Project no. TREN/07/FP6AE/S07.71574/037180 IFLY

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

iFly Deliverable D6.1
Methodological Framework for Cost-Benefit Analysis

Konstatinos Zografos
Konstantinos Androutsopoulos

AUEB-RC/TRANSLOG

Start date of project: 22 May 2007

Version: 0.3

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

DOCUMENT CONTROL SHEET

Title of document:	*Methodological Framework for Cost Effectiveness Analysis*
Authors of document:	*AUEB-RC/TRANSLOG*
Deliverable number:	*D6.1*
Project acronym:	*iFly*
Project title:	*Safety, Complexity and Responsibility based design and validation of highly automated Air Traffic Management*
Project no.:	*TREN/07/FP6AE/S07.71574/037180 IFLY*
Instrument:	*Specific Targeted Research Projects (STREP)*
Thematic Priority:	*1.3.1.4.g Aeronautics and Space*

DOCUMENT CHANGE LOG

Version #	Issue Date	Sections affected	Relevant information
0.1	26/09/07	-	First Draft
0.2	13/05/08	Section 3 Section 5 Section 6	Revise A^3 overview based on D1.3 Relation of iFly CBA methodology with SESAR, EMOSIA, and iFly Deliverable D10.1i Revision of tables of cost and benefit variables based on comments from ISDEFE, NLR, and EEC.
0.3	28/01/09	Sections 1-6	Minor changes based on additional comments received by NLR. Updated time plan according to the revised project schedule.

Version 1.0		Organisation	Signature/Date
Authors	Konstatinos Zografos Konstantinos Androutsopoulos	AUEB-RC/ TRANSLOG	
Internal reviewers	Henk Blom	NLR	
	Giorgos Chaloulos	ETZH	
	Bernard Lacroix	EEC	
External reviewers			

TABLE OF CONTENTS

1 Introduction

1.1 Background and Objectives of the Document

The development of the A^3 (Autonomous Aircraft Advanced) operational concept aims to provide a solution to the efficient management of the expected radical increase of air traffic during the forthcoming years. A necessary prerequisite for the practical implementation of the new Air Traffic Management (ATM) operational concept is the assessment of its potential positive (benefits) and negative (costs) impacts. The introduction of the A^3 operational concept is expected to generate positive and negative impacts to various stakeholders involved in and/or affected by the ATM operations, thus it is essential to consider the goals and priorities of all affected parties (e.g. Airlines, Air Navigation Service providers, etc.) in the evaluation process. Moreover, given the organizational complexities arising from the participation of multiple stakeholders in the ATM system, it is important to study the institutional and organizational issues associated with the implementation of the A^3 concept as well as to identify appropriate recommendations for the efficient and effective implementation of the proposed concept.

In this context, the objective of WP6 is to validate the economic feasibility of the A^3 operational concept [1]. This objective is achieved through a cost-benefit analysis study for assessing the associated investment and the operational impacts produced by the transition of the ATM system from its current situation to the A^3 operational concept, including several operational, technological, organizational, and institutional changes. The proposed work for achieving the above goals is divided into the following sub-WPs: i) WP6.1 Development of a methodological framework for cost-effectiveness analysis, ii) WP6.2 Institutional and Organizational analysis for the implementation of the autonomous aircraft operations, iii) WP6.3 Data collection for cost-effectiveness analysis, iv) WP6.4 Cost effectiveness analysis and results assessment.

This document presents the methodological framework for performing the abovementioned cost-benefit analysis. In particular, the present document aims to provide the major methodological steps for the comparative assessment of the current (baseline) ATM situation with the ATM under the A^3 concept in terms of costs and benefits, including the methods for estimating the costs and benefits indicators, and the workplan and schedule for performing the associated tasks. The proposed methodology covers also the assessment of the impacts of the introduction of A^3 concept on the ATM institutional and organizational framework. However, more details on this issue will be provided in a separate deliverable of the project (i.e., D6.2: Institutional and Organizational analysis for the implementation of the autonomous aircraft operations).

It should be stressed that the assessment of the various types of operational impacts, e.g., on capacity, workload, etc., should be quantified on the basis of alternative analysis scenarios.

The development of the cost-benefit analysis scenarios is based on critical input received by other WPs within iFly. Thus, substantial input is received from WP1 related to the A^3 operational concept description provided through the reports D1.1 “A3 High Level ConOps” [2], D1.2 “A^3 Airline Strategy Concept”[3] and D1.3 “A^3 ConOps” [4].. Finally, the proposed methodology has been validated in terms of being in alignment with the generic validation framework within iFly, presented in D10.1i [6].

1.2 Organisation of report

The remainder of this report consists of ten sections. Section two presents the overall methodology for achieving the goals of WP6. Section three is devoted to the presentation of an overview of the A^3 operational concept while section four provides relevant cost-benefit analysis studies for ATM improvements. Section five presents the major methodological steps of the cost-benefit analysis for assessing the A^3 operational concept while sections six, seven and eight present the relevant parameters, cost, and benefit variables respectively. Section nine provides the high level experimental design for measuring the cost and benefit variables while section ten presents the management plan for achieving the goals of the proposed cost-benefit analysis. Finally section eleven provides concluding remarks regarding the work presented in this report.

2 Overall Methodology

The assessment of the potential economic, institutional, and organizational impacts emerging from the introduction of the A^3 Operational Concept to the ATM may be achieved through the following major activities:

- Estimation of the potential positive (benefits) and negative (costs) impacts of the A^3 Operational Concept
- Identification of the Institutional and Organizational barriers and enablers for the effective implementation of the A^3 Concept
- Assessment of the performance of the A^3 Operational Concept in terms of cost-benefit analysis
- Determination of recommendations for potential institutional/organizational changes in the existing ATM framework in order to facilitate the implementation of the A3 operational concept.

The ATM system involves a set of operations that aim at the safe and efficient planning and management of the air traffic. The ATM stakeholders, the relevant institutional and organizational framework and the operational and technological issues constitute the critical factors that affect the performance of the ATM system. Thus a preliminary feasibility study for the introduction of A^3 concept in the ATM system should include the investigation of: i) the investment on new technologies and operational procedures required by the involved stakeholders, ii) the potential operational improvements and the associated benefits for the involved stakeholders, and iii) the impacts on the prevailing institutional and organizational framework. Concerning the impacts of A^3 operational concept on the safety of ATM, they are studied separately at WP7 of iFly project. Figure 1 presents the scope of the A^3 operational concept assessment within the study in WP6.

