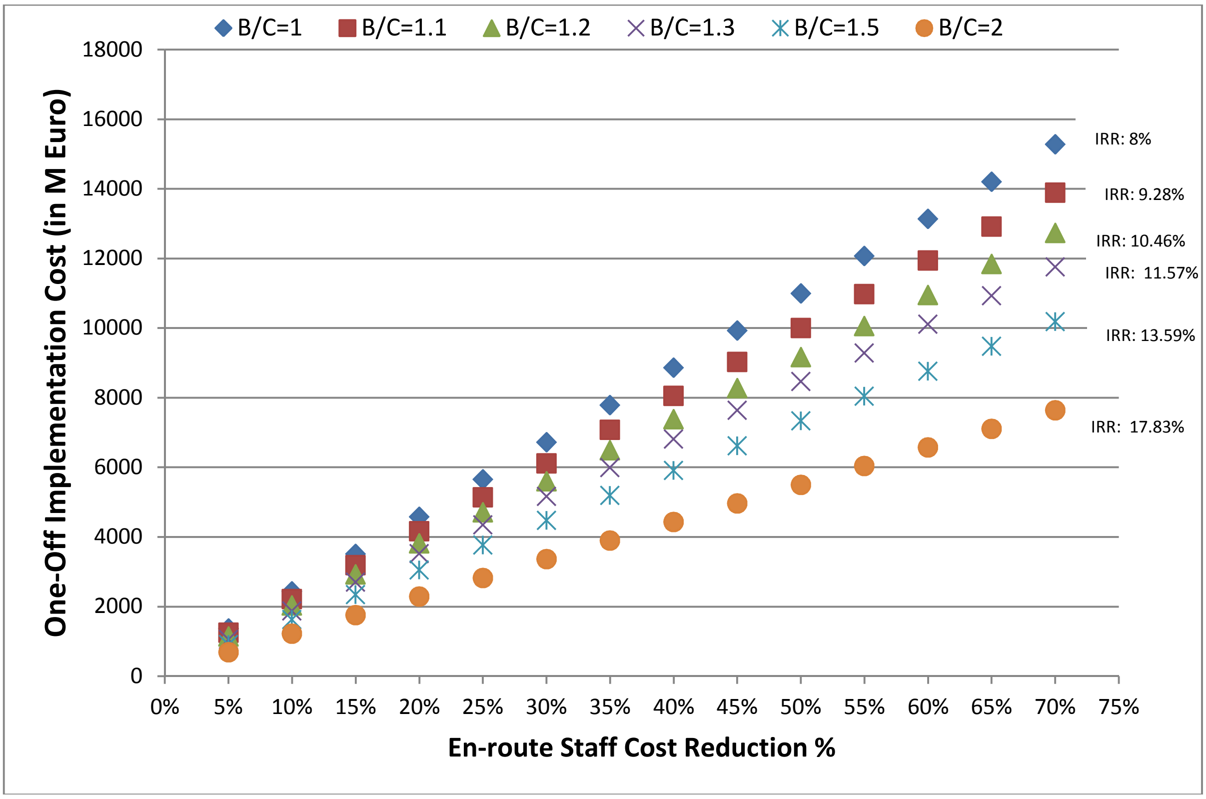

Figure 10. Relation between en-route staff cost reduction and **ANSPs** one-off implementation cost (under Operating Cost Reduction equal to 5%).

Based on the results presented in Figure 9 and Figure 10, the potential economic performance of A^3 ConOps from the ANSPs perspective may be assessed. For B/C equal to 1 (i.e., the total benefits are equal to the total costs), and given that the most pessimistic scenario is substantiated (i.e., staff cost reduction equal to 5% and operating cost equal to 0%) then the maximum ANSPs one-off implementation cost should not exceed 1.07 Billion €. The calculation of the ANSPs one-off implementation cost under this pessimistic scenario for higher B/C 1.1, 1.2, 1.3, 1.5, and 2 value yielded the following values respectively: 970 M€, 892 M€, 822 M€, 713 M€, and 535 M€. On the other hand under the most optimistic scenario where the staff cost reduction % reaches 70% and the operating cost reduction % reaches 5%, the ANSPs one-off implementation cost should not exceed: 15.2 Billion € to achieve B/C equal to 1, 13.8 Billion € for B/C equal to 1.1, 12.7 Billion € for B/C equal to 1.2, 11.7 Billion € for B/C equal to 1.3, 10.1 Billion € for B/C equal to 1.5, and 7.6 Billion € for B/C equal to 2.

For B/C equal to 1, every 1% increase in the % Staff Cost Reduction implies that up to 214 Million € of additional ANSPs One-off implementation cost may be spent by the ANSPs in order for the cost and benefits to remain balanced. In the same context, the corresponding additional costs for B/C values 1.1, 1.2, 1.3, 1.5, and 2 are: 194 Million €, 178 Million €, 164 Million €, 142 Million €, 107 Million €. However, based on the data derived from AENA, a lower bound for the ANSPs one-off implementation cost is approximately 15 Million € (see Appendix II). Thus, the marginal ANSPs one-off implementation cost counter-offered for 1% increase of the staff cost reduction, covers with certainty any potential value for the actual ANSPs one-off implementation cost. Thus, considering the benefits and costs for the ANSPs, it can be concluded that the overall en-route service cost will be significantly reduced.

4.3 Summary of Results and Concluding Remarks

In summary, the potential viability of the A^3 ConOps of the A^3 ConOps from the perspective of the ANSPs can be explored by assessing the CBA results for two scenarios encompassing a wide range of alternatives (i.e., a pessimistic and a fairly optimistic scenario). The variables that differentiate the two scenarios are: i) the (%) en-route staff cost reduction, and ii) the (%) en-route operating cost reduction. The most pessimistic scenario is defined for en-route staff cost reduction 5% (its lowest value) and operating cost reduction 0% (its lowest value). On the other hand in the fairly optimistic scenario, the (%) en-route staff cost reduction is 70% and the (%) operating cost reduction is 10%.

Table 8 presents the costs and benefits for the pessimistic scenario. Based on the assumptions of the pessimistic scenario the B/C ratio can obtain values greater than one (e.g., B/C=1.2) if the one-off implementation cost does not exceed 345.9 M€. On the other hand, Table 9 presents the cost and benefits for the fairly optimistic scenario. Based on the assumptions of the optimistic scenario the B/C ratio can obtain values greater than one (e.g., B/C=1.2) if the one-off implementation cost does not exceed 5,037 M€.

CBA Measures	B/C:	1.2	IRR:	10.4%	
	Break Even Year:	2034	NPV:	69.2 M€	
COSTS			BENEFITS		
Costs Indicators	**Present Worth(2010)**	**Annual Worth (2018-2035)**	**Benefits Indicators**	**Present Worth(2010)**	**Annual Worth (2018-2035)**
Cost of Managing the Transition to A³ ConOps	291 M€	31.9M€	*En-route Staff Cost savings (5%)*	415.2 M€	45.5M€
Training Cost of the staff to adapt to the new operations and procedures	54.9 M€	6 M€	*En-route Operating (non Staff) Cost Savings (0%)*	0 M€	0 M€
Total Cost	**345.9 M€**	**37.9 M€**	**Total Benefits**	**415.2 M€**	**45.5 M€**

Table 8. Summary of the results for the most pessimistic scenario for the ANSPs CBA, where the (%) ANSPs en-route staff cost reduction is 5% and the (%) ANSPs operating cost reduction is 0% .

CBA Measures	B/C:	1.2	IRR:	10.4%	
	Break Even Year:	2034	NPV:	1008 M€	
COSTS			BENEFITS		
Costs Indicators	**Present Worth(2010)**	**Annual Worth (2018-2035)**	**Benefits Indicators**	**Present Worth(2010)**	**Annual Worth (2018-2035)**
Cost of Managing the Transition to A³ ConOps	4,347 M€	476.5M€	*En-route Staff Cost savings (70%)*	5,813 M€	637.3M€
Training Cost of the staff to adapt to the new operations and procedures	690 M€	75.6 M€	*En-route Operating (non Staff) Cost Savings (10%)*	231 M€	25.3 M€
Total Cost	**5,037 M€**	**552.2 M€**	**Total Benefits**	**6,044 M€**	**663 M€**

Table 9. Summary of the results for the fairly optimistic scenario for the ANSPs CBA, where the (%) ANSPs en-route staff cost reduction is 70% and the (%) ANSPs operating cost reduction is 10%.

The calculations performed for these two scenarios led to the estimation of the cost savings emerging from the staff cost and the operating cost reduction. For the most pessimistic scenario, the B/C of 1.2 can still be achieved when the ANSPs one-off implementation cost (for adapting their operations and procedures to A^3 ConOps) does not exceed 345.9 M€. For the optimistic scenario, the B/C ratio of 1.2 can still be achieved when the ANSPs one-off implementation cost does not exceed 5.037 B€. From the above analysis it can be concluded that the maximum amount of money (i.e., 345.9 M€) that could be invested in the pessimistic scenario in order to obtain a B/C equal to 1.2 is substantially lower than the maximum amount of money (i.e., 5037 M€) that could be invested in the case of the fairly optimistic scenario in order to achieve the same B/C ratio. This is due to the fact that in the case of the most pessimistic scenario the assumed benefits are actually very low, thus the maximum cost they require in order to provide a B/C equal to 1.2 is relatively low. In the case of the fairly optimistic scenario the assumed benefits are rather high, allowing for a higher investment cost than in the case of the pessimistic scenario, for achieving the same B/C ratio. In conclusion, the CBA results for the ANSPs suggest that it is economically viable to consider the development of the A^3 ConOps to the next maturity stage.

5 Airlines & ANSPs Combined Analysis

5.1 Combined Analysis Scenarios

The application of the proposed A^3 ConOps CBA approach for the Airlines and the ANSPs may lead to the identification of the scenarios of costs and benefit variables (operational improvements) under which a predetermined economic performance target is achieved. This type of analysis may provide useful results regarding the economic impacts of the implementation of A^3 ConOps for each of the two stakeholders separately. However, given that the reduction of the ANSPs en-route staff cost is expected to reduce the ANSPs en-route charges collected from the Airlines, assessing the impacts of A^3 ConOps to the Airlines and the ANSPs simultaneously is essential for drawing conclusions regarding the economic implications of A^3 ConOps at system-wide level.

The simultaneous assessment of the A^3 ConOps impacts on Airlines and ANSPs is executed by considering combined analysis scenarios developed on the basis of combining valid alternative values of the uncertain variables of the ANSPs and the Airlines Given the value for the ANSPs en-route staff cost reduction % provides an estimate for the en-route ANSPS charges reduction becomes readily available based on the assumption that any reduction α% of the ANSPs en-route staff cost corresponds to 0.62α% reduction of the ANSPs charges. This assumption is based on the fact that in 2008 (ACE Report [11]) the en-route staff cost accounted for 62% of the total en-route cost of the ANSPs. Assuming that any reduction in ANSPs en-route staff costs induces an equivalent reduction in ANSPs charges, the above assumption emerges directly.

Each of the combined analysis scenarios is defined by assigning values to the ANSPs en-route staff cost reduction, the ANSPs operating cost reduction, the Airlines forward-fit cost and B/C. The expected outcome from analyzing each scenario relates to: i) the value of the ANSPs one-off implementation cost that corresponds to the values of ANSPs en-route staff cost reduction, ANSPs operating cost reduction and B/C , ii) the valid combinations of values of the Horizontal Flight Inefficiency %, Vertical Flight Inefficiency and en-route ATFM delay reduction that correspond to the specific Airlines forward-fit cost, the ANSPs charges specified by the ANSPs staff cost reduction value, and the specific B/C. The range of values used for the ANSPs en-route Staff Cost Reduction %, the ATFM En-route Delay Reduction %, and the Forward-fit cost are the same with those used in the corresponding Airlines and ANSPs analysis. Table **10** below provides a list of indicative combined analysis scenarios. The total number of scenarios developed is 126.

The ANSPs operating cost reduction % is not included in this type of analysis, implicitly assumed equal to 0%. Thus the set of analysis scenarios reflect only conservative expectations from the ANSPs operational improvements. The expected outcome of this type of analysis is to determine alternative combinations of potential operational improvements for the airlines and the maximum ANSPs One-off implementation cost which may lead to targeted B/C values for the airlines and the ANSPs given a predetermined ANSPs staff cost reduction.

ANSPs en-route Staff Cost Reduction %	ATFM En-route Delay Reduction %	Forward Fit Cost
10%	0%	24576
10%	0%	30720
10%	0%	36864
10%	0%	43008
10%	0%	49152
10%	0%	55296
10%	0%	61440
10%	0%	67584
10%	0%	73728
10%	10%	24576
10%	10%	30720
10%	10%	36864
10%	10%	43008
10%	10%	49152
10%	10%	55296
10%	10%	61440
10%	10%	67584
10%	10%	73728
…	…	…
70%	0%	24576
70%	0%	30720
70%	0%	36864
70%	0%	43008
70%	0%	49152
70%	0%	55296
70%	0%	61440
70%	0%	67584
70%	0%	73728
70%	10%	24576
70%	10%	30720
70%	10%	36864
70%	10%	43008
70%	10%	49152
70%	10%	55296
70%	10%	61440
70%	10%	67584
70%	10%	73728

Table 10. Combined Analysis Scenarios.

5.2 Results for the Airlines-ANSPs combined Scenarios

Each combined analysis scenario is defined by specifying a value for the ANSPs en-route staff cost reduction % and the Airlines forward fit cost. For any vector of values for variables ANSPs en-route staff cost reduction, Airlines Forward-Fit Cost given a predetermined B/C value the following types of results may be determined: i) results for the Airlines including alternative valid combinations of the Airlines benefits variables en-route ATFM delay reduction, Vertical Flight Efficiency Gain %, and Horizontal Flight Efficiency Gain % (% en-route charges reduction is implicitly specified in advance by the assumed en-route ANSPs staff cost reduction), and ii) results for the ANSPs including the maximum ANSPs one-off implementation cost that corresponds to the specific ANSPs en-route staff cost reduction (assuming the that ANSPs operating cost reduction is 0%).

Concerning the Airlines analysis results from the combined scenarios, the alternative combinations of benefits is specified by calculating the Horizontal Flight Efficiency Gain % for which the targeted B/C is achieved under specific values for the ANSPS en-route staff cost reduction %, en-route ATFM delay reduction %, and Vertical Flight Efficiency Gain %. The objective of this type of analysis is to identify how the potential reduction of ANSPs staff cost may affect the costs and benefits required for the Airlines to achieve a targeted economic performance. This type of analysis differs from the one performed for the Airlines in section 6.1, since in the ANSPs-Airlines combined scenarios the ANSPs charges reduction %, is implicitly specified by the Staff cost reduction. In this context, the staff cost reduction of the ANSPs is used as an input for performing the Airlines CBA. Figures 11-16 provide an overview of the results from the above analysis. Each of these figures provides a plotted graph of the pairs of values of forward-fit cost and Horizontal flight inefficiency reduction % for a predetermined B/C (in this analysis values 1.1, 1.2, and 1.3 are used) under two levels of ATFM delays reduction (0%, 5%), and ANSPs charges reduction % implicitly expressed in the graph by the Staff Cost Reduction % (10%-70%). Table 11 presents the ANSPs One-off Implementation Cost that corresponds to en-route staff cost reduction from 10-70% under various B/C values and operating (non-staff) cost reduction equal to 0%. Thus any scenario considered in this type of analysis disregards any benefit that could arise from a potential reduction of the operating (non-staff) cost. This simplification stems from the major conclusions taken from the ANSPs CBA in section 5, which implies that staff cost reduction solely is capable of covering the ANSPs costs to achieve high economic performance targets. Moreover, it has been verified in section 5 that even marginal reduction of the ANSPs en-route staff cost may be sufficient to cover the costs. This result is also verified from Table **11** which provides the maximum values for the ANSPs one-off implementation cost given various levels of en-route staff cost reduction (from 10%-70%) and 0% operating cost reduction. Even in the most pessimistic case that a 10% reduction is finally achieved through the A^3 ConOps, it is sufficient to allow for a maximum of over 2 billion Euro of ANSPs one-off implementation cost to obtain a B/C equal to 1.2. Thus, the analysis that follows is basically focused on the Airlines CBA given various alterative values for the ANSPs en-route staff cost reduction %.

Figures 11 and 12 provide the Airlines results for B/C equal to 1.1. In the worst case scenario where no ATFM delay reduction is substantiated due to A^3 ConOps then the Horizontal flight inefficiency reduction % required for balancing costs ranges from negative values (-12.4%) for staff cost reduction 70% and forward fit cost equal to €24756 up to 34% for staff cost 10% and forward fit cost equal to €73728. It should be clarified that a negative value for Horizontal flight inefficiency reduction % (e.g., -12.4%) in this analysis implies that the targeted B/C may still be achieved even in the hypothetical case that eventually Horizontal flight inefficiency is increased (by 12.4%). If a 5% reduction of ATFM en-route delay is included in the assumptions then the required Horizontal Flight Inefficiency % ranges from -15.6% (i.e., 15.6 % increase) up to 30.9%. For a moderate forward fit cost (i.e., € 49152) the range of values of Horizontal Flight Inefficiency Reduction % under the worst case (i.e., 0% ATFM en-route Delay Reduction) lies between -7% (for 70% Staff Cost reduction) and 28.9% (for 10% Staff Cost reduction).

B/C	Staff Cost Reduction %	ANSPs One-Off Implem. Cost (in Million €)
1.1	10	2224.07
	20	4448.15
	30	6672.23
	40	8896.31
	50	11120.39
	60	13344.47
	70	15568.55
1.2	10	2038.725
	20	4077.455
	30	6116.185
	40	8154.915
	50	10193.645
	60	12232.375
	70	14271.105
1.3	10	1686.985
	20	3179.055
	30	4671.125
	40	6163.195
	50	7655.265
	60	9147.335
	70	10639.405

Table 11. ANSPs One-off implementation Cost for scenarios involving B/C values 1.1, 1.2, 1.3.

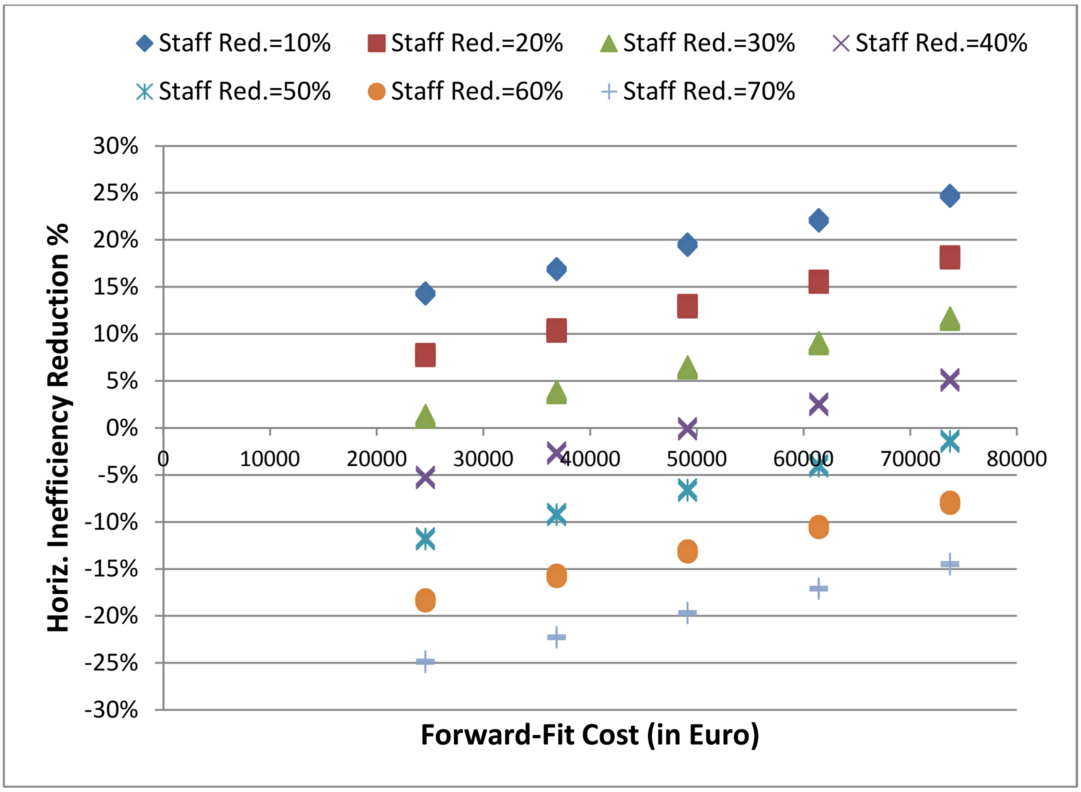

Figure 11. Relation between the Horizontal Flight Inefficiency Reduction % and the forward fit cost for B/C equal to 1.1 and ATFM delay reduction 0%.