In particular, the analysis of the impacts on the institutional and organizational framework aims at the determination of the enablers and barriers encountered for the implementation of the A^3 concept. This target will be achieved by the assessment of the compatibility of the proposed operational A^3 concept with the existing regulations and stakeholders' responsibilities. This task involves the following activities: i) determination of the operations of the ATM system and the associated stakeholders which are affected by the implementation of the A^3 concept, ii) comparative assessment of the new vs. the existing role (tasks, responsibilities and interactions) of the involved stakeholders, and iii) identification of conflicts with the existing institutional and organizational framework. The analysis described above will be based on the outcome of WP1 and WP2 referring to the changes of the current responsibilities of the involved ATM stakeholders due to the introduction of the A^3 concept. Based on this analysis, a set of recommendations will emerge referring to the institutional and organizational issues that should be reviewed in order to facilitate the implementation of the A^3 concept.

On the other hand the validation of the proposed operational concept in terms of economic sustainability, involves the assessment of the operational performance of the new ATM system in terms of costs and benefits. The objective of the proposed cost-benefit analysis is to explore if the expected operational improvements of the ATM performance due to the introduction of the A^3 concept overrun the associated costs of implementing, operating and maintaining the relevant system.

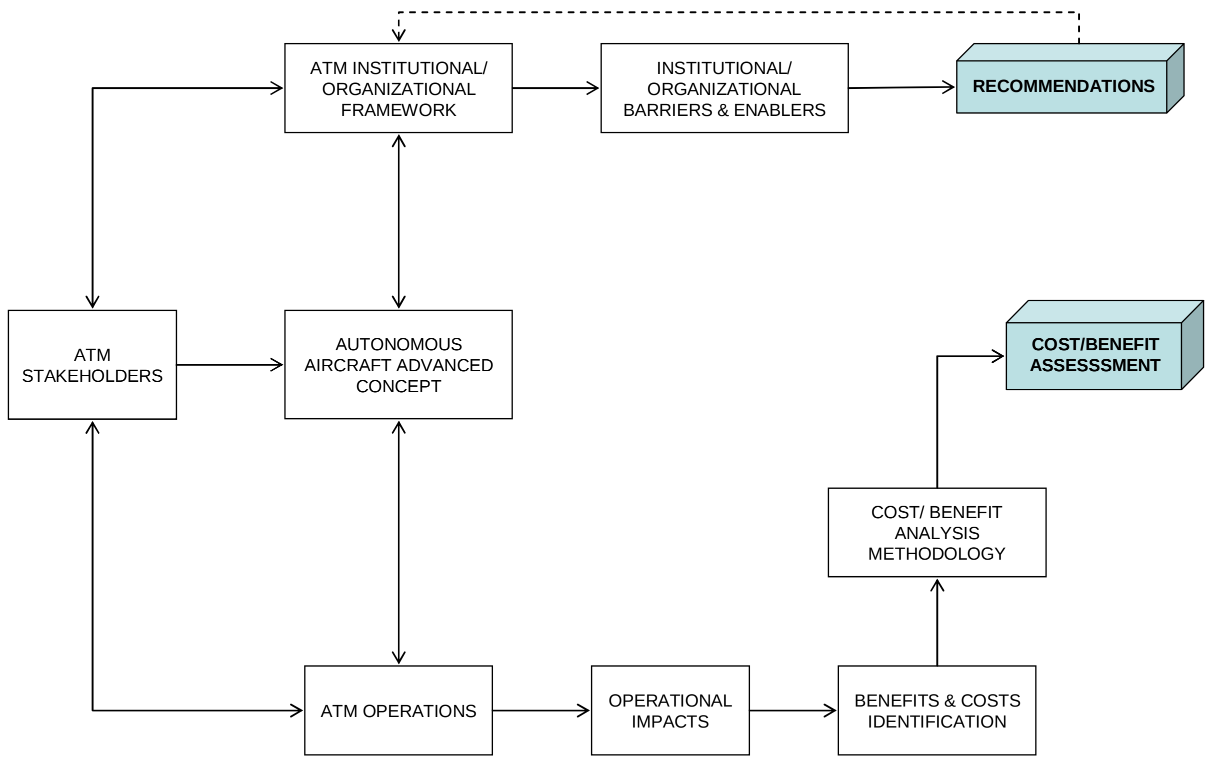

Figure 1. Overall Methodological Approach of WP6

It should be emphasized that the above evaluation process should be planned and implemented based on the assumption of increased traffic volume, leading for the forthcoming years to three-six times higher air traffic in the European airspace.

The present document is devoted to the presentation of the methodological framework for the cost-benefit analysis. The proposed approach is based on existing validation (E-OCVM[13]) and cost-benefit analysis (EMOSIA [12]) methodologies, while it takes into account the cost-benefit analysis requirements identified by SESAR [18]. More information regarding the methodology for the ATM institutional analysis is provided in a separate report of the project (D6.2 “Institutional and Organizational Analysis for the implementation of the autonomous aircraft operations”).

3 Overview of the High Level A^3 Operational Concept

The continuous growth of the traffic in the European airspace is considered as a potential bottleneck of the air transportation system. ATM constitutes a key issue in enhancing the en-route capacity of the airspace. The delegation of aircraft self separation from its surrounding traffic has been considered as an intervention in the current ATM system that could relieve the workload of the ANSPs and improve flight efficiency. The Autonomous Aircraft Advanced (A^3) operational concept aims to accommodate this change in the ATM, by providing the operations, communication systems, technologies, and responsibilities required for the implementation of the self separation tasks and activities.

Based on the high level description of the A^3 operational concept [21], the proposed approach for implementing self-separation tasks involves the following processes:

i) Pre-flight Strategic Flow Management, referring to the activities performed by the airspace users (through the Flight Operations Centres) and the ANSPs in order to form the Reference Business Trajectory (RBT) for each flight.

ii) Trajectory management, including the medium-term planning of the aircraft trajectory within the self-separation airspace. The trajectory management aims to modify the en-route aircraft trajectory in order to avoid bad weather conditions, potential airspace areas with increased traffic complexity, or other events (e.g., potential conflicts) that could decrease the flight efficiency.

iii) Separation Management, which refers to the tasks for separating the aircraft from the surrounding traffic. This process also involves the resolution of any potential conflicts of the aircraft with one or more other approaching aircraft.

The implementation of both processes from the flight crew requires substantial information regarding the aircraft environment (e.g. weather, surrounding traffic). It is also imperative that the aircraft disseminates any potential changes in its trajectory to the other aircraft en-route. On-board and ground communication systems are therefore required in order to facilitate the information sharing and transmission within the A^3 concept. More details regarding the A3 concept and the processes and technological systems requirements for supporting it, can be found in iFly Deliverable D1.1 [21] and D1.3 [4].

The identification and assessment of the impacts of the A^3 in ATM economy involves the analysis of the potential ATM operational improvements arising from trajectory management and self separation management and the costs emerging from the relevant operational, organizational, and technological changes. This document aims to present the approach for performing the economic assessment of the A^3 processes.

4 Cost-Benefit Analysis in ATM

Cost-benefit analysis constitutes a major investment analysis tool for assessing the impacts of operational, institutional or organizational changes in ATM. More than 20 ATM related research projects have endorsed economic assessment of ATM operational improvements through applying cost-benefit analysis (e.g., SESAR, C-ATM, and CASCADE). The cost-benefit analysis provides significant evidence about the effectiveness of an ATM investment for each individual stakeholder and overall as well, especially for mature ATM improvements (i.e., under the development or deployment phase).

EUROCONTROL initiative towards the development of a standardized cost benefit analysis methodology for assessing any investment in the ATM system, has led to EMOSIA (European Models for ATM Strategic Investment Analysis). EMOSIA constitutes a generic methodological framework for performing cost-benefit analysis to assess the associated ATM operational improvements [12]. It is an iterative process that facilitates economic assessment and decision making regarding ATM investments. It includes the following steps: 1) Define decision criteria and collect data, 2) Generate models for costs and benefits calculations for a specific time horizon and category of stakeholders, 3) Sensitivity analysis for a specified set of input variables, 5) Risk analysis on input variables with uncertainty, and 6) conclusions and reiteration (if necessary). EMOSIA has the following major features:

- It is a generic tool and thus appropriate customisation of its elements is needed for its application for the assessment of a given cluster of ATM operational improvements.
- It enables cost-benefit analysis from the perspective of any of the ATM stakeholders (Airport, ANSP, Airlines, General Aviation, and Military) separately while it also provides an overall cost-benefit analysis model assessing the impacts on the entire ATM system
- It provides an inventory of costs and benefits indicators and metrics applicable in assessing ATM operational improvements, accompanied with the input variables, parameters and the relevant formulae needed for calculating each metric.
- It enables the calculation of various economic measures, like the net present value, the internal rate of return and the benefit/cost ratio.
- It enables the sensitivity analysis for several variables of the cost-benefit analysis, i.e., it explores how marginal changes to any variable of the evaluation problem may affect the outcome of the cost-benefit analysis (i.e., certain cost and benefit measures).
- It determines the risk of overestimating or underestimating the cost-benefit analysis outcome. The risk analysis implied above is based on estimating the probability distribution for each of the variables (with uncertainty) that are found to affect

substantially the outcome of the cost-benefit analysis. The outcome of this process relates to the determination of the probability likelihood of each potential net present value.

EMOSIA constitutes a common assessment methodology for European ATM projects [11]. Among the recent EMOSIA users are included the ATM programme and project managers (e.g. Controlled and Harmonised Aeronautical Information Network-CHAIN [16]), an individual ANSP who customised EMOSIA for its own cost and benefit analysis and Military units [9].

Other cost-benefit analysis approaches include ATOBIA and MEDINA [19]. ATOBIA is a cost-benefit analysis tool designed for assessing ASAS (Airborne Separation Assistant System) operational improvements from the perspective of the airlines. Moreover, MEDINA is a specialised cost-benefit analysis tool for assessing ATM improvements from the perspective of ANSPs. MEDINA is built entirely on EMOSIA, focused on ANSPs. Concluding, both cost-benefit analysis approaches constitute methods for customised economic assessment. Based on a recent review of the above economic assessment methods for ATM improvements, within the context of SESAR project [19], it was found that EMOSIA is the most appropriate method to be taken into account for assessing ATM operational improvements in projects related to research activities proposed or envisaged by SESAR.

SESAR has recently reviewed EMOSIA in terms of providing additional cots and benefit indicators in order to improve the accuracy of the relevant computations [18]. The development of the proposed cost-benefit analysis assessment of A3 has been based on E-OCVM, EMOSIA, and the SESAR framework for cost-benefit analysis on ATM related improvements.

It should be emphasized that for the case of the iFly project the A^3 operational concept under consideration is at an early stage. Given the fact that the A^3 operational concept is at definition stage it is not possible to assess its potential performance through shadow-mode or operational field trials. Moreover, since the system is in premature definition stage and due to the time constraints of the project it is not possible to conduct simulation runs in order to assess the operational improvements in the envisaged ATM. Nevertheless, the application for the economic assessment of A^3 performance will be based on experts judgments, aiming to provide only an indication about the potential cost-effectiveness of the proposed ATM operational changes.

5 Methodological Framework For Cost-Benefit Analysis

The A^3 Operational Concept aims to mitigate the potential impacts emerging from the predicted growth of the traffic flow in the European airspace (three to six times increase in current air traffic levels) by improving the performance of the ATM system in terms of airspace capacity and flight efficiency. However, the introduction of the A^3 operational concept into the existing ATM will also incur costs to the stakeholders involved in or affected by the ATM operations. In this context, the cost-effectiveness assessment of the A^3 operational concept involves the estimation of the costs and benefits emerging from the associated operational, technological, and organizational changes in the ATM system. Cost-benefit analysis constitutes a powerful tool for implementing this type of assessment. This section provides a description of the proposed methodology for the cost-benefit analysis of the A^3 operational concept.

The assessment of the A^3 impacts on the ATM system has the following features:

- Many stakeholders (involved in or affected by the introduction of the proposed operational concept) with different expectations and needs
- Existence of various operational impacts on several ATM key performance areas (i.e., flight efficiency, capacity, human factors, predictability)
- Difficulty in quantifying tangible or intangible operational improvements in the ATM system performance.
- Lack of objective measurements and data for assessing benefits and costs.

A methodological framework has been developed for performing the iFLY cost-benefit analysis taking into account the above features of the problem at hand. The development of the methodological steps of the proposed approach has been based on: i) the generic model for Cost Benefit Analysis (CBA) application in ATM as presented in SESAR WP1.4.1/D1) [18], ii) EMOSIA [12], and iii) the E-OCVM [13]. In particular, the objective of the proposed methodology is to identify the steps, the metrics, and the guidelines needed for applying cost-benefit analysis for A^3. This objective is achieved on customizing EMOSIA for the case of assessing the A^3 operational concept. E-OCVM, as a generic framework for performing ATM validation, has provided the guidelines for customizing EMOSIA for the assessment of the A^3. The generic model for CBA from SESAR puts forward the objectives that should be covered by the proposed iFly CBA methodology while E-OCVM is used as a guideline for developing the relevant methodological steps of the CBA approach proposed in this report.