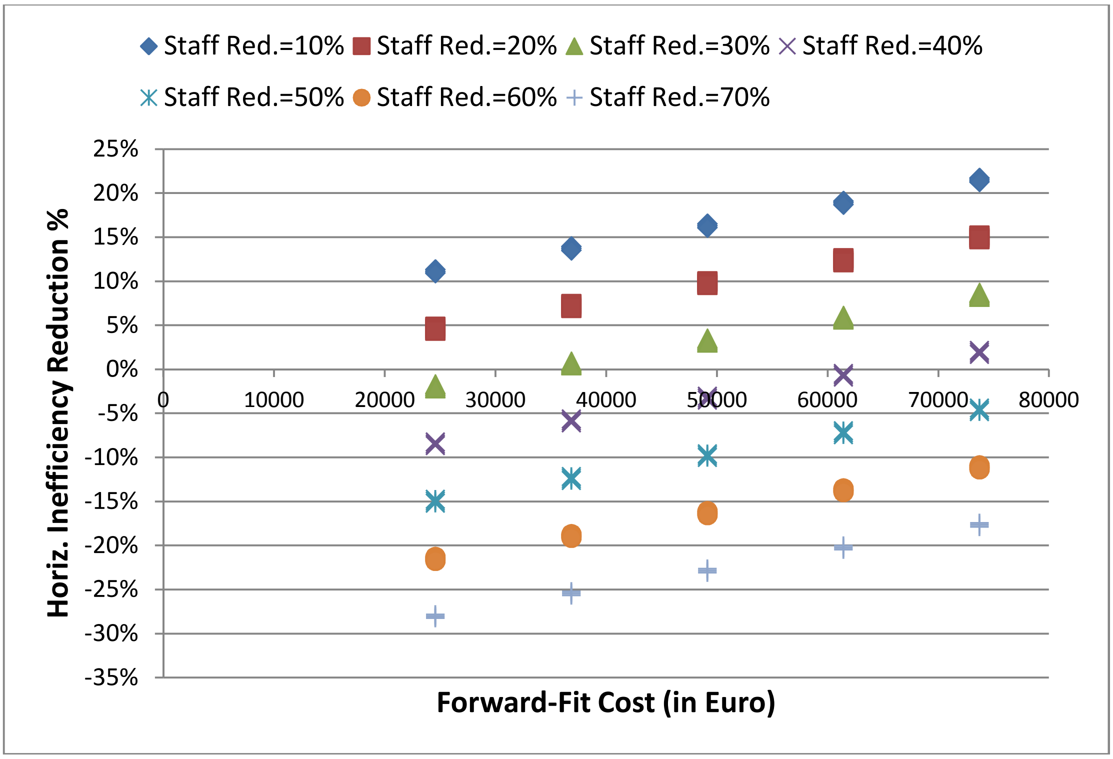

Figure 12. Relation between the Horizontal Flight Inefficiency Reduction % and the forward fit cost for B/C equal to 1.1 and ATFM delay reduction 5%.

Figures 13 and 14 provide the results for B/C equal to 1.2, where airlines benefits cash flows overrun the corresponding cost cash flows by 20%. In the worst case scenario where the staff cost is 10%, the en-route ATFM delay reduction is 0%, and forward fit cost takes its highest value (€73728) then the Horizontal Flight Inefficiency Reduction % required to achieve the predetermined B/C value of 1.2, is 37.7%. On the other hand in the most optimistic scenario considered where ATFM delay reduction is 5%, the staff cost reduction is 70%, and the forward fit cost is € 24756, then the Horizontal Flight Inefficiency value is -13% i.e., B/C of 1.2 may be achieved even if Horizontal Flight Inefficiency raised by 13%.

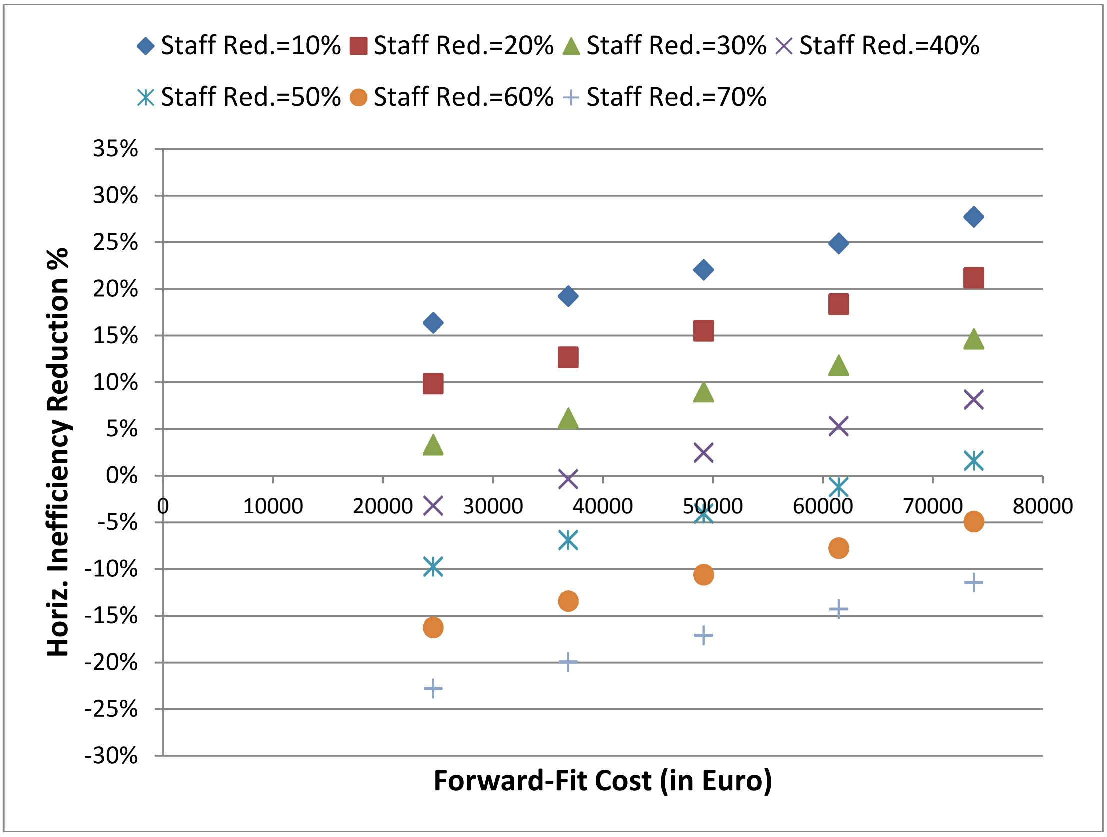

Figure 13. Relation between the Horizontal Flight Inefficiency Reduction % and the forward-fit cost for B/C equal to 1.2 and ATFM delay reduction 0%.

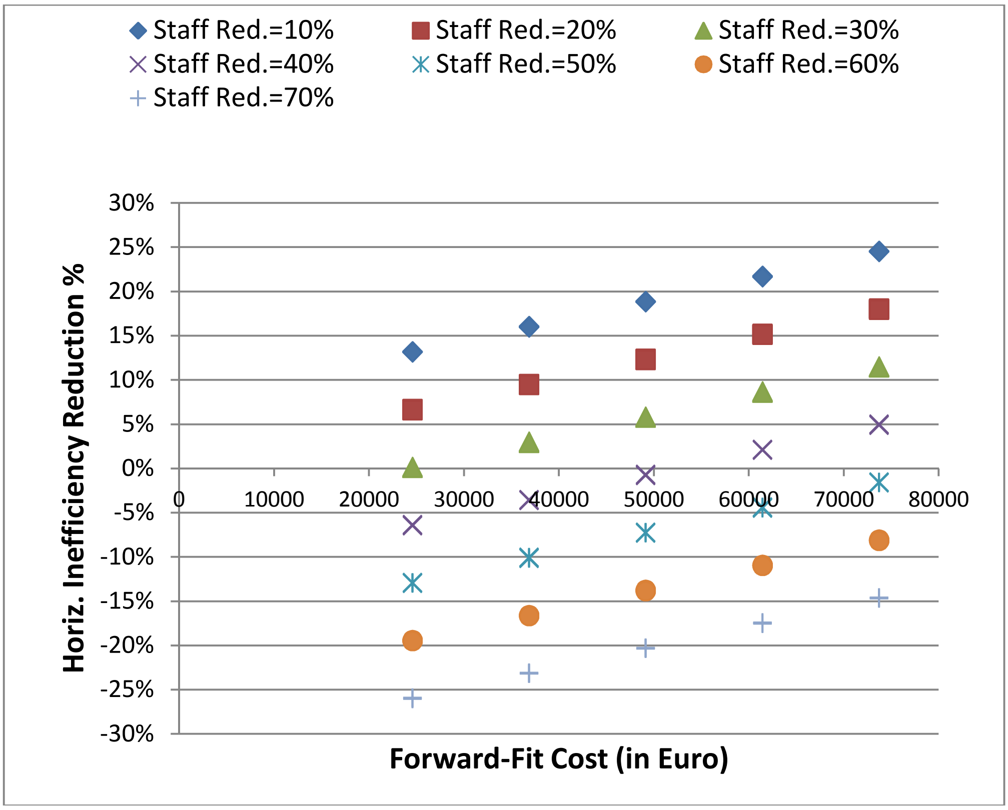

Figure 14. Relation of the Horizontal Flight Inefficiency Reduction % with the forward fit cost for B/C equal to 1.2 and ATFM delay reduction 5%.

Figures 15 and 16 provide the results for B/C equal to 1.3, where airlines benefits cash flows overrun the corresponding cost cash flows by 30%. In the same a analysis context as above, in the most pessimistic scenario where en-route ATFM delay is 0% , forward-fit cost is € 73728, and staff cost reduction is 10%, then the required Horizontal Flight Inefficiency Reduction % for achieving the predetermined B/C (1.3) is 41.3%. In the most optimistic scenario (i.e., 10% en-route ATFM delay, €24576 forward fit cost and 70% staff cost reduction) B/C equal to 1.3 may be achieved even when horizontal flight inefficiency increases by 10.5%.

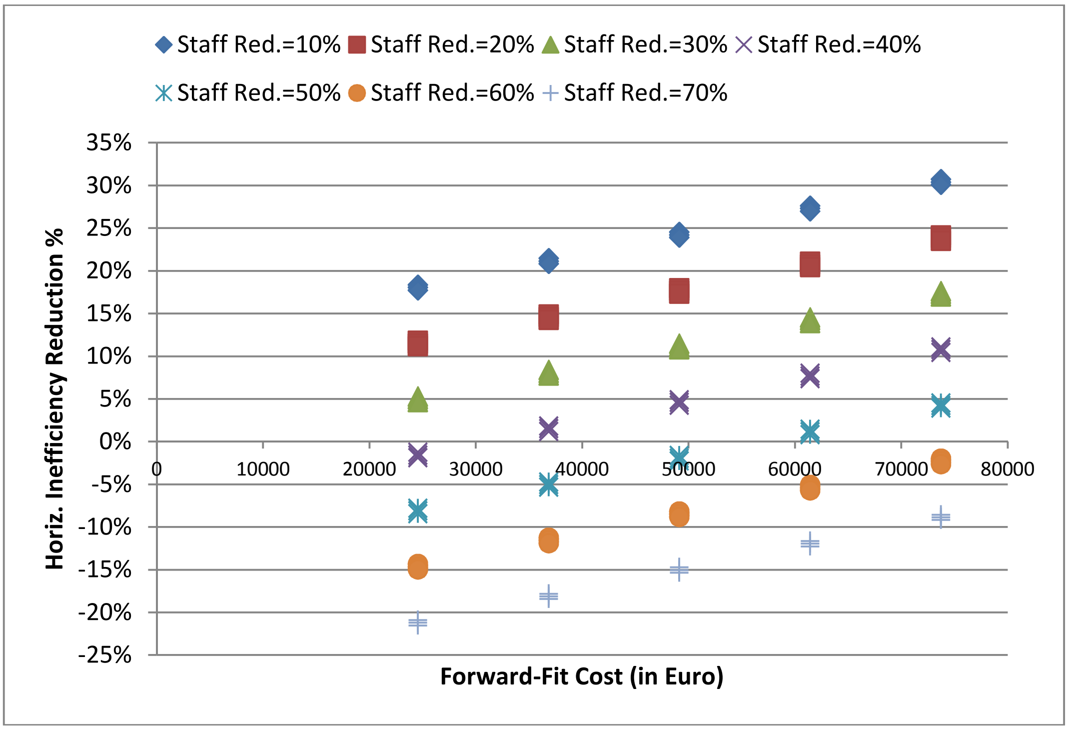

Figure 15. Relation of the Horizontal Flight Inefficiency Reduction (%) with the forward fit cost for B/C equal to 1.3, and ATFM delay reduction 0%.

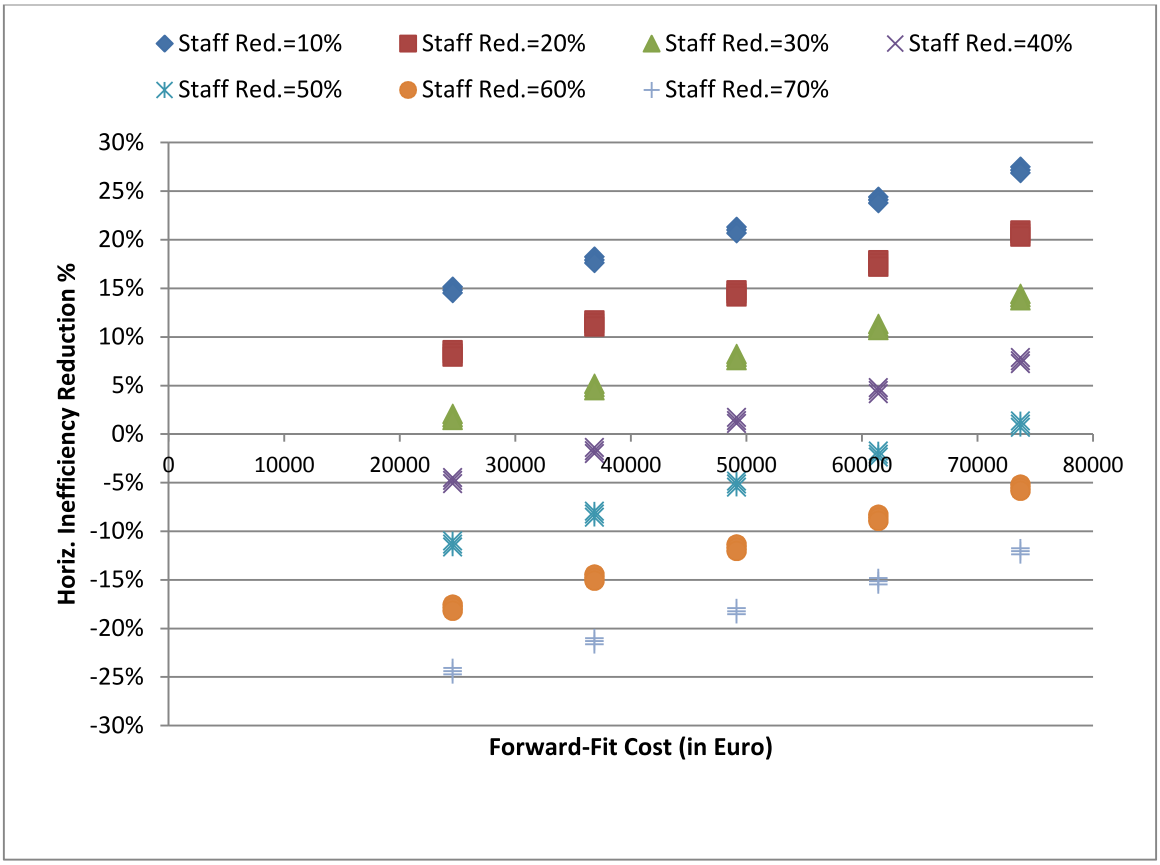

Figure 16. Relation of the Horizontal Flight Inefficiency Reduction % with the forward fit cost for B/C equal to 1.3 and ATFM delay reduction 5%.

5.3 *Summary of Results and Concluding Remarks*

In summary, the potential viability of the A^3 ConOps of the A^3 ConOps from the perspective of the Airlines and ANSPs can be explored by assessing the CBA results for two combined analysis scenarios encompassing a wide range of alternatives (i.e., a pessimistic and a fairly optimistic scenario). In both scenarios, the worst case cost performance is assumed where the forward-fit cost takes its highest value, i.e., €73728. The most pessimistic scenario is defined when the ANSPs en-route staff cost reduction (%) and the airlines expected benefit variables vertical flight efficiency gain (%) and en-route ATFM delay reduction (%) take the values 10%, 0% and 0% respectively. On the other hand in the fairly optimistic scenario, the expected ANSPs en-route staff cost reduction takes value 47% and the benefit variables (%) en-route ATFM delay reduction and (%) vertical flight efficiency gain take values 10% and 50% respectively.

Table 12 presents the costs and benefits from the most pessimistic scenario. Based on the assumptions of the most pessimistic scenario the B/C ratio can obtain values greater than one (e.g., B/C=1.2) if the (%) horizontal flight inefficiency will be reduced by at least 27.79%. The present worth value of the total cost induced in this scenario is 3,257 M€. The required horizontal flight efficiency gain % to achieve a B/C equal to 1.2 yields savings of 3,162 M€. Taking into account that under the A^3 ConOps no ATC services will be provided to the airspace users within self-separating airspace, it is expected that the implementation of the proposed ConOps will induce a significantly higher reduction of en-route staff cost than 10%.

On the other hand Table 13 presents the results from an optimistic scenario. Based on the assumptions of the optimistic scenario the B/C ratio can obtain values greater than one (e.g., B/C=1.2) even if the Horizontal Flight Inefficiency will not be reduced.

CBA Measures	**B/C:**	1.2	**IRR:**	10.6%	
	Break Even Year:	2029	**NPV:**	653 M€	
COSTS			**BENEFITS**		
Costs Indicators	**Present Worth(2010)**	**Annual Worth (2018-2035)**	**Benefits Indicators**	**Present Worth(2010)**	**Annual Worth (2018-2035)**
Total Forward-Fit Cost	421 M€	46.2 M€	*En-route Charges Savings*	743 M€	81.5 M€
Total Retrofit Cost	1,194 M€	130.9 M€	*Savings from ATFM en-route delay Reduction*	0	0
Training Cost	1,498 M€	164.2 M€	*Savings for Flight Efficiency Gains*	3,162 M€ (Horizontal: 27.79%, Vertical: 0%)	347 M€
Maintenance Cost	138 M€	15.1 M€			
Pre-Imp. Cost	6 M€	0.66 M€			
Total Cost	**3,257 M€**	**357.1 M€**	**Total Benefits**	**3,905 M€**	**428.5 M€**

Table 12. Summary of the results for the most pessimistic (from the benefits perspective) scenario for the combined Airlines-ANSPs CBA.