Two major models are included in the generic scheme for applying CBA: the cost model and the benefits model. Each of the two models calculates the cost and monetary benefit of a specified deployment scenario for a cluster of ATM changes, from the perspective of one or more stakeholders. A given baseline scenario and a set of standard inputs for a set of performance variables (also used in previous CBAs) constitute critical input to both models.

The cost-benefit analysis should be applied for each category of ATM stakeholders affected by A3 in terms of costs and benefits. Given that the A3 operational concept relates to the en-route operations of the ATM system, it is basically the ANSPs and the airspace users that will be directly encountered with costs and benefits. Moreover, based on the scope of the safety assessment in iFly [5], it is the commercial airlines air traffic that will be assessed in WP7. Thus, the commercial airlines constitute the airspace users that will be included in the cost-benefit analysis.

On the other hand, E-OCVM is a broader validation methodology for assessing ATM operational improvements under the following levels of maturity: i) V1 "Establish concept principles", ii) V2 "Initial proof of concept", iii) V3 "Concept integration re-ops simulations", iv) V4 "Industrilization/ procedure approval", and v) V5 "Implementation of processes/procedures". In [5] and [6] the iFly project has been identified to fit within the V1 phase. The E-OCVM sets the generic framework for an overall evaluation of a new concept (including institutional, organizational, operational, technological improvements) through the following major steps:

- step 0 "State Concept and Assumptions"
- step 1 "Set Validation Strategy"
- step 2 "Determine the Experimental Need"
- step 3 "Conduct Experiment"
- step 4 "Determine Results", and
- step 5 "Disseminate Information to Stakeholders".

Each of the above steps involves specific validation activities presented in Appendix I. It should be noted that the content for each of the above steps varies according to the maturity level of the ATM operational concept.

Although, the cost-benefit analysis constitutes only part of such a validation process, certain activities included in the E-OCVM steps are incorporated in the proposed methodology. In particular, the E-OCVM steps applicable for the iFly cost-benefit analysis refer to:

i) State concept and assumptions (step 0). This is also an essential step for the cost-benefit analysis, since a well defined operational concept constitutes the basis for identifying the cost and benefit elements emerging from the proposed operational improvements.

ii) Identification of the goals and expectations of the involved stakeholders from the A^3 concept (step 1.1). ,

iii) Establish validation needs (step 1.5). From the perspective of cost-benefit analysis this activity involves the input parameters and variables and their methods of measurement needed for calculating costs and benefits.

iv) Select validation tools and techniques (step 1.6), implying the surveys for collecting experts judgments needed in order to quantify the costs and benefits metrics,

v) Define validation strategy and plan (1.7), referring to the management plan for the performing the cost-benefit analysis related activities

vi) Identify indicators and metrics (step 2.4) referring to the costs and benefits indicators and metrics needed for assessing the specific operational improvements (based on the stock of metrics and variables provided in EMOSIA),

vii) Specify scenarios (step 2.5), referring to deployment scenario for the proposed operational improvements and the baseline scenario under consideration,

viii) Produce experimental plan, analysis plan, experimental design (steps 2.6, 2.7, 2.8), and

ix) Conduct the experiment (step 3), determine results (step 4), and disseminate information (step 5).

The proposed methodology for the iFly cost benefit analysis is presented in **Figure 2**. A focal point of the proposed methodology relates to the specification of the operational, technological, and organizational changes in the ATM system that will emerge from the introduction of the A^3 operational concept in the existing ATM system. Any change implied in the proposed operational concept will be analysed in order to identify the associated positive or negative impacts in the ATM operations. The emerging impacts could be considered either as negative if they involve cost expenses or positive if they imply benefits. A step further in the proposed methodology relates to specifying the corresponding economic benefits and costs indicators which are associated to the above positive and negative impacts respectively. It should be clarified at this point that the cost-benefit analysis performed within iFly relates only to the assessment of the direct impacts of A^3 on the ATM system. Thus, the proposed cost-benefit analysis will not take into account any potential broader socio-economic impacts or end users' (passengers) costs and benefits. Moreover, the A^3 impacts on safety and human factors will be explored separately by other WPs of iFly project, and therefore they will also be disregarded from our analysis.

In essence, the cost benefit analysis will be performed for each involved stakeholder separately. Thus the cost and benefits indicator will be identified for each stakeholder separately. The outcome of the proposed cost-benefit analysis involves the estimation of the net present value of the costs and benefits derived from introducing the A^3 concept. However, additional measures will be calculated including the benefits to costs ratio and the internal rate of return.

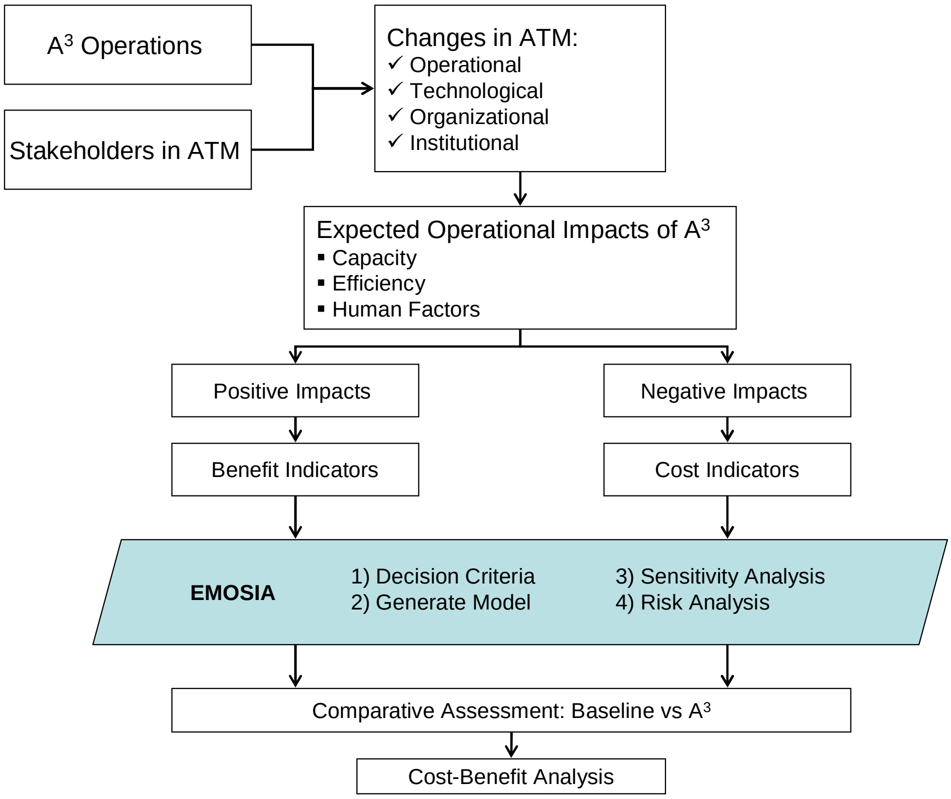

Figure 2. Methodology for cost-benefit analysis.