CBA Measures	**B/C:**	1.2	**IRR:**	10.6%	
	Break Even Year:	2029	**NPV:**	653 M€	
COSTS			**BENEFITS**		
Costs Indicators	**Present Worth(2010)**	**Annual Worth (2018-2035)**	**Benefits Indicators**	**Present Worth(2010)**	**Annual Worth (2018-2035)**
Total Forward-Fit Cost	421 M€	46.2 M€	*En-route Charges Savings*	3519 M€	386 M€
Total Retrofit Cost	1,194 M€	130.9 M€	*Savings from ATFM en-route delay Reduction*	364 M€	40 M€
Training Cost	1,498 M€	164.2 M€	*Savings for Flight Efficiency Gains*	23 M€ (Horizontal: 0%, Vertical: 50%)	2.5 M€
Maintenance Cost	138 M€	15.1 M€			
Pre-Imp. Cost	6 M€	0.66 M€			
Total Cost	**3,257 M€**	**357.1 M€**	**Total Benefits**	**3,906 M€**	**428.5 M€**

Table 13. Summary of the results for the fairly optimistic (from the benefits perspective) scenario for the combined Airlines-ANSPs CBA.

Based on the above findings it can be concluded that a wide range of plausible combinations of the benefits exist even when the forward-fit cost takes its higher value and the ATFM delay or the vertical flight efficiency gains take marginal values. The CBA results from the combined scenarios suggest that it is economically viable to consider the development of the A^3 ConOps to the next maturity stage.

6 Concluding Remarks and Future Steps

The scenario-based Cost-Benefit Analysis (CBA) for the ANSPs and the Airlines presented in this report aimed at assessing the economic viability of the A^3 ConOps by considering the associated benefits and costs for both stakeholders. In the airlines case, the application of the proposed approach involved analysis scenarios in which alternative combinations of benefit variables were determined for given forward-fit cost values on the basis of yielding a predetermined B/C. On the other hand, the application of the analysis approach for the ANSPs involved analysis scenarios in which the ANSPs one-off implementation cost was calculated on the basis of yielding a predetermined B/C for a given ANSPs en-route Staff Cost reduction and operating (non-staff) cost reduction. Moreover given that the reduction of ANSPS en-route staff cost may have a direct impact to the reduction of the ANSPs en-route charges (an uncertain benefit variable of the Airlines analysis) a set of analysis scenarios were designed in which combinations of values for the Airlines benefit variables were determined given predetermined values for the forward fit cost and the ANSPs en-route staff cost reduction. The objective of this type of analysis was to identify alternative scenarios of operational improvements and costs for the ANSPs and the Airlines (considered simultaneously) that may yield a predetermined B/C varied within {1, 1.1, 1.2, 1.3, 1.5, 2} reflecting various business expectations regarding the derived economic performance of the A^3 ConOps.

A major finding from the Airlines analysis is that as B/C increases, higher en-route charges reduction are required for the same level of ATFM delay reduction and Flight Inefficiency Reduction. However, even in the most pessimistic scenario (forward-fit Cost= €73728, ATFM delay reduction=0% & Flight Efficiency Gain=0%), en-route charges reduction above 40% is sufficient to achieve a B/C above unity. Moreover, based on the relevant CBA calculations, viable scenarios may be identified even if the forward-fit cost was underestimated by a factor of 2.5, and % en-route ATFM delay reduction and % Horizontal Flight Efficiency Gains were equal to 0%.

The ANSPs analysis indicated that even a marginal reduction of the ANSPs en-route staff cost is sufficient for achieving a B/C above 1. This finding implies that A^3 ConOps is expected to reduce substantially the en-route service cost. However, it should be pointed out that this analysis was performed on the basis that ANSPs would not bear any technological investment or R&D cost.

As an overall conclusion it can be argued that the analysis results provided in this report seem encouraging for developing A^3 ConOps to its next maturity stage from the perspective of both the Airlines and the ANSPs economic implications.

Moreover, apart from using the proposed analysis approach to assess economic impacts on involved stakeholders, it can be used to identify the ConOps economic targets under which the emerging ATM system could be sustainable. A tool has been developed in order to perform the calculations required for applying the proposed CBA approach. This CBA tool could be used by policy makers as a decision support tool for estimating alternative costs and benefits targets under which the proposed ATM ConOps may lead to a desired level of economic performance.

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8 Acronym List

Acronym	Definition
A^3	Autonomous Aircraft Advanced
ANSP	Air Navigation Services Provider
ASAS	Airborne Separation Assistance System
ASEP	Airborne Separation
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
B/C	Benefit to Cost ratio
ConOps	Concept of Operations
HMI	Human Machine Interface
MA	Managed Airspace
PBA	Performance Based Airspace
R/T	Radio Telecommunications
RAA	Restricted Airspace Area
RBT	Reference Business Trajectory
SBT	Shared Business Trajectory
SES	Single European Sky
SESAR	SES Advanced Research
SWIM	System Wide Information Management System
TMA	Terminal Area

APPENDIX I

Input Data for the Airlines Cost-Benefit Analysis

Global and Time Variables Estimates

The *Discount Rate* used for the Airlines Cost Benefit Analysis (CBA) is set equal to 8%, which is the EUROCONTROL recommended value indicated in the report "Standard Inputs for EUROCONTROL Cost-Benefit Analyses" (issued by EUROCONTROL in 2009) [14].

A key issue in estimating the costs and benefits arising from the introduction of the A^3 ConOps relates to the calculation of the discounted (present value) costs and cost savings realized throughout the pre-implementation, implementation, and post-implementation phase of A^3 ConOps. Thus, a major prerequisite for calculating costs and benefits is to specify in time the incoming and outgoing cash flows for the airlines. The timeframe, in which costs and benefit related cash flows are defined, is specified by the time variables expressing the beginning and the expected duration of various phases of A^3 ConOps implementation. Since the A^3 ConOps is still in its definition phase, no time plan is available regarding its implementation in the future. However, given that A^3 ConOps elements are also prescribed in SESAR Target Concept (any self-separation ConOps can be considered as a beyond SESAR ConOps), the time plan specified in SESAR ATM Master Plan [15] has been used in order to place the A^3 ConOps implementation in time. This section presents the time variables and their estimates used in this study. According to the SESAR ATM deployment plan for the Aircraft users, the introduction of ASAS self-separation is prescribed within ATM Capability Level 5. The ASAS self-separation features involve "*the air broadcast and reception of trajectory data and new onboard conflict detection and resolution functions to support the delegation of the separation with all other aircraft*". These ATM related functionalities provided in SESAR ATM coincide with the core operations proposed in iFLY through the A^3 ConOps. According to the SESAR ATM Master Plan [15] the implementation of the associated operations should start in 2018. The start of the pre-implementation period (R&D phase) in which algorithms for conflict detection and resolution for self separation are developed is placed in 2013. The on-board conflict detection and resolution functions will be available between 2024 and 2026. Moreover, concerning the deployment of changes to Flight Operations Centres in order to support free routing (relevant to pre-flight strategic trajectory management of A^3 ConOps), SESAR ATM Master Plan suggests that their implementation should start in 2015. The time variables used in the Airlines CBA were specified based on the above milestones indicated in the SESAR ATM Master Plan.

Variable titled *This Year* expresses the base year for performing the discounting operations of any cash flows involved in this analysis. *This Year* is set equal to 2010, which is the year in which the results of this analysis will be reported. Any monetary value used in this analysis having a base year earlier to 2010 will be converted to its equivalent value in 2010, by using the inflation rates presented in Table A-1 below, taken from [14]. Any monetary value of the future (incoming or outgoing) cash flows (beyond 2010), will be considered as real (constant) value thus avoiding to predict and use a future inflation rate.

Period	Inflation Rate
mid-2009 to mid-2010	1.4%
mid-2008 to mid-2009	0.6%
mid-2007 to mid-2008	4.3%
mid-2006 to mid-2007	2.1%
mid-2005 to mid-2006	2.4%
mid-2004 to mid-2005	2.0%
mid-2003 to mid-2004	2.3%

Table A-1. Inflation rates (1997-2010) as presented in Eurostat (http://epp.eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=0&pcode=teicp000&language=en) and [14]

Start Year variable refers to the start of the time period that is covered in this analysis. The elements of the core part of the A^3 ConOps which are envisaged beyond the SESAR target concept relate to the strategic pre-flight management of the flights, free routing capabilities in the self-separation airspace and the self separation operations (trajectory management, on-board conflict detection and resolution). However, the first point in the ATM Master Plan where an A^3 Core part element is encountered relates to the research activities for the development of algorithms for conflict detection and resolution in support of self-separation. This type of activities are included as part of the required R&D for Capability Level 4 deployment for the airspace users [15]. In this context, it is assumed that start time for the pre-implementation period for the A^3 ConOps coincides with start of the R&D activities for the SESAR Capability Level 4 (i.e., 2013).

The *Final Year* variable expresses the last year of the time period for which the analysis is performed. According to the European ATM Master Plan [15] the deployment of self separation operations will take place no earlier than 2024. Thus, the Final Year should exceed 2024 by a period of time adequate to capture a substantial amount of cost savings due to A^3 ConOps. On the other hand, the available air traffic growth forecast reach up to 2030 [16] by the time that this analysis was performed. Thus, extending the time period of the analysis far beyond 2035 might involve substantial risk in the outcome of the analysis, since many critical cost and benefit variables (e.g., total investment of forward-fitting/retro-fitting the fleet of aircraft, cost savings from flight inefficiency reduction) depend on the annual number of flights. Therefore, the proposed *Final Year* is set to 2035 while the A^3 ConOps is assumed to become operational from 2026 onwards. Under these assumptions a ten year period after the A^3 ConOps could become potentially operational is included in the analysis.

The *Benefit Start Year* expresses the year in which the start of the A^3 ConOps benefits realization is expected. The Airlines will start realizing benefits (although not in full effect) from the initial date in which the self-separation operations will be deployed to part of the currently managed European airspace. By assumption (compatible with the SESAR ATM Master Plan which places the self separation deployment no earlier than 2024) the year that A^3 ConOps becomes fully operational is 2026. Based on the above, the value of the *Benefit Start Year* is set equal to 2026, thus ignoring any benefits realized within the implementation period i.e., from 2018 to 2025. In particular, according to the European ATM Master Plan, the Self-Separation mode ("Deploy new air broadcast and reception of trajectory data and new onboard conflict detection and resolution functions to support the delegation of the separation with all other aircraft" [15]) will be in operation from 2024 while the implementation of the adaptation process to the self-separation mode is planned within 2018-2024 (transition period). Thus, any other element of the core part of the A3 ConOps is assumed to become operational beyond 2024 up to 2026 (transition period). In this context, part of the full benefits for the airlines is expected to be experienced within the transition period. However given that the time length and the rate of equipping the self-separation aircraft within the transition phase of the current ATM ConOps to the A3 ConOps, is for the time being beyond any estimation (increased uncertainty is associated to any relevant estimation), this part of benefits is not taken into account in the proposed CBA.

The *Benefit End Year* expresses the final year within the time horizon of the analysis that the benefits emerging for the A3 ConOps will still be in effect. It is expected that the relevant benefits will reach the Final Year of the analysis, i.e., 2035. Thus, the value for the *Benefit End Year* is set equal to 2035.

The *Pre-Implementation Duration* is defined by the corresponding R&D periods of the ATM capability levels for the airspace users (i.e., Level 4 and 5) year. As mentioned previously, based on the SESAR deployment roadmap for the Airspace Users the Implementation period for the ATM Capability level 4 starts in 2013 while the R&D period for ATM capability level 5 ends in 2022. Under the assumption that the pre-implementation period will overlap with the implementation period (which starts in 2018) of A3 ConOps, the pre-implementation period is assumed from 2013 up to 2022.

The *Implementation period* for the A3 ConOps coincides with the corresponding period of SESAR capability level 5 for aircraft operators, i.e., 2018-2025, Thus the implementation duration is set equal to 8 years.

Table A-2 below summarizes the time variables and their corresponding estimates while Table A-3 presents the assumed time plan (based on SESAR ATM Master Plan) for the pre-implementation, implementation, and post-implementation periods of the A3 ConOps.

NAME	VALUE	SOURCE
This Year	2010	Assumption made by the Data Analysis Team
Benefit Start Year	2026	SESAR ATM Master Plan (D5)[15]
Benefit End Year	2035	Assumption made by the Data Analysis Team
Final Year	2035	Assumption made by the Data Analysis Team
Implementation Duration	8 years	SESAR ATM Master Plan (D5)[15]
Start Year	2013	Assumption made by the Data Analysis Team
Pre-Impl. Start year	2013	SESAR ATM Master Plan (D5)[15]
Pre-Imp duration	10 years	SESAR ATM Master Plan (D5)[15]

Table A-2. Time variables and corresponding estimates.

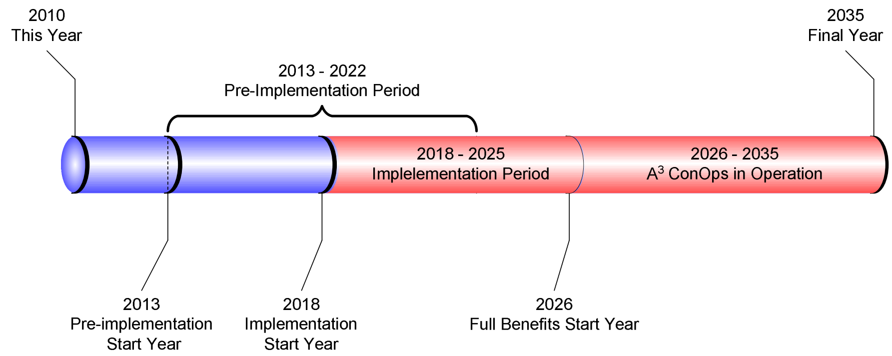

Table A-3. Graphical presentation of the time plan used for the application of the CBA for the Airlines.

Estimates for the Baseline Variables

The baseline variables used in this analysis express the evolution of the air traffic and aircraft fleet growth, and the operational performance measures of flight efficiency and delays under the baseline scenario. The Baseline scenario refers to the ATM that will emerge from the implementation of the SESAR Target Concept (based on the deployment proposed in SESAR ATM Master Plan) excluding the operations proposed in SESAR relevant to the self-separation (which constitute the core part of the A^3 ConOps). The baseline variables include: i) the *Annual Air Traffic Growth Rate,* ii) the *Aircraft Baseline (BL) Number*, iii) the *Annual Retirement Rate*, iv) the *Baseline (BL) Annual Flights*, v) the *Average Flight Duration*, vi) *Baseline (BL) Delay per Flight Time Series (TS)*, vii) *Baseline (BL)Flight Path Inefficiency, viii) the Baseline (BL) Vertical Flight Inefficiency, and ix) Jet Fuel price.*.

The *air traffic growth rate* within the baseline scenario has been based on the STAFOR forecast (published in February 2009) for the air traffic in EUROCONTROL Statistical Reference Area for the periods 2008-2030 [16]. In particular, based on the EUROCONTROL Long-Term forecast, the average air traffic growth rate between 2007 and 2030 is equal to 3% (under the “Business as usual scenario”[2]). It is assumed that the implementation of SESAR will succeed in maintaining the air traffic growth rate at this level beyond 2030 (at least until 2035 where the analysis time horizon terminates).

The fleet of aircraft considered in this analysis includes the aircraft operated within the managed airspace. In 2009, 16759 aircraft were operating within the controlled airspace of Europe [14]. Assuming a 3% annual growth rate the *Aircraft BL Number* becomes 17260 in 2010. In estimating the *Aircraft BL Number* it is implicitly assumed that any aircraft retired, it is by default replaced by a new one. The *Annual Retirement Rate* expresses the percentage of the aircraft withdrawn from operation on an annual basis. Thus, the annual deliveries for aircraft every year corresponds to the sum of the proportion of the annual retirement rate plus the annual air traffic growth. The annual retirement rate for this analysis is set equal to 2%. This value is proposed in EUROCONTROL (2001) Enhanced Mode S CBA, EMOSIA BL Scenario (2010)[3]. Based on the above assumptions regarding the evolution

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[3] Available at: http://www.eurocontrol.int/ecosoc/public/site_preferences/display_library_list_public.html

of the fleet of aircraft in Europe, Table A- 4 provides the emerging series of values for the number of aircraft and the annual deliveries (i.e., retired/replaced plus new) of aircraft in Europe.

Year	Number of Aircraft	Annual Deliveries
2010	17261	863
2011	17779	889
2012	18312	916
2013	18862	943
2014	19427	971
2015	20010	1001
2016	20611	1031
2017	21229	1061
2018	21866	1093
2019	22522	1126
2020	23197	1160
2021	23893	1195
2022	24610	1231
2023	25348	1267
2024	26109	1305
2025	26892	1345
2026	27699	1385
2027	28530	1426
2028	29386	1469
2029	30267	1513
2030	31175	1559
2031	32111	1606
2032	33074	1654
2033	34066	1703
2034	35088	1754
2035	36141	1807

Table A- 4. Times series of the number of aircraft and the annual deliveries.

Concerning the *BL Annual Flights*, in 2008, 10,1 M flights were performed within Europe (ECAC Region)[8]. The annual flights time series from 2008 up to 2035 is calculated assuming a 3% annual growth. Thus in 2010 (the start year of the analysis), the number of flights is expected to will reach 10715000 flights.

The *Average Flight Duration* is taken from the EUROCONTROL Report on standard inputs for ATM CBA (2009 version) [14], in which it is estimated to 106 min.

According to the Performance Review Report (PRR) for 2008 [8], the average delay (ATFM en-route delay) per flight within 2008 was 1.9 min. In this analysis we assume that the implementation of SESAR will keep delays at the same level (i.e., 1.9 min/flight) as the annual baseline delay for any year up to 2035. Note that PRR 2008 also presents the proportional contribution of the potential delay factors in the total ATFM en-route delay as follows: i) ATC Capacity and Staffing related issues account for 76% of the total delay, ii) weather conditions account for 9.7 %, and iii) Other reasons account for 14.3%, including ATM-related (strike, equipment, etc.). Given that the A^3 ConOps affects basically the ATC capacity, any relevant delay reduction refers to the corresponding part of delay (i.e. 76% or up to 1.44 min/flight).

The ANSPs en-route charges for year 2008 were 6122 M€. Given the inflation rates in 2009 and 2010, the equivalent value in 2010 is 6245 M€. In this analysis it is assumed that the en-route charges will not exceed this value for the entire period from 2010 up to 2035.

The *BL Horizontal Flight Path Inefficiency %* expresses the proportion of the average route extension (i.e. difference between the actual distance flown and the shortest direct distance between the two Terminal Areas (TMA). Figure A-1 presents graphically the actual route of a flight (green line) and the direct route which is the shortest route connecting the point of departing from the Terminal Area of Airport A and the point of entrance in Terminal Area of Airport B. The difference of the distance of these two routes expresses the route extension of a flight.

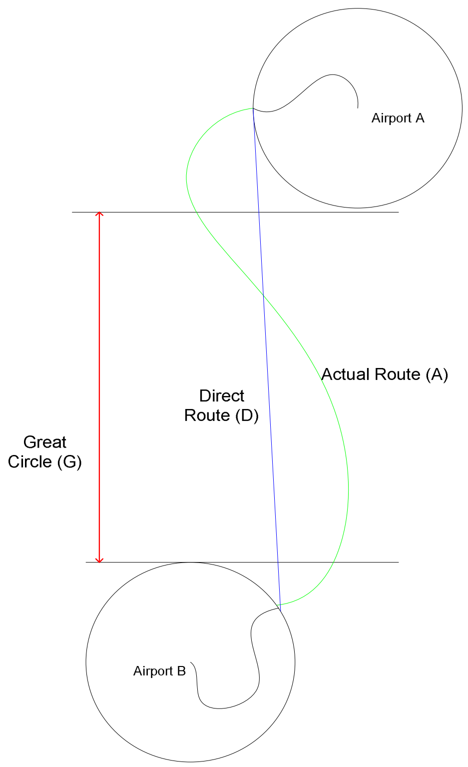

Figure A-1. Graphical display of the direct route (D), actual route (A), and the great circle distance (G) of a flight between two airports.