The calculation of the total benefits and costs associated with any stakeholder at a specific time period will be based on the differences between the expected cost and benefit for the rolling baseline situation i.e., by comparing the situation with and without the A^3. Thus, the benefits and cost calculation constitutes an iterative process based on a rolling and continuously evolving baseline scenario. More information on this issue will be provided in the section that presents the detailed calculations for estimating the costs and benefits. The identification and estimation of the metrics associated with the cost and benefit indicators will be based on the relevant inventory of metrics and estimation formulae of EMOSIA.

6 Parameters of the Cost-Benefit Analysis

This section outlines the basic input parameters needed for performing the cost-benefit analysis calculations. This set of parameters includes: i) the discount rate, ii) the timing parameters of the analysis, iii) the geographical coverage of the operational concept, iv) the airspace coverage of the proposed concept, v) the air traffic growth rate for each year in the time horizon of the analysis, and vi) the aircraft annual growth and retirement rate throughout the time horizon of the analysis. The potential values of the above parameters will be decided by the iFly consortium taking into account the corresponding values in relevant ATM investment analysis [15], the existing performance review studies [10], and the analysis scenarios that will be developed. Note that the timing parameters (e.g. start year of the analysis, implementation period), the airspace covered, and the geographical coverage of the analysis will be based on the detailed description of the A^3 operational concept. Thus, deliverable D1.3 regarding the description of the A^3 operational concept should provide the essential information required for determining the above parameters. The remainder of this section provides a more detailed description of the major cost-benefit analysis input parameters, enhanced with the potential sources for identifying their potential values.

6.1 Discount Rate

The discount rate (r) constitutes a major prerequisite for calculating the present values of the costs and benefits. In general, assuming that X_T is the monetary value of an asset at year (T), its present value X_0 (where present is denoted with t=0) is given by formulae (1) below [20]:

$$X_0 := \frac{X_T}{(1+r)^T} \tag{1}$$

Specifying the value of the discount rate is critical in performing the computations and therefore it should be made before the data collection process begins. Similar investment analysis studies should be consulted in order to decide on the discount rate value. For instance in the investment analysis study for the Free Route Airspace concept, the discount rate used was 8% [15]. Note however, that more than one values could be selected (i.e. maximum, average, and minimum) reflecting the corresponding values prevailing throughout Europe.

6.2 Timing Parameters

The timing parameters of the cost-benefit analysis refer to the following elements of time pertinent to the implementation of the A3 operational concept:

- Time Horizon of the cost-benefit analysis
- Start year of the analysis
- Pre-implementation period of A^3
- Implementation period of A^3
- Benefits Lag
- Aircraft Retrofit Period

The specification of the time horizon of our analysis plays a key role in estimating the influence of the A^3 concept in the ATM system performance. It should take into account the time required for the implementation of the system and the time required for being fully operational within the European airspace. The selection of the appropriate time horizon for the cost benefit analysis constitutes a critical decision and basically lies on the assessment of the iFly partners regarding the time required for operationalising (putting into operation) the relevant A^3 functionalities. The start year of the analysis is defined as the point in time in the future that the operational, organizational, and operational changes implied in the A^3 Operational Concept will take effect within the ATM system.

The start year will be used as the base year for calculating the present value of the costs and benefits. The specification of the start year of the cost-benefit analysis constitutes the basis for initialising the remaining input parameters, e.g., the airspace traffic growth rate. A more definite estimation for this parameter will be made after the detailed A^3 operational concept will be finalized and issued.

The pre-implementation period refers to the preparatory tasks and activities (simulations, pilot applications, validation) needed for the implementation of the A^3 operational concept, while the implementation period refers to the actual introduction of A^3 operations into the current ATM system. It is unlikely that upon the start of the implementation period, the benefits emerging from this concept will simultaneously arise. Two major time elements are critical in this aspect: i) the year that benefits will start, and ii) the year after which the entire spectrum of benefits are encountered. The benefits lag is the difference between these two points in time.

The aircraft retrofit period refers to the time needed for all aircraft in operation to be equipped with the on-board systems required for applying the A^3 operations.

The above critical time elements of the cost-benefit analysis depend on the content of the proposed A^3 operational concept. Therefore, the completion of the proposed concept constitutes a major prerequisite for specifying the above time elements. The support and judgment of the A3 operational concept developers is essential in estimating these parameters.

6.3 Air Traffic Growth Rate

Based on the iFly technical annex [1], the A^3 operational concept should be assessed for increased traffic volume three to six times higher than the existing traffic level. Increase of delays and capacity deficiencies are foreseen for the forthcoming years given the expected saturation of the airspace under the existing ATM operational concept. It is evident that the projection of the traffic level on the time horizon of our analysis plays a key role especially for the estimation of the increase of capacity and the delays reduction due to the introduction of A^3 concept. However, performing forecasting in order to estimate the evolution of traffic is definitely a complex task which is out of the scope of the iFly project. Alternatively, it has been decided that the traffic projection for performing the cost-benefit analysis will be based on the corresponding projections of other relevant research projects for comparable time horizon. Anyhow, the selection of the annual air traffic growth rate should be decided by the iFly consortium. A useful source of information for this decision could be the Performance Review Report [10] issued for 2006 by the Performance Review Commission of the EUROCONTROL (or any other more recent version, if available), which provides the projection of the air traffic growth rate up to year 2012.

6.4 Annual Aircraft Fleet Growth/ Retirement rates

The aircraft annual growth and retirement rates per type of aircraft refer to the average rate of the new aircraft included in the European fleet and the corresponding rate of the aircraft being deactivate each year. Both parameters could be used in order to estimate the costs of the new (if any) airborne technologies introduced by A^3 concept. The values for these two rates will be based on the relevant data provided by EUROCONTROL [10] while similar studies will be consulted in order to estimate any potential changes within the time horizon of the analysis.

6.5 Airspace and Geographical Area Covered by A^3

This parameter refers to the part of the European airspace and geographical area that the proposed operational concept will cover. The entire European airspace and geographical area will be considered as the basis for developing the cost-benefit analysis operational scenarios.

6.6 Stakeholders

The stakeholders involved in or affected by the implementation of the A^3 operational concept are: i) the Air Navigation Service Providers (ANSPs), ii) the Airspace users (Airlines and

General Aviation), iii) Airport authorities, iv) the Central Flow Management Unit (CFMU), and v) the regulatory authorities.