This variable is expressed as a time series, where each value expresses the average annual inefficiency for the corresponding year. Based on PRR 2008 this proportion was 5,6 % for 2008 and consists of two parts: i) the direct route extension due to the en-route network, and ii) the extension due to the TMA interface. The direct route extension accounts for 3,9% of the total inefficiency and 1,7 % is attributed to the TMA interface. It should be emphasized that the driving factor for the inefficiency is the en-route route design. This implies that the maximum inefficiency reduction that can be potentially achieved directly due to A^3 ConOps is 3.9%. It is assumed that due to the SESAR implementation, the flight path inefficiency will remain constant throughout the analysis time horizon (up to 2035), despite the expected increase in air traffic.

The Vertical Flight Inefficiency is defined as the additional fuel consumption per flight due to the deviation of the vertical flight profile from the corresponding profile of the optimal (from the perspective of fuel consumption) trajectory. Based on the PRR 2009, 271 Kg of additional jet fuel is consumed per flight. This additional fuel consumption corresponds to 6% of the total fuel consumption per flight. The fuel inefficiency is decomposed to: i) horizontal en-route flight path inefficiency (163 kg/flight), ii) vertical en-route flight profile deviation (25 kg), and iii) taxi out and airborne terminal related inefficiency (83 kg). Given that A^3 ConOps enables the flight trajectory management and the (long-term/medium term) conflict detection and resolution, deviation of the optimum trajectory is expected to be reduced, thus decreasing both horizontal and vertical flight inefficiencies. While horizontal flight path inefficiency reduction is expected to have an impact to the entire flight time (as described above), vertical inefficiency is expected to reduce fuel consumption. The Vertical flight inefficiency variable is expressed as a percentage of reduction of the additional fuel consumed per flight due to the vertical profile deviation from the optimal trajectory.

The calculation of the cost savings due to the reduction of the Vertical Flight Inefficiency requires the consideration of a Jet Fuel price. Based on the fuel prices published in the IATA site (http://www.iata.org/whatwedo/economics/fuel_monitor/Pages/index.aspx), the jet fuel price for 2010 was €655.

Table A-5 below summarizes the baseline variables and their corresponding estimates.

NAME	VALUE	UNITS	SOURCE
Aircraft BL number	16759 (2009)	Number of aircraft	Eurocontrol Standard Input for CBA (2009[14])
Aircraft Growth Rate (annual)	3%	-	EMOSIA BL Scenario (2010)
Annual Retirement Rate	2%	-	EUROCONTROL (2001) Enhanced Mode S CBA, EMOSIA BL Scenario (2010)
BL Annual Flights	10.1 (2008) 10,7 (2010)	Number (million)	Performance Review Report 2009 [8]
Average Flight Duration (min)	106	min	2009 edition of standard inputs for EUROCONTROL CBA
BL Delay per flight TS	1,9	min/flight	Assumption based on the PRR 2009 [8]
S1 Horizontal BL Flight Path Inefficiency % (TS)	3.7%	-	PRR 0 [8]
Vertical Flight Inefficiency	0.6% (of the total jet fuel consumed per flight)	-	PRR09 [8]
Jet Fuel Price	655 (2010)	€/metric ton(mt)	IATA (http://www.iata.org/whatwedo/economics/fuel_monitor/Pages/index.aspx)

Table A-5. Baseline variables and corresponding estimates.

Cost Variables Estimates

The cost variables considered in the present analysis include: i) forward-fit and retro-fit costs, ii) the additional ground staff cost, iii) the maintenance costs for the trajectory management system and the ASAS applications, iii) the pilot's training cost, and iv) the pre-implementation (R&D) cost.

The deployment of the A^3 ConOps involves the installation of the relevant systems/equipment on any aircraft operated within the Self-Separation Airspace. A major assumption of the A^3 ConOps is that 100% of the fleet of aircraft should be equipped with the following new airborne systems (packages of systems):

- Airborne Surveillance System (Information Processing and Display)
- Airborne Separation Assistance System (ASAS) including the conflict detection and resolution functionalities within a self-separation airspace
- Air-Air and Air to Ground Communication (ADS-B, data link)
- Corresponding Human Machine Interface (HMI)

The above packages of systems are also envisaged in the SESAR ATM Master Plan. In particular, the Airborne Surveillance System proposed in SESAR relate to the Airborne Traffic Situation Awareness (ATSAW) which is planned within Capability Level 1 of the SESAR Deployment Plan [15]. Given that the Airborne Surveillance System proposed in A^3 ConOps is not fully specified, it is not clear whether any enhancements in ATSAW will be needed. The ASAS applications proposed in SESAR relate to: ASAS Separation Crossing & Passing/Wake Vortex/In Trail Procedure and ASAS Self-Separation for enabling the temporarily delegation of Separation from the ATC to the flight crew. In the context of A^3 ConOps the ASAS for self-separation needs to be enhanced with functions for detecting and resolving conflicts potentially created in self-separation airspace. The Air-Air and Air-Ground Communication systems based on ADS-B and data link are included in Capability Level 1 of the SESAR ATM Master Plan. No additional infrastructure is foreseen for the communication systems in order to implement A^3 ConOps. The HMI used by the flight crew for performing the separation task should facilitate the conflict detection and resolution procedures.

For the proposed analysis, the implementation of the A^3 ConOps involves the installation of the ASAS applications for self-separation and the corresponding HMI. Due to difficulties in obtaining cost estimates for the above systems, comparable cost estimates for relevant systems from project ASSTAR [9] were utilized. A major objective of ASSTAR was to assess implementation of Self-Separation –Free Flight Track (SSEP-FFT) applications in oceanic airspace. The forward-fit installation of the SSEP-FFT was estimated to €23100 (in 2007). Note that the enhancements needed for the Flight Management System (necessary for the interface with the SSEP-FFT) have been included in the cost presented above. The above cost estimates are used only as lower bounds for the corresponding avionics cost required by the A^3 ConOps. Given that no reliable estimate can be inferred for the forward-fit and retro-fit costs, different analysis scenarios will be developed by varying the values specified in this section. The development of this type of analysis scenarios is based on the assumption that the retro-fit and the forward-fit ratio is given. A candidate value for the retro-fit to forward-fit cost ratio is the one used in the SESAR CBA [17] equal to 2.

In A^3 ConOps, the investment of the airlines on new ground system packages involves the Cost of software/hardware for 4D trajectory planning and management for the flights within self-separation airspace. Any other costs related to installing an interface with SWIM is attributed to SESAR deployment thus not considered as an A^3 ConOps related ground system investment of the airlines. More information regarding the ground system mentioned above can be found in [1]. In SESAR the ground costs of Airlines Operations Centers (AOC) are considered as the cost of services provided from third parties. Based on this assumption, the Ground cost of the Airlines for A^3 ConOps is considered as part of the operating cost.

Given the assumption made above regarding the Ground Cost, airlines' operating costs include the additional ground staff cost required for planning & managing the 4D flight trajectories in the self-separation airspace and the maintenance cost for the trajectory management system and the ASAS applications installed in the self-separating aircraft. Additional communication costs may also emerge due to the use of SWIM for exchanging information with the ANSPs (or any other relevant stakeholder) regarding the Reference Business Trajectory. However, this type of costs is assumed to be absorbed by the SWIM communication costs held by the airlines for SWIM in general, and thus it is attributed to SESAR rather than to A^3 ConOps. The cost estimates for the additional ground staff required for the 4D trajectory planning and management were based on relevant SESAR cost estimates for similar systems in SESAR Implementation Package (IP) 2 [7]. Based on SESAR IP2 [7], 1 additional person is needed for trajectory planning and management for every 200 flights per day at an average cost of 50K€/person-year (in 2008, for major/regional airlines).This gives an additional cost of 250K€/year (in 2008) for 1000 flights per day. Moreover, 1 additional person is needed for 300 flight per day at an average cost of 30K€ per person-year (for low fares airlines). This gives an additional cost of 100 K€/year for 1000 flights per day. Based on SESAR IP2, no additional staff cost is assumed for business aviation [7].

The maintenance cost for the trajectory management system was based on the corresponding cost estimates for SESAR Implementation Phase (IP) 2 [7], where it was estimated 3 €/flight (in 2008) for the major airlines, 1.5 €/flight (in 2008) for the regional airlines, and 0.5 €/flight (in 2008) for low-fare airlines. The weighted sum of these estimates provides an estimate of 2.07 €/flight (in 2008). The average annual maintenance cost for this type of system is estimated to 40 M€ for the period 2026-2035.

The maintenance cost for the ASAS applications needed for A^3 ConOps was taken from the ASSTAR Cost-Benefit Analysis Report [9]. The relevant estimation of the maintenance cost for the Self-Separation-Free flight Track system (SSEP-FFT) was €1200 per aircraft per annum (in 2007). This estimate can be used as a lower bound for the corresponding cost of the ASAS application required for the A^3 ConOps implementation. This leads to an annual maintenance cost equal 22.5 M€. The average annual operating cost over the entire analysis period is estimated to 66.3 M€.

The Airlines one-off implementation cost for the deployment of A^3 ConOps refers to the training of the pilots. ASSTAR CBA report has been used once more in order to provide estimates for this type of cost. In ASSTAR it has been estimated that the SSEP-FFT involves training cost € 131000 (in 2007) per aircraft retro-fitted and € 78000 (in 2007) for any new aircraft (forward-fitted).

Concerning the pre-implementation cost, in SESAR Implementation Plan, it is assumed that the airlines will be involved in the R&D activities for Implementation Package 2 (2013-2020) with 20 person-years (i.e., 240 PM). Extending this R&D effort until 2025 to cover Implementation Package 3 and beyond (i.e. 12,5 Person-Years on top of the effort up to 2020), the total R&D effort of the airlines reaches to 390 PM. Assuming the each PM costs 15000 € (in 2008), the total R&D costs for the airlines yields 5,85 M€ (in 2008), which can be considered as an upper bound for the actual R&D costs for the implementation of the A^3 ConOps.

Table A-6 below summarizes the estimates calculated for the cost variables of the airlines CBA.

NAME	VALUE	UNITS	SOURCE
Forward-fit Cost (Lower bound)	23100 (2007) 24576 (2010)	€/aircraft	ASSTAR Cost-Benefit Analysis Report [9]
Ground Staff Cost	10,2 (2008)	M€/ year	SESAR Cost Deployment plan [7]
Maintenance Cost for the Trajectory Management System	33.6 (2008)	M€/year	SESAR Cost Deployment plan [7]
Maintenance Cost for the ASAS applications	22.5 (2007)	M€/year	ASSTAR Cost-Benefit Analysis Report [9]
(Overall Annual Operating Cost)	66.3 (2007) 70.54 (2010)	M€/year	SESAR Cost Deployment plan [7] & ASSTAR Cost-Benefit Analysis Report [9]
Airlines One-off Implementation cost	131000 (2007) 139377 (2010) 78000 (2007) 82988 (2010)	€/retro-fitted aircraft €/forward-fitted aircraft	ASSTAR Cost-Benefit Analysis Report [9]
Total Pre-Implementation Cost	5.85 (2008) 5.97 (2010)	M€	SESAR Cost Deployment plan [7]

Table A-6. Cost variables and corresponding estimates.

Benefit Variables' Estimates

The variables required for the calculation of the benefits are the following: i) *Cost per unpredictable Delay Minute*, ii) *Cost per flight minute*, iii) *Incremental Efficiency Gain (%)*, iv) *Incremental Delay Reduction,* and v) *Savings from reduced ANSPs en-route charges*. No estimates could be obtained for the *Incremental Efficiency Gain (%)*, the *Incremental Delay Reduction,* and the *Savings from reduced ANSPs en-route charges.*

The cost per unpredictable delay minute expresses the average cost of each minute of unpredictable en-route delay. This cost includes the additional fuel cost, maintenance cost, and crew cost. It does not include the passenger opportunity cost. The estimate for this variable is 84 (2008 value) which was found in the EUROCONTROL report "Standard Input for ATM CBA". This value emerged from discounting the 2004 value provided in [18]. In 2010 values (March) taking into account the average EURO inflation rate evolution (see Table A-1) from June 2008 until March 2010, this variable becomes €88.

The Cost per flight minute has been estimated based on the cost per flight distance which is 8.8 €/flight Km (in 2008, taken from the EUROCONTROL report "Standard Input for ATM CBA"[14]). Given that the Average flight Duration is 106 min and the Average Flight Distance is 824 km, the cost per flight min is estimated as follows: (824/106)*8.8=68.4 €/flight min.

The reduction of the Flight Inefficiency is a major expected outcome of the A^3 ConOps. The deployment of the 4D trajectory planning and the transition from the managed airspace to the self-separation airspace constitutes significant enablers for reducing flight path inefficiency. The share of flight path inefficiency in the total inefficiency is around 3.9% (of total inefficiency 5.6%), i.e. 70%. Given that the flight inefficiency will not be increased up to 2025 (due to SESAR interventions), any improvement in flight efficiency arising from the A^3 ConOps can be considered as affecting the 70% of the total inefficiency.

The reduction of the en-route delays through the introduction of the A^3 ConOps may be basically achieved due to the expected increase of the Airspace capacity. The delegation of the separation task to the flight crew leaves out of the process the ATC which is a major bottleneck in the airspace capacity. Thus, any reduction in the ATFM delays relates directly to the reduction of the part of the ATFM delay attributed to the ATC. According to the PRR issued for 2008, the total ATFM en-route delays is estimated to 1.9 min/flight [8]. In this analysis it is assumed that the ATFM delay will not increase up to 2025 given that SESAR interventions will succeed in accommodating the expected increase in traffic (i.e., an average of 3% annually). The part of the en-route delay accounts for 76% of the total [8].

Given the delegation of the separation task from the ANSPs to the flight crews, it is expected that the en-route charges paid to the ANSPs for ATS will be significantly reduced. In 2007 the en-route charges of the airlines to the ANSPs were 6122 M€ [11]. In this analysis it is assumed that the reduction in charges will be proportional to the expected reduction in the Area Control Centers staff cost (see next section for more details). Although no estimate regarding this variable could be obtained, an assumption that could prevail in the data analysis would be to consider a maximum service cost difference of 980 M€ per year from 2025-2035.

Table A-7. summarizes the benefit variables and the corresponding estimates. Ranges of values are specified for the uncertain variables (i.e., benefit variables for which no estimates could be determined).

NAME	VALUE	UNITS	SOURCE
Cost per unpredictable Delay Minute	88 (2008)	€/min	"Standard Input for ATM CBA"[14]
Cost per flight minute	68.4 (2008)	€/flight min	"Standard Input for ATM CBA"[14]
Incremental Efficiency Gain (%)	(0-3,9)	%	PRR 2008
Incremental Delay Reduction	(0-70)	%	PRR 2008
Savings from reduced ANSPs en-route charges	(0-980)	M€	ACE report [11]

Table A-7. Benefit variables and corresponding estimates.

APPENDIX II

Input Data for the ANSPs Cost-Benefit Analysis

ANSPs Global and Time Variables Estimates

The *Discount Rate* used for the ANSPs CBA is set equal to 8%, which is the EUROCONTROL recommended value indicated in the report "Standard Inputs for EUROCONTROL Cost-Benefit Analyses" (issued by EUROCONTROL in 2009) [14].

The time variables *This Year*, *Final year*, and the *Benefit End Year* used in the CBA for ANSPs refer to the time horizon of the proposed analysis. Their values are identical with those used in the Airlines CBA, i.e., *This Year* is set equal to 2010, while *Final Year* and *Benefit End Year* are set equal to 2035. Similarly with the Airlines analysis, any monetary value having a base year earlier to 2010 will be converted to its equivalent value in 2010, by using the inflation rates presented in Table A-1 (section 3), taken from [14]. Moreover, constant (real) values will be used for any future (incoming or outgoing) cash flows considering 2010 the reference year for any monetary value.

Given that no time plan exists for the deployment of A^3 ConOps features affecting the ANSPs operations, the corresponding time plan for the ANSPs included in the SESAR ATM Master plan is used to estimate the relevant time variables of the propose ASNPs CBA. According to the SESAR ATM Master Plan, the adaptation of ANSPs to the self-separation is prescribed in Capacity Level 5 of the TMA and En-Route ANS Providers. The pre-implementation start period for this type of changes is planned for 2016 while the implementation period is planned to start in 2018. The implementation period reaches up to 2025, while it is expected that the changes will be operational from 2024 [15]. The corresponding time periods for the ANSPs CBA for A^3 ConOps are aligned with above time plan. Thus, the R&D process involves the definition and validation of ATC support functions for self-separation and is planned from 2016 to 2022 [15] (*Pre-Implementation Duration* is set equal to 7 years). The corresponding implementation period ranges from 2018 up to 2025.

The *Implementation period* for the A^3 ConOps coincides with the corresponding period of SESAR capability level 5 for ANSPs, i.e., 2018-2025. Thus, the implementation duration is set equal to 8 years. The Benefit Start Year defines the period in which the benefits of the A^3 ConOps are expected to be realized by the ANSPs. The potential benefits of the ANSPs refer to the operating staff cost savings due to the reduction of the ACC ATCOs workload since the A^3 ConOps implies no en-route ATC services. Based on the SESAR ATM Capability Level 5 for the ANSPs (which includes "Adaptation to self-separation: Update the ATC sub-systems to support self-separation") the implementation of the A^3 ConOps from the perspective of the ANSPs is assumed to start on 2018 (this is the start year for the implementation of the enablers for SESAR Capability Level 5)[15]. However, the full benefits from the A^3 ConOps will be realized from 2025 onwards, when it is assumed that A^3 ConOps will be in operation.

Table A-8 below summarizes the time variables and their corresponding estimates while Figure A-2 presents the assumed time plan (based on SESAR ATM Master Plan) for the pre-implementation, implementation, and post-implementation periods of the A^3 ConOps.

NAME	VALUE	SOURCE
This Year	2010	Assumption made by the Data Analysis Team
Benefit Start Year	2026	SESAR ATM Master Plan (D5)[15]
Benefit End Year	2035	Assumption made by the Data Analysis Team
Final Year	2035	Assumption made by the Data Analysis Team
Implementation Duration	8 Years	SESAR ATM Master Plan (D5)[15]
Pre-Impl. Start year	2016	SESAR ATM Master Plan (D5)[15]
Pre-Imp duration	7 Years	SESAR ATM Master Plan (D5)[15]
Start Year	2016	Assumption made by the Data Analysis Team

Table A-8. Time variables and corresponding estimates for the ANSPs CBA.

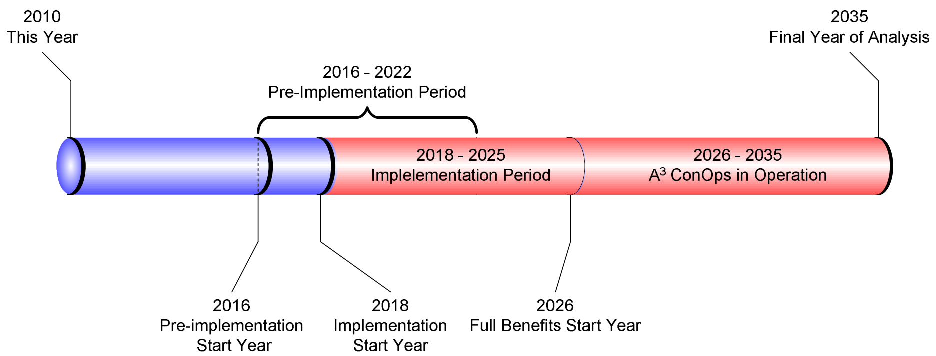

Figure A-2. Graphical presentation of the time plan used for the estimation of the time variables of the CBA for the ANSPs.

ANSPs Cost Variables Estimates

The A^3 ConOps implies the delegation of the separation task from the ANSPs to the flight crew within the self-separation airspace. Although not clarified in the existing version of A^3 ConOps, this change is going to modify substantially the role and the operations of ANSPs within the self-separation airspace. These changes in the role of ANSPs may involve new ground systems in order to adapt their operations to the self-separation airspace and one-off implementation activities to facilitate the transition to the ATM system envisaged through the A^3 ConOps. The Ground systems include the interface with the SWIM (per ANSP or ANSP unit). However, the installation of the interface with SWIM is planned to take place within SESAR deployment and therefore the corresponding costs are not attributed to A^3 ConOps. Thus, the major categories of cost attributed to A^3 ConOps relate to the One-off Implementation Cost (M-Euro) needed for the adaptation of the ANSPs operations within the A^3 ConOps framework and the pre-implementation cost (cost for R&D). The ANSPs *One-off Implementation Cost (M-Euro)* is the total investment of the ANSPs on one-off implementation activities, including the management of the transition process from the baseline ATM operational framework (SESAR inclusive) to the one proposed in the A^3 ConOps, and the training of the staff at the new operations. In particular, the cost of managing the transition involves the cost for the reorganization of ANSPs in order to implement the new procedures for the ANSPs ground support.

The cost for training involves the ANSPs expenses for training the staff to use the new systems and implement the new procedures introduced by the A^3 ConOps.

Although the A^3 ConOps implies that ANSPs will not be involved in the separation task it does not provide any specific information regarding their new role in the Self Separating Airspace operations. Lack of information regarding the transition phase from the current situation (SESAR changes included) to the A^3 ConOps ATM implies a high level of uncertainty associated to an estimate to this cost variable. The cost estimates for the transition process that were provided for a single organization (AENA [12]) were: i) High: 1.2 M€, ii) Base:1 M€, iii) Low:0.9 M€ (in 2009 prices). However, this estimate referred to an average value for transitions and not specifically for the potential transition associated to the implementation of the A^3 ConOps. The corresponding estimates (for AENA) for the training cost were: i) High:0,25 M€, ii) Base:0,2 M€, and iii) Low:0.18 M€ (in 2009 prices).

In order to estimate the aggregate cost of transition for all ANSPs in Europe, it is assumed that the cost of transition of each ANSP organization is proportional to the workload of the Area Control Centers (ACCs) of the corresponding organization. Therefore, the cost estimates of AENA were divided by the total annual number of controlled flight-hours of the ACCs of AENA and the results is multiplied with the total annual flight-hours covered by the European ACCs. The resulting aggregate cost estimates for the transition process are: i) High 12.4 M€, ii) Base 10.3 M€, and iii) Low 9.3 M€ (in 2009 prices). Concerning the estimation of the aggregate training cost for the ANSPs covering Europe, the cost values provided for AENA are divided by the number of ATCOs in OPS (in ACCs) and the result is multiplied with the total number of ATCOs in Operation in ACCs. This estimation procedure yield the following results: i) High: 2.12 M€, ii) Base: 1.7 M€, and iii) Low: 1.53 M€ (in 2009 prices). Given the uncertainty associated to the above estimates for the transition and the training cost, the high-value estimates will be used as lower bounds of the corresponding variables. No estimates could be obtained for the pre-implementation cost, i.e., the ANSPs investment on R&D for adapting and validating their procedures within the A^3 ConOps.

ANSPs Baseline Variables Estimates

The operating and staff cost for the en-route ANSP services may calculated by two alternative ways: i) on the basis of service units, and ii) assuming a constant minimum cost throughout the time horizon of the analysis. In the former case, it is assumed that the annual service units rise with a 3 % annual growth rate (similar with the traffic growth rate). Note that the services units covered by the ANSPs in Europe 2009 were 112,727,104 Service Units. Based on the EMOSIA ANSPs Baseline scenario, the operating (non-staff) and the staff costs are assumed to be linearly dependent on the total service units (in thousands). Moreover specific formulas are provided (in the EMOSIA Baseline Scenario Spreadsheet) for predicting the staff cost and the operating cost of ANSPs. Given the predicted time series of the service units (from 2010 to 2035), the associated staff cost and the operating cost may be readily calculated through the corresponding EMOSIA formulas. However, based on the ACE Report for 2008 , the share of the en-route staff cost in the total staff cost is equal to 75.5%, while the share of the en-route operating cost in the total operation cost is equal to 43.6%. Assuming that the above percentages remain constant throughout the analysis horizon, the annual en-route staff and operating costs may be readily calculated from the corresponding predicted values for the total staff and operating costs. Table A-9 presents the time series of the service units and the corresponding estimates for the annual staff cost and operating staff cost from 2010 up to 2035, and the corresponding en-route staff and operating costs. It should be pointed out however that the formulas found in the spreadsheet for predicting the staff and operating costs were developed for the period 2005-2015.

Year	Service Units (in Thousands)	Staff Cost (in million €)	En-route Staff Cost (in million €)	Operating Cost (in million €)	En-route Operating Cost (in million €)
2010	112727	2819	2129	1138	499
2011	116108	2913	2200	1176	515
2012	119592	3010	2273	1215	532
2013	123180	3109	2348	1255	550
2014	126875	3212	2425	1297	568
2015	130681	3318	2505	1339	587
2016	134602	3427	2588	1383	606
2017	138640	3539	2672	1428	626
2018	142799	3655	2760	1475	646
2019	147083	3774	2850	1523	667
2020	151495	3897	2942	1572	689
2021	156040	4023	3038	1623	711
2022	160721	4153	3136	1676	734
2023	165543	4287	3237	1730	758
2024	170509	4425	3341	1785	782
2025	175625	4567	3449	1843	807
2026	180893	4714	3559	1902	833
2027	186320	4865	3673	1962	860
2028	191910	5020	3791	2025	887
2029	197667	5180	3911	2089	915
2030	203597	5345	4036	2156	944
2031	209705	5515	4164	2224	974
2032	215996	5690	4296	2295	1005
2033	222476	5870	4432	2367	1037
2034	229151	6055	4572	2442	1070
2035	236025	6246	4716	2519	1103

Table A-9. Estimation of the annual service units for the baseline scenario and the corresponding annual staff cost time series.

Alternatively, a more conservative scenario can be used to calculate the baseline en-route staff and operating costs by considering that the corresponding values up to 2035 will not exceed the 2008 en-route staff and operating costs of 3617 M€ (3690 M€ in 2010 prices) and 1008 M€ (1028 M€ in 2010 prices) respectively. Given the arising uncertainties from using the predicted values in Table A-10 and in order to avoid overestimating the staff and operating cost reduction, the analysis team decided to use the above constant values as the time series for the baseline staff and operating costs for the ANSPs.

ANSPs Benefit Variables Estimates

The benefits realised by ANSPs from the implementation of the A^3 ConOps relate to the potential disengagement of ATC resources currently employed in the Area Control Centres (ACC) operations. Although no information is provided in the current version of the A^3 ConOps regarding the ANSPs role in the Self-Separation Airspace, it is assumed in this analysis that part of the ATC resources currently engaged in ACC will remain in their position with modified responsibilities, while the remaining employees will be engaged to other tasks of the ANSPs. It is also assumed that the number of ATC currently engaged in ACC will be gradually reduced within the time horizon of implementing the A^3 ConOps. In this context, the benefits encountered by the ANSPs within the A^3 ConOps relates to the potential reduction of the staff operating cost and the non-staff operating cost. Based on the A^3 ConOps, no ATC services are provided within the Self-Separation Airspace. Thus, after 2025 (when the A^3 ConOps is assumed to be in operation) the staff cost for ATC will be significantly reduced. The Staff cost savings is estimated based on the proportional reduction of the staff due to the delegation of the separation task from the ACC ATCos to the flight crew. Based on the 2007 ACE report [11], 50% of the total staff cost is attributed to Air Traffic Controllers. Given that the staff cost for the en-route ATC account for the 74% of the total ATC staff cost, it can be deduced that the en-route Air Traffic Controllers (ATCOs) staff cost accounts for 37% of the total staff cost. Note however, that the reduction of the ACC ATCOs will be gradually reduced during the A^3 ConOps implementation period. The remaining staff categories are assumed to remain unchanged throughout this analysis.

The non-staff operating cost includes the ANSPs costs arising from non-staff operating expenses due to telecommunication, energy, outsourced maintenance etc. The savings on this type of expenditure due to the A^3 ConOps can be expressed as an annual proportional reduction of the operating cost. In particular, the non-staff operating cost savings will be derived from the reduction of the part of these costs dedicated to en-route services. While the gate-to-gate non-staff operating cost in 2007 was 1290 M€, the en-route non-staff operating cost was 984 M€, i.e. 76.2 %. Although A^3 ConOps implies direct reduction of staff cost, this is not the case for the en-route operating cost, since telecommunication cost, energy cost, and maintenance cost will not necessarily decrease. Even if they decrease it would have been very difficult to estimate the proportional reduction. Thus, two alternative options will be taken in to account the proposed analysis: i) marginal reduction (e.g. 5%), and ii) no reduction (i.e., 0%). **Table A-10** below presents the valid ranges of values for the estimation of the benefits variables for the ANSPs CBA.

NAME	VALUE	UNITS	SOURCE
Staff Cst Avoid % (ATCOs ACCs Staff reduction %, ATC assistants reduction))	0-70% (of total baseline staff cost)	Percentage	Assumption made by the analysis team
Operating (non-staff) cost avoidance %	0-10% (of total baseline operating cost)	Percentage	Assumption made by the analysis team

Table A-10. Benefit variables and valid ranges of values for the ANSPs.

APPENDIX III

RESULTS FROM AIRLINES ANALYSIS SCENARIOS

Input Value			Results			
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1	24576	8%	0.00%	0.00%	0.00%	18.17%
1	24576	8%	0.00%	0.00%	50.00%	18.07%
1	24576	8%	0.00%	0.00%	100.00%	17.97%
1	24576	8%	0.00%	10.00%	0.00%	8.73%
1	24576	8%	0.00%	10.00%	50.00%	8.63%
1	24576	8%	0.00%	10.00%	100.00%	8.53%
1	24576	8%	0.00%	20.00%	0.00%	-0.71%
1	24576	8%	0.00%	20.00%	50.00%	-0.81%
1	24576	8%	0.00%	20.00%	100.00%	-0.91%
1	24576	8%	5.00%	0.00%	0.00%	15.13%
1	24576	8%	5.00%	0.00%	50.00%	15.03%
1	24576	8%	5.00%	0.00%	100.00%	14.93%
1	24576	8%	5.00%	10.00%	0.00%	5.69%
1	24576	8%	5.00%	10.00%	50.00%	5.59%
1	24576	8%	5.00%	10.00%	100.00%	5.49%
1	24576	8%	5.00%	20.00%	0.00%	-3.75%
1	24576	8%	5.00%	20.00%	50.00%	-3.85%
1	24576	8%	5.00%	20.00%	100.00%	-3.95%
1	24576	8%	10.00%	0.00%	0.00%	12.09%
1	24576	8%	10.00%	0.00%	50.00%	11.99%
1	24576	8%	10.00%	0.00%	100.00%	11.89%
1	24576	8%	10.00%	10.00%	0.00%	2.65%
1	24576	8%	10.00%	10.00%	50.00%	2.55%
1	24576	8%	10.00%	10.00%	100.00%	2.45%
1	24576	8%	10.00%	20.00%	0.00%	-6.79%
1	24576	8%	10.00%	20.00%	50.00%	-6.89%
1	24576	8%	10.00%	20.00%	100.00%	-6.99%
1	49152	8%	0.00%	0.00%	0.00%	22.66%
1	49152	8%	0.00%	0.00%	50.00%	22.56%
1	49152	8%	0.00%	0.00%	100.00%	22.46%
1	49152	8%	0.00%	10.00%	0.00%	13.22%
1	49152	8%	0.00%	10.00%	50.00%	13.12%
1	49152	8%	0.00%	10.00%	100.00%	13.02%
1	49152	8%	0.00%	20.00%	0.00%	3.78%
1	49152	8%	0.00%	20.00%	50.00%	3.68%
1	49152	8%	0.00%	20.00%	100.00%	3.58%
1	49152	8%	5.00%	0.00%	0.00%	19.62%
1	49152	8%	5.00%	0.00%	50.00%	19.52%
1	49152	8%	5.00%	0.00%	100.00%	19.42%
1	49152	8%	5.00%	10.00%	0.00%	10.18%
1	49152	8%	5.00%	10.00%	50.00%	10.08%
1	49152	8%	5.00%	10.00%	100.00%	9.98%
1	49152	8%	5.00%	20.00%	0.00%	0.74%
1	49152	8%	5.00%	20.00%	50.00%	0.64%
1	49152	8%	5.00%	20.00%	100.00%	0.54%
1	49152	8%	10.00%	0.00%	0.00%	16.58%
1	49152	8%	10.00%	0.00%	50.00%	16.48%
1	49152	8%	10.00%	0.00%	100.00%	16.38%
1	49152	8%	10.00%	10.00%	0.00%	7.14%
1	49152	8%	10.00%	10.00%	50.00%	7.04%
1	49152	8%	10.00%	10.00%	100.00%	6.94%
1	49152	8%	10.00%	20.00%	0.00%	-2.30%
1	49152	8%	10.00%	20.00%	50.00%	-2.40%
1	49152	8%	10.00%	20.00%	100.00%	-2.50%
1	73728	8%	0.00%	0.00%	0.00%	27.15%
1	73728	8%	0.00%	0.00%	50.00%	27.05%
1	73728	8%	0.00%	0.00%	100.00%	26.95%
1	73728	8%	0.00%	10.00%	0.00%	17.71%

Input Value			Results			
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1	73728	8%	0.00%	10.00%	50.00%	17.61%
1	73728	8%	0.00%	10.00%	100.00%	17.51%
1	73728	8%	0.00%	20.00%	0.00%	8.27%
1	73728	8%	0.00%	20.00%	50.00%	8.17%
1	73728	8%	0.00%	20.00%	100.00%	8.07%
1	73728	8%	5.00%	0.00%	0.00%	24.11%
1	73728	8%	5.00%	0.00%	50.00%	24.01%
1	73728	8%	5.00%	0.00%	100.00%	23.91%
1	73728	8%	5.00%	10.00%	0.00%	14.67%
1	73728	8%	5.00%	10.00%	50.00%	14.57%
1	73728	8%	5.00%	10.00%	100.00%	14.47%
1	73728	8%	5.00%	20.00%	0.00%	5.23%
1	73728	8%	5.00%	20.00%	50.00%	5.13%
1	73728	8%	5.00%	20.00%	100.00%	5.03%
1	73728	8%	10.00%	0.00%	0.00%	21.07%
1	73728	8%	10.00%	0.00%	50.00%	20.97%
1	73728	8%	10.00%	0.00%	100.00%	20.87%
1	73728	8%	10.00%	10.00%	0.00%	11.63%
1	73728	8%	10.00%	10.00%	50.00%	11.53%
1	73728	8%	10.00%	10.00%	100.00%	11.43%
1	73728	8%	10.00%	20.00%	0.00%	2.19%
1	73728	8%	10.00%	20.00%	50.00%	2.09%
1	73728	8%	10.00%	20.00%	100.00%	1.99%
1	36864	8%	0.00%	0.00%	0.00%	20.42%
1	36864	8%	0.00%	0.00%	50.00%	20.32%
1	36864	8%	0.00%	0.00%	100.00%	20.22%
1	36864	8%	0.00%	10.00%	0.00%	10.98%
1	36864	8%	0.00%	10.00%	50.00%	10.88%
1	36864	8%	0.00%	10.00%	100.00%	10.78%
1	36864	8%	0.00%	20.00%	0.00%	1.54%
1	36864	8%	0.00%	20.00%	50.00%	1.44%
1	36864	8%	0.00%	20.00%	100.00%	1.34%
1	36864	8%	5.00%	0.00%	0.00%	17.38%
1	36864	8%	5.00%	0.00%	50.00%	17.28%
1	36864	8%	5.00%	0.00%	100.00%	17.18%
1	36864	8%	5.00%	10.00%	0.00%	7.94%
1	36864	8%	5.00%	10.00%	50.00%	7.84%
1	36864	8%	5.00%	10.00%	100.00%	7.74%
1	36864	8%	5.00%	20.00%	0.00%	-1.51%
1	36864	8%	5.00%	20.00%	50.00%	-1.60%
1	36864	8%	5.00%	20.00%	100.00%	-1.70%
1	36864	8%	10.00%	0.00%	0.00%	14.34%
1	36864	8%	10.00%	0.00%	50.00%	14.24%
1	36864	8%	10.00%	0.00%	100.00%	14.14%
1	36864	8%	10.00%	10.00%	0.00%	4.90%
1	36864	8%	10.00%	10.00%	50.00%	4.80%
1	36864	8%	10.00%	10.00%	100.00%	4.70%
1	36864	8%	10.00%	20.00%	0.00%	-4.55%
1	36864	8%	10.00%	20.00%	50.00%	-4.64%
1	36864	8%	10.00%	20.00%	100.00%	-4.74%
1	61440	8%	0.00%	0.00%	0.00%	24.91%
1	61440	8%	0.00%	0.00%	50.00%	24.81%
1	61440	8%	0.00%	0.00%	100.00%	24.71%
1	61440	8%	0.00%	10.00%	0.00%	15.47%
1	61440	8%	0.00%	10.00%	50.00%	15.37%
1	61440	8%	0.00%	10.00%	100.00%	15.27%
1	61440	8%	0.00%	20.00%	0.00%	6.03%
1	61440	8%	0.00%	20.00%	50.00%	5.93%
1	61440	8%	0.00%	20.00%	100.00%	5.83%

Input Value		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1	61440	8%	5.00%	0.00%	0.00%	21.87%
1	61440	8%	5.00%	0.00%	50.00%	21.77%
1	61440	8%	5.00%	0.00%	100.00%	21.67%
1	61440	8%	5.00%	10.00%	0.00%	12.43%
1	61440	8%	5.00%	10.00%	50.00%	12.33%
1	61440	8%	5.00%	10.00%	100.00%	12.23%
1	61440	8%	5.00%	20.00%	0.00%	2.99%
1	61440	8%	5.00%	20.00%	50.00%	2.89%
1	61440	8%	5.00%	20.00%	100.00%	2.79%
1	61440	8%	10.00%	0.00%	0.00%	18.83%
1	61440	8%	10.00%	0.00%	50.00%	18.73%
1	61440	8%	10.00%	0.00%	100.00%	18.63%
1	61440	8%	10.00%	10.00%	0.00%	9.39%
1	61440	8%	10.00%	10.00%	50.00%	9.29%
1	61440	8%	10.00%	10.00%	100.00%	9.19%
1	61440	8%	10.00%	20.00%	0.00%	-0.05%
1	61440	8%	10.00%	20.00%	50.00%	-0.15%
1	61440	8%	10.00%	20.00%	100.00%	-0.25%

Table A-11. Results for Airlines analysis scenarios with B/C equal to 1.