The ANSPs include the following categories of organizations: i) The Air Traffic Management service providers (i.e. Air Traffic Controllers such as NATS, DFS, AENA etc.), ii) the Communication, Navigation, and Surveillance (CNS) service providers including organizations like SITA, INMARSAT, and ITU , iii) the Aeronautical Information service providers, and iv) the Meteorological (MET) service providers. The A^3 operational concept is expected to relieve the workload of the ANSPs since the responsibility of some[1] of their tasks for traffic separation will be delegated to the aircraft operators.

The airspace users within the context of iFly pertain to the General Air Traffic, i.e., commercial air transport (e.g. passenger and cargo airlines), Business Aviation, General Aviation, and military flights (for transport purposes). The A^3 operational concept aims to enable the flight crew in performing the en-route separation and trajectory management task on its own. This aspect of A^3 is expected to increase the efficiency of the flight routes. In this context, the flight efficiency is expected to increase while the en-route delays will be reduced.

The airport authorities involved in or affected by the A^3 operational concept will benefit from the increased punctuality of the flights (due to reduced delays) and the corresponding improvement of the resources utilization. However, the current version of the A3 operational concept does not cover airports.

The CFMU provides the ATC and the airspace users with the flight plan data while it aims at the best utilisation of the airspace capacity within Europe (smoothing of traffic flows and avoidance of traffic overloads). The A^3 system is expected to affect the role and operations of the CFMU since flexible flight routes determined by the airspace users are expected to be supported by the A^3 operational concept.

Finally, the introduction of the A^3 operational concept will definitely require the intervention of the regulatory authorities for tackling the implications to the existing institutional and organizational ATM framework. More information regarding the role of each of the above stakeholders will be provided in Deliverable D6.2 “Institutional and Organizational Analysis for the implementation of the autonomous aircraft operations”.

Based on the above analysis, the ANSPs and the Airspace Users are the actors which will potentially face direct economic impacts due to the A3 Operational Concept. Therefore, the cost-benefit analysis will be focused on the benefits and costs associated with these actors only.

[1] By the time that this document was written, no detailed description of the A3 operational concept was available. Therefore, this issue will be further specified when the detailed description of the A3 operational concept will be available (i.e. D1.3).

Figure 3 below, presents the major financial and service flows among the major stakeholders involved in the A^3 Operational Concept. This representation facilitates the specification of the interrelationships among the involved stakeholders along with the specification of the major costs and benefits categories per stakeholder. The information for developing Figure 3 was taken from EUROCONTROL document [14].

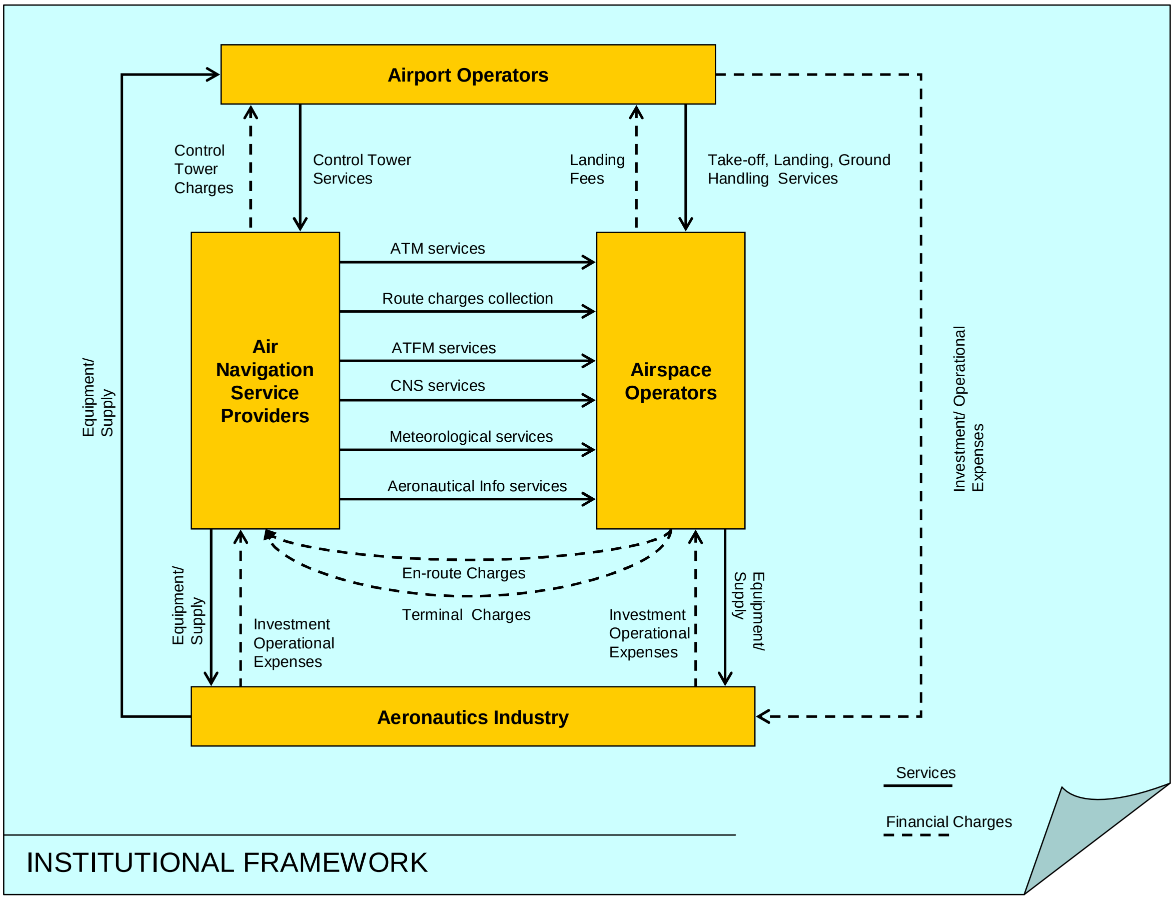

Figure 3. Major financial and service flows among the ATM community

6.7 Basic Cost-Benefit Analysis Variables

The objective of this section is to determine the basic input variables which will be used for the calculation of the associated cost and benefit elements. The identification of the variables involved in this analysis was based on the customisation of the EMOSIA variables for the case of the A^3 operational concept. The correspondence of the iFly cost-benefit analysis variables with their counterparts from the EMOSIA models are also clarified in order to validate the conformance of the proposed analysis with EMOSIA. Moreover, the cost-benefit analysis variables will be grouped into the following categories ([23]):

- *Global variables*, referring to variables which remain constant throughout the analysis.