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.1	24576	8.883%	0.00%	0.00%	0.00%	19.99%
1.1	24576	8.883%	0.00%	0.00%	50.00%	19.79%
1.1	24576	8.883%	0.00%	0.00%	100.00%	19.59%
1.1	24576	8.883%	0.00%	10.00%	0.00%	10.49%
1.1	24576	8.883%	0.00%	10.00%	50.00%	10.29%
1.1	24576	8.883%	0.00%	10.00%	100.00%	10.09%
1.1	24576	8.883%	0.00%	20.00%	0.00%	0.99%
1.1	24576	8.883%	0.00%	20.00%	50.00%	0.79%
1.1	24576	8.883%	0.00%	20.00%	100.00%	0.59%
1.1	24576	8.883%	5.00%	0.00%	0.00%	16.95%
1.1	24576	8.883%	5.00%	0.00%	50.00%	16.75%
1.1	24576	8.883%	5.00%	0.00%	100.00%	16.55%
1.1	24576	8.883%	5.00%	10.00%	0.00%	7.45%
1.1	24576	8.883%	5.00%	10.00%	50.00%	7.25%
1.1	24576	8.883%	5.00%	10.00%	100.00%	7.05%
1.1	24576	8.883%	5.00%	20.00%	0.00%	-2.05%
1.1	24576	8.883%	5.00%	20.00%	50.00%	-2.25%
1.1	24576	8.883%	5.00%	20.00%	100.00%	-2.45%
1.1	24576	8.883%	10.00%	0.00%	0.00%	13.91%
1.1	24576	8.883%	10.00%	0.00%	50.00%	13.71%
1.1	24576	8.883%	10.00%	0.00%	100.00%	13.51%
1.1	24576	8.883%	10.00%	10.00%	0.00%	4.41%
1.1	24576	8.883%	10.00%	10.00%	50.00%	4.21%
1.1	24576	8.883%	10.00%	10.00%	100.00%	4.01%
1.1	24576	8.883%	10.00%	20.00%	0.00%	-5.09%
1.1	24576	8.883%	10.00%	20.00%	50.00%	-5.29%
1.1	24576	8.883%	10.00%	20.00%	100.00%	-5.49%
1.1	49152	8.938%	0.00%	0.00%	0.00%	24.92%
1.1	49152	8.938%	0.00%	0.00%	50.00%	24.72%
1.1	49152	8.938%	0.00%	0.00%	100.00%	24.52%
1.1	49152	8.938%	0.00%	10.00%	0.00%	15.42%
1.1	49152	8.938%	0.00%	10.00%	50.00%	15.22%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.1	49152	8.938%	0.00%	10.00%	100.00%	15.02%
1.1	49152	8.938%	0.00%	20.00%	0.00%	5.92%
1.1	49152	8.938%	0.00%	20.00%	50.00%	5.72%
1.1	49152	8.938%	0.00%	20.00%	100.00%	5.52%
1.1	49152	8.938%	5.00%	0.00%	0.00%	21.88%
1.1	49152	8.938%	5.00%	0.00%	50.00%	21.68%
1.1	49152	8.938%	5.00%	0.00%	100.00%	21.48%
1.1	49152	8.938%	5.00%	10.00%	0.00%	12.38%
1.1	49152	8.938%	5.00%	10.00%	50.00%	12.18%
1.1	49152	8.938%	5.00%	10.00%	100.00%	11.98%
1.1	49152	8.938%	5.00%	20.00%	0.00%	2.88%
1.1	49152	8.938%	5.00%	20.00%	50.00%	2.68%
1.1	49152	8.938%	5.00%	20.00%	100.00%	2.48%
1.1	49152	8.938%	10.00%	0.00%	0.00%	18.84%
1.1	49152	8.938%	10.00%	0.00%	50.00%	18.64%
1.1	49152	8.938%	10.00%	0.00%	100.00%	18.44%
1.1	49152	8.938%	10.00%	10.00%	0.00%	9.34%
1.1	49152	8.938%	10.00%	10.00%	50.00%	9.14%
1.1	49152	8.938%	10.00%	10.00%	100.00%	8.94%
1.1	49152	8.938%	10.00%	20.00%	0.00%	-0.16%
1.1	49152	8.938%	10.00%	20.00%	50.00%	-0.36%
1.1	49152	8.938%	10.00%	20.00%	100.00%	-0.56%
1.1	73728	8.983%	0.00%	0.00%	0.00%	29.85%
1.1	73728	8.983%	0.00%	0.00%	50.00%	29.65%
1.1	73728	8.983%	0.00%	0.00%	100.00%	29.45%
1.1	73728	8.983%	0.00%	10.00%	0.00%	20.35%
1.1	73728	8.983%	0.00%	10.00%	50.00%	20.15%
1.1	73728	8.983%	0.00%	10.00%	100.00%	19.95%
1.1	73728	8.983%	0.00%	20.00%	0.00%	10.85%
1.1	73728	8.983%	0.00%	20.00%	50.00%	10.65%
1.1	73728	8.983%	0.00%	20.00%	100.00%	10.45%
1.1	73728	8.983%	5.00%	0.00%	0.00%	26.81%
1.1	73728	8.983%	5.00%	0.00%	50.00%	26.61%
1.1	73728	8.983%	5.00%	0.00%	100.00%	26.41%
1.1	73728	8.983%	5.00%	10.00%	0.00%	17.31%
1.1	73728	8.983%	5.00%	10.00%	50.00%	17.11%
1.1	73728	8.983%	5.00%	10.00%	100.00%	16.91%
1.1	73728	8.983%	5.00%	20.00%	0.00%	7.81%
1.1	73728	8.983%	5.00%	20.00%	50.00%	7.61%
1.1	73728	8.983%	5.00%	20.00%	100.00%	7.41%
1.1	73728	8.983%	10.00%	0.00%	0.00%	23.77%
1.1	73728	8.983%	10.00%	0.00%	50.00%	23.57%
1.1	73728	8.983%	10.00%	0.00%	100.00%	23.37%
1.1	73728	8.983%	10.00%	10.00%	0.00%	14.27%
1.1	73728	8.983%	10.00%	10.00%	50.00%	14.07%
1.1	73728	8.983%	10.00%	10.00%	100.00%	13.87%
1.1	73728	8.983%	10.00%	20.00%	0.00%	4.77%
1.1	73728	8.983%	10.00%	20.00%	50.00%	4.57%
1.1	73728	8.983%	10.00%	20.00%	100.00%	4.37%
1.1	36864	8.912%	0.00%	0.00%	0.00%	22.46%
1.1	36864	8.912%	0.00%	0.00%	50.00%	22.26%
1.1	36864	8.912%	0.00%	0.00%	100.00%	22.06%
1.1	36864	8.912%	0.00%	10.00%	0.00%	12.96%
1.1	36864	8.912%	0.00%	10.00%	50.00%	12.76%
1.1	36864	8.912%	0.00%	10.00%	100.00%	12.56%
1.1	36864	8.912%	0.00%	20.00%	0.00%	3.46%
1.1	36864	8.912%	0.00%	20.00%	50.00%	3.26%
1.1	36864	8.912%	0.00%	20.00%	100.00%	3.06%
1.1	36864	8.912%	5.00%	0.00%	0.00%	19.42%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.1	36864	8.912%	5.00%	0.00%	50.00%	19.22%
1.1	36864	8.912%	5.00%	0.00%	100.00%	19.02%
1.1	36864	8.912%	5.00%	10.00%	0.00%	9.92%
1.1	36864	8.912%	5.00%	10.00%	50.00%	9.72%
1.1	36864	8.912%	5.00%	10.00%	100.00%	9.51%
1.1	36864	8.912%	5.00%	20.00%	0.00%	0.42%
1.1	36864	8.912%	5.00%	20.00%	50.00%	0.22%
1.1	36864	8.912%	5.00%	20.00%	100.00%	0.01%
1.1	36864	8.912%	10.00%	0.00%	0.00%	16.38%
1.1	36864	8.912%	10.00%	0.00%	50.00%	16.18%
1.1	36864	8.912%	10.00%	0.00%	100.00%	15.98%
1.1	36864	8.912%	10.00%	10.00%	0.00%	6.88%
1.1	36864	8.912%	10.00%	10.00%	50.00%	6.68%
1.1	36864	8.912%	10.00%	10.00%	100.00%	6.47%
1.1	36864	8.912%	10.00%	20.00%	0.00%	-2.62%
1.1	36864	8.912%	10.00%	20.00%	50.00%	-2.83%
1.1	36864	8.912%	10.00%	20.00%	100.00%	-3.03%
1.1	61440	8.962%	0.00%	0.00%	0.00%	27.39%
1.1	61440	8.962%	0.00%	0.00%	50.00%	27.19%
1.1	61440	8.962%	0.00%	0.00%	100.00%	26.99%
1.1	61440	8.962%	0.00%	10.00%	0.00%	17.89%
1.1	61440	8.962%	0.00%	10.00%	50.00%	17.69%
1.1	61440	8.962%	0.00%	10.00%	100.00%	17.49%
1.1	61440	8.962%	0.00%	20.00%	0.00%	8.39%
1.1	61440	8.962%	0.00%	20.00%	50.00%	8.19%
1.1	61440	8.962%	0.00%	20.00%	100.00%	7.99%
1.1	61440	8.962%	5.00%	0.00%	0.00%	24.35%
1.1	61440	8.962%	5.00%	0.00%	50.00%	24.15%
1.1	61440	8.962%	5.00%	0.00%	100.00%	23.95%
1.1	61440	8.962%	5.00%	10.00%	0.00%	14.85%
1.1	61440	8.962%	5.00%	10.00%	50.00%	14.65%
1.1	61440	8.962%	5.00%	10.00%	100.00%	14.45%
1.1	61440	8.962%	5.00%	20.00%	0.00%	5.35%
1.1	61440	8.962%	5.00%	20.00%	50.00%	5.15%
1.1	61440	8.962%	5.00%	20.00%	100.00%	4.95%
1.1	61440	8.962%	10.00%	0.00%	0.00%	21.31%
1.1	61440	8.962%	10.00%	0.00%	50.00%	21.11%
1.1	61440	8.962%	10.00%	0.00%	100.00%	20.91%
1.1	61440	8.962%	10.00%	10.00%	0.00%	11.81%
1.1	61440	8.962%	10.00%	10.00%	50.00%	11.61%
1.1	61440	8.962%	10.00%	10.00%	100.00%	11.41%
1.1	61440	8.962%	10.00%	20.00%	0.00%	2.31%
1.1	61440	8.962%	10.00%	20.00%	50.00%	2.11%
1.1	61440	8.962%	10.00%	20.00%	100.00%	1.91%

Table A-12. Results for Airlines analysis scenarios with B/C equal to 1.1.

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.2	24576	9.689%	0.00%	0.00%	0.00%	21.80%
1.2	24576	9.689%	0.00%	0.00%	50.00%	21.74%
1.2	24576	9.689%	0.00%	0.00%	100.00%	21.68%
1.2	24576	9.689%	0.00%	10.00%	0.00%	12.30%
1.2	24576	9.689%	0.00%	10.00%	50.00%	12.24%
1.2	24576	9.689%	0.00%	10.00%	100.00%	12.18%
1.2	24576	9.689%	0.00%	20.00%	0.00%	2.80%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.2	24576	9.689%	0.00%	20.00%	50.00%	2.74%
1.2	24576	9.689%	0.00%	20.00%	100.00%	2.68%
1.2	24576	9.689%	5.00%	0.00%	0.00%	18.76%
1.2	24576	9.689%	5.00%	0.00%	50.00%	18.70%
1.2	24576	9.689%	5.00%	0.00%	100.00%	18.64%
1.2	24576	9.689%	5.00%	10.00%	0.00%	9.26%
1.2	24576	9.689%	5.00%	10.00%	50.00%	9.20%
1.2	24576	9.689%	5.00%	10.00%	100.00%	9.14%
1.2	24576	9.689%	5.00%	20.00%	0.00%	-0.24%
1.2	24576	9.689%	5.00%	20.00%	50.00%	-0.30%
1.2	24576	9.689%	5.00%	20.00%	100.00%	-0.36%
1.2	24576	9.689%	10.00%	0.00%	0.00%	15.72%
1.2	24576	9.689%	10.00%	0.00%	50.00%	15.66%
1.2	24576	9.689%	10.00%	0.00%	100.00%	15.60%
1.2	24576	9.689%	10.00%	10.00%	0.00%	6.22%
1.2	24576	9.689%	10.00%	10.00%	50.00%	6.16%
1.2	24576	9.689%	10.00%	10.00%	100.00%	6.10%
1.2	24576	9.689%	10.00%	20.00%	0.00%	-3.28%
1.2	24576	9.689%	10.00%	20.00%	50.00%	-3.34%
1.2	24576	9.689%	10.00%	20.00%	100.00%	-3.40%
1.2	49152	9.793%	0.00%	0.00%	0.00%	27.19%
1.2	49152	9.793%	0.00%	0.00%	50.00%	27.13%
1.2	49152	9.793%	0.00%	0.00%	100.00%	27.07%
1.2	49152	9.793%	0.00%	10.00%	0.00%	17.69%
1.2	49152	9.793%	0.00%	10.00%	50.00%	17.63%
1.2	49152	9.793%	0.00%	10.00%	100.00%	17.57%
1.2	49152	9.793%	0.00%	20.00%	0.00%	8.19%
1.2	49152	9.793%	0.00%	20.00%	50.00%	8.13%
1.2	49152	9.793%	0.00%	20.00%	100.00%	8.07%
1.2	49152	9.793%	5.00%	0.00%	0.00%	24.15%
1.2	49152	9.793%	5.00%	0.00%	50.00%	24.09%
1.2	49152	9.793%	5.00%	0.00%	100.00%	24.03%
1.2	49152	9.793%	5.00%	10.00%	0.00%	14.65%
1.2	49152	9.793%	5.00%	10.00%	50.00%	14.59%
1.2	49152	9.793%	5.00%	10.00%	100.00%	14.53%
1.2	49152	9.793%	5.00%	20.00%	0.00%	5.15%
1.2	49152	9.793%	5.00%	20.00%	50.00%	5.09%
1.2	49152	9.793%	5.00%	20.00%	100.00%	5.03%
1.2	49152	9.793%	10.00%	0.00%	0.00%	21.11%
1.2	49152	9.793%	10.00%	0.00%	50.00%	21.05%
1.2	49152	9.793%	10.00%	0.00%	100.00%	20.99%
1.2	49152	9.793%	10.00%	10.00%	0.00%	11.61%
1.2	49152	9.793%	10.00%	10.00%	50.00%	11.55%
1.2	49152	9.793%	10.00%	10.00%	100.00%	11.49%
1.2	49152	9.793%	10.00%	20.00%	0.00%	2.11%
1.2	49152	9.793%	10.00%	20.00%	50.00%	2.05%
1.2	49152	9.793%	10.00%	20.00%	100.00%	1.99%
1.2	73728	9.879%	0.00%	0.00%	0.00%	32.58%
1.2	73728	9.879%	0.00%	0.00%	50.00%	32.52%
1.2	73728	9.879%	0.00%	0.00%	100.00%	32.46%
1.2	73728	9.879%	0.00%	10.00%	0.00%	23.08%
1.2	73728	9.879%	0.00%	10.00%	50.00%	23.02%
1.2	73728	9.879%	0.00%	10.00%	100.00%	22.96%
1.2	73728	9.879%	0.00%	20.00%	0.00%	13.58%
1.2	73728	9.879%	0.00%	20.00%	50.00%	13.52%
1.2	73728	9.879%	0.00%	20.00%	100.00%	13.46%
1.2	73728	9.879%	5.00%	0.00%	0.00%	29.54%
1.2	73728	9.879%	5.00%	0.00%	50.00%	29.48%
1.2	73728	9.879%	5.00%	0.00%	100.00%	29.42%
1.2	73728	9.879%	5.00%	10.00%	0.00%	20.04%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.2	73728	9.879%	5.00%	10.00%	50.00%	19.98%
1.2	73728	9.879%	5.00%	10.00%	100.00%	19.92%
1.2	73728	9.879%	5.00%	20.00%	0.00%	10.54%
1.2	73728	9.879%	5.00%	20.00%	50.00%	10.48%
1.2	73728	9.879%	5.00%	20.00%	100.00%	10.42%
1.2	73728	9.879%	10.00%	0.00%	0.00%	26.50%
1.2	73728	9.879%	10.00%	0.00%	50.00%	26.44%
1.2	73728	9.879%	10.00%	0.00%	100.00%	26.38%
1.2	73728	9.879%	10.00%	10.00%	0.00%	17.00%
1.2	73728	9.879%	10.00%	10.00%	50.00%	16.94%
1.2	73728	9.879%	10.00%	10.00%	100.00%	16.88%
1.2	73728	9.879%	10.00%	20.00%	0.00%	7.50%
1.2	73728	9.879%	10.00%	20.00%	50.00%	7.44%
1.2	73728	9.879%	10.00%	20.00%	100.00%	7.38%
1.2	36864	9.744%	0.00%	0.00%	0.00%	24.50%
1.2	36864	9.744%	0.00%	0.00%	50.00%	24.44%
1.2	36864	9.744%	0.00%	0.00%	100.00%	24.38%
1.2	36864	9.744%	0.00%	10.00%	0.00%	15.00%
1.2	36864	9.744%	0.00%	10.00%	50.00%	14.94%
1.2	36864	9.744%	0.00%	10.00%	100.00%	14.88%
1.2	36864	9.744%	0.00%	20.00%	0.00%	5.50%
1.2	36864	9.744%	0.00%	20.00%	50.00%	5.44%
1.2	36864	9.744%	0.00%	20.00%	100.00%	5.38%
1.2	36864	9.744%	5.00%	0.00%	0.00%	21.46%
1.2	36864	9.744%	5.00%	0.00%	50.00%	21.40%
1.2	36864	9.744%	5.00%	0.00%	100.00%	21.34%
1.2	36864	9.744%	5.00%	10.00%	0.00%	11.96%
1.2	36864	9.744%	5.00%	10.00%	50.00%	11.90%
1.2	36864	9.744%	5.00%	10.00%	100.00%	11.84%
1.2	36864	9.744%	5.00%	20.00%	0.00%	2.46%
1.2	36864	9.744%	5.00%	20.00%	50.00%	2.40%
1.2	36864	9.744%	5.00%	20.00%	100.00%	2.34%
1.2	36864	9.744%	10.00%	0.00%	0.00%	18.42%
1.2	36864	9.744%	10.00%	0.00%	50.00%	18.36%
1.2	36864	9.744%	10.00%	0.00%	100.00%	18.30%
1.2	36864	9.744%	10.00%	10.00%	0.00%	8.92%
1.2	36864	9.744%	10.00%	10.00%	50.00%	8.86%
1.2	36864	9.744%	10.00%	10.00%	100.00%	8.80%
1.2	36864	9.744%	10.00%	20.00%	0.00%	-0.58%
1.2	36864	9.744%	10.00%	20.00%	50.00%	-0.64%
1.2	36864	9.744%	10.00%	20.00%	100.00%	-0.70%
1.2	61440	9.838%	0.00%	0.00%	0.00%	29.89%
1.2	61440	9.838%	0.00%	0.00%	50.00%	29.83%
1.2	61440	9.838%	0.00%	0.00%	100.00%	29.77%
1.2	61440	9.838%	0.00%	10.00%	0.00%	20.39%
1.2	61440	9.838%	0.00%	10.00%	50.00%	20.33%
1.2	61440	9.838%	0.00%	10.00%	100.00%	20.27%
1.2	61440	9.838%	0.00%	20.00%	0.00%	10.89%
1.2	61440	9.838%	0.00%	20.00%	50.00%	10.83%
1.2	61440	9.838%	0.00%	20.00%	100.00%	10.77%
1.2	61440	9.838%	5.00%	0.00%	0.00%	26.85%
1.2	61440	9.838%	5.00%	0.00%	50.00%	26.79%
1.2	61440	9.838%	5.00%	0.00%	100.00%	26.73%
1.2	61440	9.838%	5.00%	10.00%	0.00%	17.35%
1.2	61440	9.838%	5.00%	10.00%	50.00%	17.29%
1.2	61440	9.838%	5.00%	10.00%	100.00%	17.23%
1.2	61440	9.838%	5.00%	20.00%	0.00%	7.85%
1.2	61440	9.838%	5.00%	20.00%	50.00%	7.79%
1.2	61440	9.838%	5.00%	20.00%	100.00%	7.73%
1.2	61440	9.838%	10.00%	0.00%	0.00%	23.81%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.2	61440	9.838%	10.00%	0.00%	50.00%	23.75%
1.2	61440	9.838%	10.00%	0.00%	100.00%	23.69%
1.2	61440	9.838%	10.00%	10.00%	0.00%	14.31%
1.2	61440	9.838%	10.00%	10.00%	50.00%	14.25%
1.2	61440	9.838%	10.00%	10.00%	100.00%	14.19%
1.2	61440	9.838%	10.00%	20.00%	0.00%	4.81%
1.2	61440	9.838%	10.00%	20.00%	50.00%	4.75%
1.2	61440	9.838%	10.00%	20.00%	100.00%	4.69%

Table A-13. Results for Airlines analysis scenarios with B/C equal to 1.2.