- *Global timing variables,* referring to time variables associated with critical events e.g. start of implementation period.

- *Uncertain timing variables*, i.e. time variables which involve uncertainty

- *Uncertainties,* referring to those cost and benefit related variables which involve uncertainty, i.e. they cannot be assessed with accuracy based on objective measurements. The estimation of this type of variables will be achieved by identifying a range of values provided by experts, instead of a single point estimate.

- *Baseline variables* referring to the performance variables for the baseline scenario.

- *Deterministic variables*, i.e. composite variables which are calculated based other variables

In what follows there is an exposition of the Global and Global Timing input Variables along with the Uncertain, Baseline, and Deterministic Input Variables in tabular form. Each of the tables provided includes the name of the variable, its definition, the measurement units, the corresponding EMOSIA variable, the applicable stakeholders categories (i.e. airspace users, ANSPs, and airports), and the potential sources of information for estimating its value. In particular, this last column refers either to a relevant study or an organization involved in iFly that could potentially handle the provision of the corresponding estimate.

Name	Description	EMOSIA Ref	Stakeholders	Potential Estimation Sources
Aircraft Baseline Number	The number of aircraft in the system during the start year of the model. There is no distinction in the model of the type of aircraft (number of seats, weight, etc.)	Aircraft BL Num	Airspace Users	iFly Consortium
Aircraft Growth Rate	Annual growth in the aircraft fleet.	Aircraft Growth Rate	Airspace Users	iFly Consortium
Aircraft Retirement Rate	The annual retirement rate of aircraft in the system. Used to calculate annual deliveries (i.e. the number of new aircraft entering the system in order to reach the total number indicated by the aircraft growth rate).	Ann Retirement Rate	Airspace Users	iFly Consortium
Average Flight Length	Average flight length of commercial airline flight (From standard inputs document)	Avg Flt Length Min S1	Airspace Users	iFly Consortium
Discount Rate	Discount rate applied for net present value calculation.	Discount Rate	Airspace Users, ANSP, Airports	Standard Inputs for EUROCONTROL CBA [8]
Optimum delay per flight	The target delay per flight. Delay reduction is not allowed to exceed this target.	Optimum delay per flight	Airspace Users	iFly Consortium
Annual number of Flights	The number of airline flights in the system during the start year of the model.	S1 BL Ann Flts	Airspace Users	iFly Consortium
User Share	Percent of total service costs that user	User Share	Airspace Users	iFly Consortium

	pays for.			
Value of Additional Flight	The net value of adding one additional flight on an annual basis, after taking into account incremental costs associated with the incremental flight.	Value of Addtn'l Flt	Airspace Users	Standard Inputs for EUROCONTROL CBA [8], UCAM

Table 1. EMOSIA Global Variables applicable for the A3 cost-benefit analysis .

Table 2 below presents the EMOSIA uncertain timing variables which are applicable for the economic assessment of the A3 operational concept.

Name	Description	EMOSIA Ref	Stakeholders	Potential Estimation Source
Benefits Lag	The lag between implementation start and benefits start and implementation end and benefits achieved at full operating capability.	Benefits Lag (years)	Airspace Users, ANSPs, Airports	iFly Consortium
Implementation Duration	The duration of the A^3 implementation period.	Imp Duration (years)	Airspace Users, ANSPs, Airports	iFly Consortium
Pre-Implementation Duration	The length of time for pre-implementation expenditures, beginning in the pre-implementation start year. (Input a non-zero number, even if associated costs are zero).	Pre-Imp Duration (years)	Airspace Users, ANSPs, Airports	iFly Consortium
Retrofit Duration	The length of time for retrofitting aircraft, beginning in implementation start year. (Input a non-zero number, even if associated costs are zero).	Retrofit Duration (years)	Airspace Users	iFly Consortium

Table 2. EMOSIA Uncertain Timing Variables applicable for the A3 cost-benefit analysis .

7 Major Cost categories

The A^3 operational concept constitutes a cluster of operational improvements which can be integrated into the ATM system through a process including the following phases: i) pre-implementation phase, which involves the research, and development activities for the proposed A^3 system operations, ii) implementation phase, referring to the period devoted to introducing the A^3 operations into the existing ATM system, including technological systems installation, personnel training, monitoring and management activities for a testing period, and iii) operational (post-implementation) phase including the activities for operating the modified ATM system according to the A3 operational concept. In accordance with the above analysis, the total cost for the A^3 system involves the following major categories: i) pre-implementation cost, ii) implementation and installation cost, and iii) operating cost. This type of analysis of the total investment cost is also incorporated in EMOSIA [12].

A more detailed analysis of the above categories of cost leads to the cost elements pertinent to the iFly cost-benefit analysis. Thus, the pre-implementation cost involves the cost of resources for covering A^3 operational, technological, and organizational requirements and validating the emerging ATM system in terms of safety, operational performance, and economic sustainability. The implementation cost includes the cost of the resources needed for training controllers and pilots, and managing the overall process of incorporating the new or modified operations in the existing ATM system. It also includes the installation cost referring to the acquisition of the on-board and ground equipment required for the implementation of the A^3 concept. The operating cost refers to the additional cost of the resources needed for the A^3 operations and the associated maintenance additional cost required throughout the entire time horizon of our analysis, i.e. the additional operating cost arising from the introduction of the A^3 operational concept.

More details regarding the constituent elements of the above cost categories is provided for each stakeholders separately in order to assure that all potential cost elements have been taken into account. Thus, in what follows there is an exposition of the preliminary set of cost elements applicable to each of the involved stakeholders separately. The description of each cost element is further enhanced with an approach and the required data for estimating its value. The set of cost elements will be updated and revised (if necessary) when the actual content of the detailed A^3 operational concept and the associated technological and functional requirements will be issued.

7.1 Air Navigation Service Providers' cost elements

Applying the proposed operational concept involves the development and validation of new operational procedures for the Air Navigation Service Providers (ANSPs). The pre-implementation cost associated to the ANSPs relates to the validation of these new operational procedures in the new context of ATM. Moreover, the introduction of the A^3 operational concept in ATM will impose on the ANSPs the following elements of implementation cost: i) capital implementation cost, including the cost of any new ground systems and the cost of the interface with the System Wide information System (SWIM), and ii) the one-off implementation cost including the Project Management Cost for systems transition and the Training Cost. Finally, the operating costs are basically induced from the maintenance of any new ground systems. However, since the A3 system is expected to reduce the operating cost of the ANSPs, this element of cost is studied under the benefits analysis. In what follows there is a detailed description of each of the above cost elements categories for the ANSPs.