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.3	24576		0.00%	0.00%	0.00%	23.61%
1.3	24576	10.434%	0.00%	0.00%	50.00%	23.31%
1.3	24576	10.434%	0.00%	0.00%	100.00%	23.01%
1.3	24576	10.434%	0.00%	10.00%	0.00%	14.13%
1.3	24576	10.434%	0.00%	10.00%	50.00%	13.83%
1.3	24576	10.434%	0.00%	10.00%	100.00%	13.53%
1.3	24576	10.434%	0.00%	20.00%	0.00%	4.65%
1.3	24576	10.434%	0.00%	20.00%	50.00%	4.35%
1.3	24576	10.434%	0.00%	20.00%	100.00%	4.05%
1.3	24576	10.434%	5.00%	0.00%	0.00%	20.56%
1.3	24576	10.434%	5.00%	0.00%	50.00%	20.26%
1.3	24576	10.434%	5.00%	0.00%	100.00%	19.96%
1.3	24576	10.434%	5.00%	10.00%	0.00%	11.08%
1.3	24576	10.434%	5.00%	10.00%	50.00%	10.78%
1.3	24576	10.434%	5.00%	10.00%	100.00%	10.48%
1.3	24576	10.434%	5.00%	20.00%	0.00%	1.60%
1.3	24576	10.434%	5.00%	20.00%	50.00%	1.30%
1.3	24576	10.434%	5.00%	20.00%	100.00%	1.00%
1.3	24576	10.434%	10.00%	0.00%	0.00%	17.51%
1.3	24576	10.434%	10.00%	0.00%	50.00%	17.21%
1.3	24576	10.434%	10.00%	0.00%	100.00%	16.91%
1.3	24576	10.434%	10.00%	10.00%	0.00%	8.03%
1.3	24576	10.434%	10.00%	10.00%	50.00%	7.73%
1.3	24576	10.434%	10.00%	10.00%	100.00%	7.43%
1.3	24576	10.434%	10.00%	20.00%	0.00%	-1.45%
1.3	24576	10.434%	10.00%	20.00%	50.00%	-1.75%
1.3	24576	10.434%	10.00%	20.00%	100.00%	-2.05%
1.3	49152	10.580%	0.00%	0.00%	0.00%	29.46%
1.3	49152	10.580%	0.00%	0.00%	50.00%	29.16%
1.3	49152	10.580%	0.00%	0.00%	100.00%	28.86%
1.3	49152	10.580%	0.00%	10.00%	0.00%	19.98%
1.3	49152	10.580%	0.00%	10.00%	50.00%	19.68%
1.3	49152	10.580%	0.00%	10.00%	100.00%	19.38%
1.3	49152	10.580%	0.00%	20.00%	0.00%	10.50%
1.3	49152	10.580%	0.00%	20.00%	50.00%	10.20%
1.3	49152	10.580%	0.00%	20.00%	100.00%	9.90%
1.3	49152	10.580%	5.00%	0.00%	0.00%	26.41%
1.3	49152	10.580%	5.00%	0.00%	50.00%	26.11%
1.3	49152	10.580%	5.00%	0.00%	100.00%	25.81%
1.3	49152	10.580%	5.00%	10.00%	0.00%	16.93%
1.3	49152	10.580%	5.00%	10.00%	50.00%	16.63%
1.3	49152	10.580%	5.00%	10.00%	100.00%	16.33%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.3	49152	10.580%	5.00%	20.00%	0.00%	7.45%
1.3	49152	10.580%	5.00%	20.00%	50.00%	7.15%
1.3	49152	10.580%	5.00%	20.00%	100.00%	6.85%
1.3	49152	10.580%	10.00%	0.00%	0.00%	23.36%
1.3	49152	10.580%	10.00%	0.00%	50.00%	23.06%
1.3	49152	10.580%	10.00%	0.00%	100.00%	22.76%
1.3	49152	10.580%	10.00%	10.00%	0.00%	13.88%
1.3	49152	10.580%	10.00%	10.00%	50.00%	13.58%
1.3	49152	10.580%	10.00%	10.00%	100.00%	13.28%
1.3	49152	10.580%	10.00%	20.00%	0.00%	4.40%
1.3	49152	10.580%	10.00%	20.00%	50.00%	4.10%
1.3	49152	10.580%	10.00%	20.00%	100.00%	3.80%
1.3	73728	10.703%	0.00%	0.00%	0.00%	35.31%
1.3	73728	10.703%	0.00%	0.00%	50.00%	35.01%
1.3	73728	10.703%	0.00%	0.00%	100.00%	34.71%
1.3	73728	10.703%	0.00%	10.00%	0.00%	25.83%
1.3	73728	10.703%	0.00%	10.00%	50.00%	25.53%
1.3	73728	10.703%	0.00%	10.00%	100.00%	25.23%
1.3	73728	10.703%	0.00%	20.00%	0.00%	16.35%
1.3	73728	10.703%	0.00%	20.00%	50.00%	16.05%
1.3	73728	10.703%	0.00%	20.00%	100.00%	15.75%
1.3	73728	10.703%	5.00%	0.00%	0.00%	32.26%
1.3	73728	10.703%	5.00%	0.00%	50.00%	31.96%
1.3	73728	10.703%	5.00%	0.00%	100.00%	31.66%
1.3	73728	10.703%	5.00%	10.00%	0.00%	22.78%
1.3	73728	10.703%	5.00%	10.00%	50.00%	22.48%
1.3	73728	10.703%	5.00%	10.00%	100.00%	22.18%
1.3	73728	10.703%	5.00%	20.00%	0.00%	13.30%
1.3	73728	10.703%	5.00%	20.00%	50.00%	13.00%
1.3	73728	10.703%	5.00%	20.00%	100.00%	12.70%
1.3	73728	10.703%	10.00%	0.00%	0.00%	29.21%
1.3	73728	10.703%	10.00%	0.00%	50.00%	28.91%
1.3	73728	10.703%	10.00%	0.00%	100.00%	28.61%
1.3	73728	10.703%	10.00%	10.00%	0.00%	19.73%
1.3	73728	10.703%	10.00%	10.00%	50.00%	19.43%
1.3	73728	10.703%	10.00%	10.00%	100.00%	19.13%
1.3	73728	10.703%	10.00%	20.00%	0.00%	10.25%
1.3	73728	10.703%	10.00%	20.00%	50.00%	9.95%
1.3	73728	10.703%	10.00%	20.00%	100.00%	9.65%
1.3	36864	10.509%	0.00%	0.00%	0.00%	26.54%
1.3	36864	10.509%	0.00%	0.00%	50.00%	26.24%
1.3	36864	10.509%	0.00%	0.00%	100.00%	25.94%
1.3	36864	10.509%	0.00%	10.00%	0.00%	17.06%
1.3	36864	10.509%	0.00%	10.00%	50.00%	16.76%
1.3	36864	10.509%	0.00%	10.00%	100.00%	16.46%
1.3	36864	10.509%	0.00%	20.00%	0.00%	7.58%
1.3	36864	10.509%	0.00%	20.00%	50.00%	7.28%
1.3	36864	10.509%	0.00%	20.00%	100.00%	6.98%
1.3	36864	10.509%	5.00%	0.00%	0.00%	23.49%
1.3	36864	10.509%	5.00%	0.00%	50.00%	23.19%
1.3	36864	10.509%	5.00%	0.00%	100.00%	22.89%
1.3	36864	10.509%	5.00%	10.00%	0.00%	14.01%
1.3	36864	10.509%	5.00%	10.00%	50.00%	13.71%
1.3	36864	10.509%	5.00%	10.00%	100.00%	13.41%
1.3	36864	10.509%	5.00%	20.00%	0.00%	4.53%
1.3	36864	10.509%	5.00%	20.00%	50.00%	4.23%
1.3	36864	10.509%	5.00%	20.00%	100.00%	3.93%
1.3	36864	10.509%	10.00%	0.00%	0.00%	20.44%
1.3	36864	10.509%	10.00%	0.00%	50.00%	20.14%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.3	36864	10.509%	10.00%	0.00%	100.00%	19.84%
1.3	36864	10.509%	10.00%	10.00%	0.00%	10.96%
1.3	36864	10.509%	10.00%	10.00%	50.00%	10.66%
1.3	36864	10.509%	10.00%	10.00%	100.00%	10.36%
1.3	36864	10.509%	10.00%	20.00%	0.00%	1.48%
1.3	36864	10.509%	10.00%	20.00%	50.00%	1.18%
1.3	36864	10.509%	10.00%	20.00%	100.00%	0.88%
1.3	61440	10.644%	0.00%	0.00%	0.00%	32.39%
1.3	61440	10.644%	0.00%	0.00%	50.00%	32.09%
1.3	61440	10.644%	0.00%	0.00%	100.00%	31.79%
1.3	61440	10.644%	0.00%	10.00%	0.00%	22.91%
1.3	61440	10.644%	0.00%	10.00%	50.00%	22.61%
1.3	61440	10.644%	0.00%	10.00%	100.00%	22.31%
1.3	61440	10.644%	0.00%	20.00%	0.00%	13.43%
1.3	61440	10.644%	0.00%	20.00%	50.00%	13.13%
1.3	61440	10.644%	0.00%	20.00%	100.00%	12.83%
1.3	61440	10.644%	5.00%	0.00%	0.00%	29.34%
1.3	61440	10.644%	5.00%	0.00%	50.00%	29.04%
1.3	61440	10.644%	5.00%	0.00%	100.00%	28.74%
1.3	61440	10.644%	5.00%	10.00%	0.00%	19.86%
1.3	61440	10.644%	5.00%	10.00%	50.00%	19.56%
1.3	61440	10.644%	5.00%	10.00%	100.00%	19.26%
1.3	61440	10.644%	5.00%	20.00%	0.00%	10.38%
1.3	61440	10.644%	5.00%	20.00%	50.00%	10.08%
1.3	61440	10.644%	5.00%	20.00%	100.00%	9.78%
1.3	61440	10.644%	10.00%	0.00%	0.00%	26.29%
1.3	61440	10.644%	10.00%	0.00%	50.00%	25.99%
1.3	61440	10.644%	10.00%	0.00%	100.00%	25.69%
1.3	61440	10.644%	10.00%	10.00%	0.00%	16.81%
1.3	61440	10.644%	10.00%	10.00%	50.00%	16.51%
1.3	61440	10.644%	10.00%	10.00%	100.00%	16.21%
1.3	61440	10.644%	10.00%	20.00%	0.00%	7.33%
1.3	61440	10.644%	10.00%	20.00%	50.00%	7.03%
1.3	61440	10.644%	10.00%	20.00%	100.00%	6.73%

Table A-14. Results for Airlines analysis scenarios with B/C equal to 1.3.

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.5	24576	11.762%	0.00%	0.00%	0.00%	27.25%
1.5	24576	11.762%	0.00%	0.00%	50.00%	27.05%
1.5	24576	11.762%	0.00%	0.00%	100.00%	26.85%
1.5	24576	11.762%	0.00%	10.00%	0.00%	17.75%
1.5	24576	11.762%	0.00%	10.00%	50.00%	17.55%
1.5	24576	11.762%	0.00%	10.00%	100.00%	17.35%
1.5	24576	11.762%	0.00%	20.00%	0.00%	8.25%
1.5	24576	11.762%	0.00%	20.00%	50.00%	8.05%
1.5	24576	11.762%	0.00%	20.00%	100.00%	7.85%
1.5	24576	11.762%	5.00%	0.00%	0.00%	24.21%
1.5	24576	11.762%	5.00%	0.00%	50.00%	24.01%
1.5	24576	11.762%	5.00%	0.00%	100.00%	23.81%
1.5	24576	11.762%	5.00%	10.00%	0.00%	14.71%
1.5	24576	11.762%	5.00%	10.00%	50.00%	14.51%
1.5	24576	11.762%	5.00%	10.00%	100.00%	14.31%
1.5	24576	11.762%	5.00%	20.00%	0.00%	5.21%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.5	24576	11.762%	5.00%	20.00%	50.00%	5.01%
1.5	24576	11.762%	5.00%	20.00%	100.00%	4.81%
1.5	24576	11.762%	10.00%	0.00%	0.00%	21.17%
1.5	24576	11.762%	10.00%	0.00%	50.00%	20.97%
1.5	24576	11.762%	10.00%	0.00%	100.00%	20.77%
1.5	24576	11.762%	10.00%	10.00%	0.00%	11.67%
1.5	24576	11.762%	10.00%	10.00%	50.00%	11.47%
1.5	24576	11.762%	10.00%	10.00%	100.00%	11.27%
1.5	24576	11.762%	10.00%	20.00%	0.00%	2.17%
1.5	24576	11.762%	10.00%	20.00%	50.00%	1.97%
1.5	24576	11.762%	10.00%	20.00%	100.00%	1.77%
1.5	49152	11.987%	0.00%	0.00%	0.00%	33.98%
1.5	49152	11.987%	0.00%	0.00%	50.00%	33.78%
1.5	49152	11.987%	0.00%	0.00%	100.00%	33.58%
1.5	49152	11.987%	0.00%	10.00%	0.00%	24.48%
1.5	49152	11.987%	0.00%	10.00%	50.00%	24.28%
1.5	49152	11.987%	0.00%	10.00%	100.00%	24.08%
1.5	49152	11.987%	0.00%	20.00%	0.00%	14.98%
1.5	49152	11.987%	0.00%	20.00%	50.00%	14.78%
1.5	49152	11.987%	0.00%	20.00%	100.00%	14.58%
1.5	49152	11.987%	5.00%	0.00%	0.00%	30.94%
1.5	49152	11.987%	5.00%	0.00%	50.00%	30.74%
1.5	49152	11.987%	5.00%	0.00%	100.00%	30.54%
1.5	49152	11.987%	5.00%	10.00%	0.00%	21.44%
1.5	49152	11.987%	5.00%	10.00%	50.00%	21.24%
1.5	49152	11.987%	5.00%	10.00%	100.00%	21.04%
1.5	49152	11.987%	5.00%	20.00%	0.00%	11.94%
1.5	49152	11.987%	5.00%	20.00%	50.00%	11.74%
1.5	49152	11.987%	5.00%	20.00%	100.00%	11.54%
1.5	49152	11.987%	10.00%	0.00%	0.00%	27.90%
1.5	49152	11.987%	10.00%	0.00%	50.00%	27.70%
1.5	49152	11.987%	10.00%	0.00%	100.00%	27.50%
1.5	49152	11.987%	10.00%	10.00%	0.00%	18.40%
1.5	49152	11.987%	10.00%	10.00%	50.00%	18.20%
1.5	49152	11.987%	10.00%	10.00%	100.00%	18.00%
1.5	49152	11.987%	10.00%	20.00%	0.00%	8.90%
1.5	49152	11.987%	10.00%	20.00%	50.00%	8.70%
1.5	49152	11.987%	10.00%	20.00%	100.00%	8.50%
1.5	73728	12.174%	0.00%	0.00%	0.00%	40.71%
1.5	73728	12.174%	0.00%	0.00%	50.00%	40.51%
1.5	73728	12.174%	0.00%	0.00%	100.00%	40.31%
1.5	73728	12.174%	0.00%	10.00%	0.00%	31.21%
1.5	73728	12.174%	0.00%	10.00%	50.00%	31.01%
1.5	73728	12.174%	0.00%	10.00%	100.00%	30.81%
1.5	73728	12.174%	0.00%	20.00%	0.00%	21.71%
1.5	73728	12.174%	0.00%	20.00%	50.00%	21.51%
1.5	73728	12.174%	0.00%	20.00%	100.00%	21.31%
1.5	73728	12.174%	5.00%	0.00%	0.00%	37.67%
1.5	73728	12.174%	5.00%	0.00%	50.00%	37.47%
1.5	73728	12.174%	5.00%	0.00%	100.00%	37.27%
1.5	73728	12.174%	5.00%	10.00%	0.00%	28.17%
1.5	73728	12.174%	5.00%	10.00%	50.00%	27.97%
1.5	73728	12.174%	5.00%	10.00%	100.00%	27.77%
1.5	73728	12.174%	5.00%	20.00%	0.00%	18.67%
1.5	73728	12.174%	5.00%	20.00%	50.00%	18.47%
1.5	73728	12.174%	5.00%	20.00%	100.00%	18.27%
1.5	73728	12.174%	10.00%	0.00%	0.00%	34.63%
1.5	73728	12.174%	10.00%	0.00%	50.00%	34.43%
1.5	73728	12.174%	10.00%	0.00%	100.00%	34.23%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.5	73728	12.174%	10.00%	10.00%	0.00%	25.13%
1.5	73728	12.174%	10.00%	10.00%	50.00%	24.93%
1.5	73728	12.174%	10.00%	10.00%	100.00%	24.73%
1.5	73728	12.174%	10.00%	20.00%	0.00%	15.63%
1.5	73728	12.174%	10.00%	20.00%	50.00%	15.43%
1.5	73728	12.174%	10.00%	20.00%	100.00%	15.23%
1.5	36864	11.880%	0.00%	0.00%	0.00%	30.62%
1.5	36864	11.880%	0.00%	0.00%	50.00%	30.42%
1.5	36864	11.880%	0.00%	0.00%	100.00%	30.22%
1.5	36864	11.880%	0.00%	10.00%	0.00%	21.12%
1.5	36864	11.880%	0.00%	10.00%	50.00%	20.92%
1.5	36864	11.880%	0.00%	10.00%	100.00%	20.72%
1.5	36864	11.880%	0.00%	20.00%	0.00%	11.62%
1.5	36864	11.880%	0.00%	20.00%	50.00%	11.42%
1.5	36864	11.880%	0.00%	20.00%	100.00%	11.22%
1.5	36864	11.880%	5.00%	0.00%	0.00%	27.58%
1.5	36864	11.880%	5.00%	0.00%	50.00%	27.38%
1.5	36864	11.880%	5.00%	0.00%	100.00%	27.18%
1.5	36864	11.880%	5.00%	10.00%	0.00%	18.08%
1.5	36864	11.880%	5.00%	10.00%	50.00%	17.88%
1.5	36864	11.880%	5.00%	10.00%	100.00%	17.68%
1.5	36864	11.880%	5.00%	20.00%	0.00%	8.58%
1.5	36864	11.880%	5.00%	20.00%	50.00%	8.38%
1.5	36864	11.880%	5.00%	20.00%	100.00%	8.18%
1.5	36864	11.880%	10.00%	0.00%	0.00%	24.54%
1.5	36864	11.880%	10.00%	0.00%	50.00%	24.34%
1.5	36864	11.880%	10.00%	0.00%	100.00%	24.14%
1.5	36864	11.880%	10.00%	10.00%	0.00%	15.04%
1.5	36864	11.880%	10.00%	10.00%	50.00%	14.84%
1.5	36864	11.880%	10.00%	10.00%	100.00%	14.64%
1.5	36864	11.880%	10.00%	20.00%	0.00%	5.54%
1.5	36864	11.880%	10.00%	20.00%	50.00%	5.34%
1.5	36864	11.880%	10.00%	20.00%	100.00%	5.14%
1.5	61440	12.084%	0.00%	0.00%	0.00%	37.35%
1.5	61440	12.084%	0.00%	0.00%	50.00%	37.15%
1.5	61440	12.084%	0.00%	0.00%	100.00%	36.95%
1.5	61440	12.084%	0.00%	10.00%	0.00%	27.85%
1.5	61440	12.084%	0.00%	10.00%	50.00%	27.65%
1.5	61440	12.084%	0.00%	10.00%	100.00%	27.45%
1.5	61440	12.084%	0.00%	20.00%	0.00%	18.35%
1.5	61440	12.084%	0.00%	20.00%	50.00%	18.15%
1.5	61440	12.084%	0.00%	20.00%	100.00%	17.95%
1.5	61440	12.084%	5.00%	0.00%	0.00%	34.31%
1.5	61440	12.084%	5.00%	0.00%	50.00%	34.11%
1.5	61440	12.084%	5.00%	0.00%	100.00%	33.91%
1.5	61440	12.084%	5.00%	10.00%	0.00%	24.81%
1.5	61440	12.084%	5.00%	10.00%	50.00%	24.61%
1.5	61440	12.084%	5.00%	10.00%	100.00%	24.41%
1.5	61440	12.084%	5.00%	20.00%	0.00%	15.31%
1.5	61440	12.084%	5.00%	20.00%	50.00%	15.11%
1.5	61440	12.084%	5.00%	20.00%	100.00%	14.91%
1.5	61440	12.084%	10.00%	0.00%	0.00%	31.27%
1.5	61440	12.084%	10.00%	0.00%	50.00%	31.07%
1.5	61440	12.084%	10.00%	0.00%	100.00%	30.87%
1.5	61440	12.084%	10.00%	10.00%	0.00%	21.77%
1.5	61440	12.084%	10.00%	10.00%	50.00%	21.57%
1.5	61440	12.084%	10.00%	10.00%	100.00%	21.37%
1.5	61440	12.084%	10.00%	20.00%	0.00%	12.27%
1.5	61440	12.084%	10.00%	20.00%	50.00%	12.07%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
1.5	61440	12.084%	10.00%	20.00%	100.00%	11.87%

Table A-15. Results for Airlines analysis scenarios with B/C equal to 1.5.

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
2	24576	14.453%	0.00%	0.00%	0.00%	36.33%
2	24576	14.453%	0.00%	0.00%	50.00%	36.03%
2	24576	14.453%	0.00%	0.00%	100.00%	35.73%
2	24576	14.453%	0.00%	10.00%	0.00%	26.83%
2	24576	14.453%	0.00%	10.00%	50.00%	26.53%
2	24576	14.453%	0.00%	10.00%	100.00%	26.23%
2	24576	14.453%	0.00%	20.00%	0.00%	17.33%
2	24576	14.453%	0.00%	20.00%	50.00%	17.03%
2	24576	14.453%	0.00%	20.00%	100.00%	16.73%
2	24576	14.453%	5.00%	0.00%	0.00%	33.29%
2	24576	14.453%	5.00%	0.00%	50.00%	32.99%
2	24576	14.453%	5.00%	0.00%	100.00%	32.69%
2	24576	14.453%	5.00%	10.00%	0.00%	23.79%
2	24576	14.453%	5.00%	10.00%	50.00%	23.49%
2	24576	14.453%	5.00%	10.00%	100.00%	23.19%
2	24576	14.453%	5.00%	20.00%	0.00%	14.29%
2	24576	14.453%	5.00%	20.00%	50.00%	13.99%
2	24576	14.453%	5.00%	20.00%	100.00%	13.69%
2	24576	14.453%	10.00%	0.00%	0.00%	30.25%
2	24576	14.453%	10.00%	0.00%	50.00%	29.95%
2	24576	14.453%	10.00%	0.00%	100.00%	29.65%
2	24576	14.453%	10.00%	10.00%	0.00%	20.75%
2	24576	14.453%	10.00%	10.00%	50.00%	20.45%
2	24576	14.453%	10.00%	10.00%	100.00%	20.15%
2	24576	14.453%	10.00%	20.00%	0.00%	11.25%
2	24576	14.453%	10.00%	20.00%	50.00%	10.95%
2	24576	14.453%	10.00%	20.00%	100.00%	10.65%
2	49152	14.823%	0.00%	0.00%	0.00%	45.32%
2	49152	14.823%	0.00%	0.00%	50.00%	45.02%
2	49152	14.823%	0.00%	0.00%	100.00%	44.72%
2	49152	14.823%	0.00%	10.00%	0.00%	35.82%
2	49152	14.823%	0.00%	10.00%	50.00%	35.52%
2	49152	14.823%	0.00%	10.00%	100.00%	35.22%
2	49152	14.823%	0.00%	20.00%	0.00%	26.32%
2	49152	14.823%	0.00%	20.00%	50.00%	26.02%
2	49152	14.823%	0.00%	20.00%	100.00%	25.72%
2	49152	14.823%	5.00%	0.00%	0.00%	42.28%
2	49152	14.823%	5.00%	0.00%	50.00%	41.98%
2	49152	14.823%	5.00%	0.00%	100.00%	41.68%
2	49152	14.823%	5.00%	10.00%	0.00%	32.78%
2	49152	14.823%	5.00%	10.00%	50.00%	32.48%
2	49152	14.823%	5.00%	10.00%	100.00%	32.18%
2	49152	14.823%	5.00%	20.00%	0.00%	23.28%
2	49152	14.823%	5.00%	20.00%	50.00%	22.98%
2	49152	14.823%	5.00%	20.00%	100.00%	22.68%
2	49152	14.823%	10.00%	0.00%	0.00%	39.24%
2	49152	14.823%	10.00%	0.00%	50.00%	38.94%
2	49152	14.823%	10.00%	0.00%	100.00%	38.64%
2	49152	14.823%	10.00%	10.00%	0.00%	29.74%
2	49152	14.823%	10.00%	10.00%	50.00%	29.44%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
2	49152	14.823%	10.00%	10.00%	100.00%	29.14%
2	49152	14.823%	10.00%	20.00%	0.00%	20.24%
2	49152	14.823%	10.00%	20.00%	50.00%	19.94%
2	49152	14.823%	10.00%	20.00%	100.00%	19.64%
2	73728	15.134%	0.00%	0.00%	0.00%	54.31%
2	73728	15.134%	0.00%	0.00%	50.00%	54.01%
2	73728	15.134%	0.00%	0.00%	100.00%	53.71%
2	73728	15.134%	0.00%	10.00%	0.00%	44.81%
2	73728	15.134%	0.00%	10.00%	50.00%	44.51%
2	73728	15.134%	0.00%	10.00%	100.00%	44.21%
2	73728	15.134%	0.00%	20.00%	0.00%	35.31%
2	73728	15.134%	0.00%	20.00%	50.00%	35.01%
2	73728	15.134%	0.00%	20.00%	100.00%	34.71%
2	73728	15.134%	5.00%	0.00%	0.00%	51.27%
2	73728	15.134%	5.00%	0.00%	50.00%	50.97%
2	73728	15.134%	5.00%	0.00%	100.00%	50.67%
2	73728	15.134%	5.00%	10.00%	0.00%	41.77%
2	73728	15.134%	5.00%	10.00%	50.00%	41.47%
2	73728	15.134%	5.00%	10.00%	100.00%	41.17%
2	73728	15.134%	5.00%	20.00%	0.00%	32.27%
2	73728	15.134%	5.00%	20.00%	50.00%	31.97%
2	73728	15.134%	5.00%	20.00%	100.00%	31.67%
2	73728	15.134%	10.00%	0.00%	0.00%	48.23%
2	73728	15.134%	10.00%	0.00%	50.00%	47.93%
2	73728	15.134%	10.00%	0.00%	100.00%	47.63%
2	73728	15.134%	10.00%	10.00%	0.00%	38.73%
2	73728	15.134%	10.00%	10.00%	50.00%	38.43%
2	73728	15.134%	10.00%	10.00%	100.00%	38.13%
2	73728	15.134%	10.00%	20.00%	0.00%	29.23%
2	73728	15.134%	10.00%	20.00%	50.00%	28.93%
2	73728	15.134%	10.00%	20.00%	100.00%	28.63%
2	36864	14.647%	0.00%	0.00%	0.00%	40.83%
2	36864	14.647%	0.00%	0.00%	50.00%	40.53%
2	36864	14.647%	0.00%	0.00%	100.00%	40.23%
2	36864	14.647%	0.00%	10.00%	0.00%	31.33%
2	36864	14.647%	0.00%	10.00%	50.00%	31.03%
2	36864	14.647%	0.00%	10.00%	100.00%	30.73%
2	36864	14.647%	0.00%	20.00%	0.00%	21.83%
2	36864	14.647%	0.00%	20.00%	50.00%	21.53%
2	36864	14.647%	0.00%	20.00%	100.00%	21.23%
2	36864	14.647%	5.00%	0.00%	0.00%	37.79%
2	36864	14.647%	5.00%	0.00%	50.00%	37.49%
2	36864	14.647%	5.00%	0.00%	100.00%	37.19%
2	36864	14.647%	5.00%	10.00%	0.00%	28.29%
2	36864	14.647%	5.00%	10.00%	50.00%	27.99%
2	36864	14.647%	5.00%	10.00%	100.00%	27.69%
2	36864	14.647%	5.00%	20.00%	0.00%	18.79%
2	36864	14.647%	5.00%	20.00%	50.00%	18.49%
2	36864	14.647%	5.00%	20.00%	100.00%	18.19%
2	36864	14.647%	10.00%	0.00%	0.00%	34.75%
2	36864	14.647%	10.00%	0.00%	50.00%	34.45%
2	36864	14.647%	10.00%	0.00%	100.00%	34.15%
2	36864	14.647%	10.00%	10.00%	0.00%	25.25%
2	36864	14.647%	10.00%	10.00%	50.00%	24.95%
2	36864	14.647%	10.00%	10.00%	100.00%	24.65%
2	36864	14.647%	10.00%	20.00%	0.00%	15.75%
2	36864	14.647%	10.00%	20.00%	50.00%	15.45%
2	36864	14.647%	10.00%	20.00%	100.00%	15.15%
2	61440	14.985%	0.00%	0.00%	0.00%	49.82%
2	61440	14.985%	0.00%	0.00%	50.00%	49.52%

Input Values		Results				
B/C	Forward-Fit Cost (€)	IRR	% Reduction ATFM Delay	Horizontal Flight Efficiency Gain (%)	Vertical Flight Efficiency Gain (%)	% Reduction en-route charges
2	61440	14.985%	0.00%	0.00%	100.00%	49.22%
2	61440	14.985%	0.00%	10.00%	0.00%	40.32%
2	61440	14.985%	0.00%	10.00%	50.00%	40.02%
2	61440	14.985%	0.00%	10.00%	100.00%	39.72%
2	61440	14.985%	0.00%	20.00%	0.00%	30.82%
2	61440	14.985%	0.00%	20.00%	50.00%	30.52%
2	61440	14.985%	0.00%	20.00%	100.00%	30.22%
2	61440	14.985%	5.00%	0.00%	0.00%	46.78%
2	61440	14.985%	5.00%	0.00%	50.00%	46.48%
2	61440	14.985%	5.00%	0.00%	100.00%	46.18%
2	61440	14.985%	5.00%	10.00%	0.00%	37.28%
2	61440	14.985%	5.00%	10.00%	50.00%	36.98%
2	61440	14.985%	5.00%	10.00%	100.00%	36.68%
2	61440	14.985%	5.00%	20.00%	0.00%	27.78%
2	61440	14.985%	5.00%	20.00%	50.00%	27.48%
2	61440	14.985%	5.00%	20.00%	100.00%	27.18%
2	61440	14.985%	10.00%	0.00%	0.00%	43.74%
2	61440	14.985%	10.00%	0.00%	50.00%	43.44%
2	61440	14.985%	10.00%	0.00%	100.00%	43.14%
2	61440	14.985%	10.00%	10.00%	0.00%	34.24%
2	61440	14.985%	10.00%	10.00%	50.00%	33.94%
2	61440	14.985%	10.00%	10.00%	100.00%	33.64%
2	61440	14.985%	10.00%	20.00%	0.00%	24.74%
2	61440	14.985%	10.00%	20.00%	50.00%	24.44%
2	61440	14.985%	10.00%	20.00%	100.00%	24.14%

Table A-16. Results for Airlines analysis scenarios with B/C equal to 2.

APPENDIX IV

RESULTS FROM ANSPs ANALYSIS SCENARIOS

Input Values			Results
B/C	% En-route Staff Cost Reduction	% Operating Cost Reduction	ANSPs One-off Implementation Cost (in M€)
1	5%	0%	1069.90
1	10%	0%	2139.39
1	15%	0%	3208.88
1	20%	0%	4278.37
1	25%	0%	5347.86
1	30%	0%	6417.35
1	35%	0%	7486.84
1	40%	0%	8556.33
1	45%	0%	9625.82
1	50%	0%	10695.31
1	55%	0%	11764.80
1	60%	0%	12834.29
1	65%	0%	13903.78
1	70%	0%	14973.27
1	5%	5%	1368.16
1	10%	5%	2437.65
1	15%	5%	3507.14
1	20%	5%	4576.63
1	25%	5%	5646.12
1	30%	5%	6715.61
1	35%	5%	7785.10
1	40%	5%	8854.59
1	45%	5%	9924.08
1	50%	5%	10993.57
1	55%	5%	12063.06
1	60%	5%	13132.55
1	65%	5%	14202.04
1	70%	5%	15271.53

Table A-17. Results from the application of the CBA for the ANSPs analysis scenarios where B/C ratio is equal to 1.

Input Values			Results
B/C	% En-route Staff Cost Reduction	% Operating Cost Reduction	ANSPs One-off Implementation Cost (in M€)
1.1	5%	0%	972.63
1.1	10%	0%	1945.27
1.1	15%	0%	2917.90
1.1	20%	0%	3890.54
1.1	25%	0%	4863.17
1.1	30%	0%	5835.81
1.1	35%	0%	6808.44
1.1	40%	0%	7781.08
1.1	45%	0%	8753.71
1.1	50%	0%	9726.35
1.1	55%	0%	10698.98
1.1	60%	0%	11671.62
1.1	65%	0%	12644.25
1.1	70%	0%	13616.89
1.1	5%	5%	1243.60
1.1	10%	5%	2216.23

1.1	15%	5%	3188.87
1.1	20%	5%	4161.50
1.1	25%	5%	5134.14
1.1	30%	5%	6106.77
1.1	35%	5%	7079.41
1.1	40%	5%	8052.04
1.1	45%	5%	9024.68
1.1	50%	5%	9997.31
1.1	55%	5%	10969.95
1.1	60%	5%	11942.58
1.1	65%	5%	12915.22
1.1	70%	5%	13887.85

Table A-18. Results from the application of the CBA for the ANSPs analysis scenarios where B/C ratio is equal to 1.1.

Input Values			Results
B/C	**% En-route Staff Cost Reduction**	**% Operating Cost Reduction**	**ANSPs One-off Implementation Cost (in M€)**
1.2	5%	0%	891.58
1.2	10%	0%	1783.15
1.2	15%	0%	2674.72
1.2	20%	0%	3566.29
1.2	25%	0%	4457.86
1.2	30%	0%	5349.43
1.2	35%	0%	6241.00
1.2	40%	0%	7132.57
1.2	45%	0%	8024.14
1.2	50%	0%	8915.71
1.2	55%	0%	9807.28
1.2	60%	0%	10698.85
1.2	65%	0%	11590.42
1.2	70%	0%	12481.99
1.2	5%	5%	1139.98
1.2	10%	5%	2031.55
1.2	15%	5%	2923.12
1.2	20%	5%	3814.69
1.2	25%	5%	4706.26
1.2	30%	5%	5597.83
1.2	35%	5%	6489.40
1.2	40%	5%	7380.97
1.2	45%	5%	8272.54
1.2	50%	5%	9164.11
1.2	55%	5%	10055.68
1.2	60%	5%	10947.25
1.2	65%	5%	11838.82
1.2	70%	5%	12730.39

Table A-19. Results from the application of the CBA for the ANSPs analysis scenarios where B/C ratio is equal to 1.2.

Input Values			Results
B/C	**% En-route Staff Cost Reduction**	**% Operating Cost Reduction**	**ANSPs One-off Implementation Cost (in M€)**
1.3	5%	0%	822.99
1.3	10%	0%	1645.99

1.3	15%	0%	2468.98
1.3	20%	0%	3291.98
1.3	25%	0%	4114.97
1.3	30%	0%	4937.97
1.3	35%	0%	5760.96
1.3	40%	0%	6583.96
1.3	45%	0%	7406.95
1.3	50%	0%	8229.95
1.3	55%	0%	9052.94
1.3	60%	0%	9875.94
1.3	65%	0%	10698.93
1.3	70%	0%	11521.93
1.3	5%	5%	1052.28
1.3	10%	5%	1875.27
1.3	15%	5%	2698.27
1.3	20%	5%	3521.26
1.3	25%	5%	4344.26
1.3	30%	5%	5167.25
1.3	35%	5%	5990.25
1.3	40%	5%	6813.24
1.3	45%	5%	7636.24
1.3	50%	5%	8459.23
1.3	55%	5%	9282.23
1.3	60%	5%	10105.22
1.3	65%	5%	10928.22
1.3	70%	5%	11751.21

Table A-20. Results from the application of the CBA for the ANSPs analysis scenarios where B/C ratio is equal to 1.3.

Input Values			Results
B/C	**% En-route Staff Cost Reduction**	**% Operating Cost Reduction**	**ANSPs One-off Implementation Cost (in M€)**
1.5	5%	0%	713.26
1.5	10%	0%	1426.52
1.5	15%	0%	2139.78
1.5	20%	0%	2853.04
1.5	25%	0%	3566.30
1.5	30%	0%	4279.56
1.5	35%	0%	4992.82
1.5	40%	0%	5706.08
1.5	45%	0%	6419.34
1.5	50%	0%	7132.60
1.5	55%	0%	7845.86
1.5	60%	0%	8559.12
1.5	65%	0%	9272.38
1.5	70%	0%	9985.64
1.5	5%	5%	911.98
1.5	10%	5%	1625.24
1.5	15%	5%	2338.50
1.5	20%	5%	3051.76
1.5	25%	5%	3765.02
1.5	30%	5%	4478.28
1.5	35%	5%	5191.54
1.5	40%	5%	5904.80
1.5	45%	5%	6618.06
1.5	50%	5%	7331.32

1.5	55%	5%	8044.58
1.5	60%	5%	8757.84
1.5	65%	5%	9471.10
1.5	70%	5%	10184.36

Table A-21. Results from the application of the CBA for the ANSPs analysis scenarios where B/C ratio is equal to 1.5.

Input Values			Results
B/C	**% En-route Staff Cost Reduction**	**% Operating Cost Reduction**	**ANSPs One-off Implementation Cost (in M€)**
2	5%	0%	534.94
2	10%	0%	1069.89
2	15%	0%	1604.83
2	20%	0%	2139.78
2	25%	0%	2674.72
2	30%	0%	3209.67
2	35%	0%	3744.61
2	40%	0%	4279.56
2	45%	0%	4814.50
2	50%	0%	5349.45
2	55%	0%	5884.39
2	60%	0%	6419.34
2	65%	0%	6954.28
2	70%	0%	7489.23
2	5%	5%	683.99
2	10%	5%	1218.93
2	15%	5%	1753.88
2	20%	5%	2288.82
2	25%	5%	2823.77
2	30%	5%	3358.71
2	35%	5%	3893.66
2	40%	5%	4428.60
2	45%	5%	4963.55
2	50%	5%	5498.49
2	55%	5%	6033.44
2	60%	5%	6568.38
2	65%	5%	7103.33
2	70%	5%	7638.27

Table A-22. Results from the application of the CBA for the ANSPs analysis scenarios where B/C ratio is equal to 2.