7.1.1 System Pre-implementation Cost

The integration of the A^3 concept into the ATM involves the specification of the operational procedures for the ANSPs (e.g. procedures that apply for clearances (if any), ATC-pilot communication, navigation service provision, flight planning). This cost element includes the investment on resources for validating the proposed operational procedures through performing and analysing simulation runs, experiments or/and collecting experts judgements. Expert judgements will be collected and analysed in order to provide an estimate about the total cost of the pre-implementation phase of the A3 operational concept.

7.1.2 Cost of new air-ground information communication systems

This cost category refers to the investment on new communication systems and technologies which are essential to the ANSPs in order to exchange information with the flight crew (through SWIM). The estimation of this type of cost requires the determination of the actual systems (e.g. data link communication) emerging from the A^3 operational concept and therefore more details will be provided as soon as this information is available. However, one should note that this cost may differ significantly among the various ANSPs across Europe since the required systems and technologies may be already available at various levels of maturity at some of the corresponding working environments. Thus, the estimation of this cost will be based on the experts judgment regarding the A^3 systems required for each ANSP involved with the A^3 operational concept.

7.1.3 Acquisition cost of an interface with the SWIM

The availability of the airspace constitutes critical information for the provision of air navigation services from ANSPs. Acquiring this type of information involves the development of an interface with the ISS. The cost for developing this interface (if not already available) should also be included in the ANSPs costs. EUROCONTROL constitutes the major source of information for estimating this type cost.

7.1.4 Project Management Cost for system transition

Incorporating new systems and procedures in the ATM constitutes a critical task in terms of safety. Thus, an implementation management and monitoring process is required for assuring the safe incorporation of the new operational concept in ATM. The project management cost for system transition refers to the investment of the ANSPs on the management of the process for setting up the new system(s) and procedures within the working environment of the ANSPs. This cost can be measured by multiplying the number of person months required for this process with the cost of each person month. Experts judgments will be elicited in order to estimate the number of person months required for this task, and the associated cost per person month.

7.1.5 ANSPs Training Cost

The implementation of the new procedures of the ANSPs for offering the air traffic services implies the appropriate training of the ANSPs personnel in order to safely and efficiently apply the new procedures. The associated training cost may be measured by the product of the cost for training an air traffic controller and the number of controllers applying the A^3 related procedures.

7.1.6 ANSPs Cost Variables

Table 3 summarises the cost elements pertinent to the A^3 operational concept and associates them with the corresponding EMOSIA (EMOSIA ANSP Cost model) variables. The EMOSIA cost model for ANSPs will be used for measuring the total costs emerging from the A^3 operational concept. Table 4 presents the EMOSIA deterministic variables needed for the calculation of the ANSPs total costs while Table 5 presents the EMOSIA uncertain variables needed for estimating the deterministic ANSPs cost variables mentioned above. Note that at the last column of Table 5 the iFly consortium is indicated for handling the provision of the corresponding estimates.

Cost Category	EMOSIA Variable	iFly Context Descritpion	Function of	
			EMOSIA Variable	*Variable Category*
Pre-Implementation Cost	S1 Pre-Imp Cst TS	Time series used to schedule pre-implementation costs for system transition. Assumption is costs are spread evenly over pre-implementation time period.	S1_Ann_Pre_Imp_Cst_M_Eu	Uncertain
			S1_Pre_Imp_Start_Year	Timing
			S1_Pre_Imp_Duration	Uncertain
Implemetnation Capital Cost	S1 Capital Cst Imp TS	Time series used to schedule the following capital costs: i) Cost of new air-ground information communication systems, ii) cost for Interface with the ISS. Assumption is costs are spread evenly over implementation time period.	S1_Ann_Cap_Imp_Cst	Deterministics
			S1_Imp_Start_Year	Timing
			S1_Imp_Duration	Uncertain
One-off Implementation Cost	S1 One-Off Imp TS	Time series used to schedule one-off implementation costs including: i) Project Management Cost for system transition, and ii) Training Cost. Assumption is costs are spread evenly over implementation time period.	S1_Ann_One_Off_Imp_M_Eu	Deterministic
			S1_Imp_Start_Year	Timing
			S1_Imp_Duration	Uncertain

Table 3. Cost categories for the ANSPs

Deterministic Cost Variables for ANSPs

Name	Units	Description	Function of:
S1 Investment	€ M	Cost of the A3 investment during the total life span from an ANSP perspective.	**S1_Pre_Imp_Cst_TS** **S1_One_Off_Imp_TS** **S1_Capital_Cst_Imp_TS**
-S1 Pre-Imp Cst TS	€ M per year	Time series used to schedule pre-implementation costs. Assumption is costs are spread evenly over pre-implementation time period.	S1_Ann_Pre_Imp_Cst_M_Eu S1_Pre_Imp_Start_Year S1_Pre_Imp_Duration
-S1 Ann One-Off Imp M-Eu	€ M	One-off implementation costs on an annual basis.	S1_One_Off_Imp_Costs_M_Eu Implementation Duration.
Imp Start Year	calendar year	Implementation start year. Used for ground/space equipment.	Pre_Imp_Start_Year Pre_Imp_Duration
-S1 Capital Cst Imp TS	€ M	Time series used to schedule capital costs. Assumption is costs are spread evenly over implementation time period.	S1_Ann_Cap_Imp_Cst S1_Imp_Start_Year S1_Imp_Duration
S1 Ann Cap Imp Cst M-Eu	€ M	Capital implementation costs on an annual basis.	S1_Ground_Space_Imp_Cst_M_Eu Imp_Duration.

Table 4. Deterministic EMOSIA variables related to ANSPs costs, applicable for the A^3 cost-benefit analysis [22].

Uncertain Cost Variables for ANSPs

Name	Description	Potential Sources	Estimation
S1 Ground Space Imp Cst M-Eu (€ M)	Total ground/space implementation costs for segment 1.	iFly Consortium	
S1 One-Off Imp Cst M-Eu (€ M)	One time implementation costs that doesn't require replacement. (e.g. training)	iFly Consortium	
S1 Ann Pre-Imp Cst M-Eu (€ M per year)	Annual pre-implementation costs for segment 1.	iFly Consortium	

Table 5. Uncertain EMOSIA variables related to ANSPs costs, applicable for the A^3 cost-benefit analysis [22].

7.2 Airspace Users' Costs

The categories of cost elements applicable for the Airspace Users refer to: i) the pre-implementation, ii) the capital implementation cost including the On-board Communication Systems Cost, the On-board flight planning and management Systems Cost, and the Cost of developing an Interface with the Information Sharing System (ISS), iii) the one-off implementation cost including the system Transition Cost and the Training Cost, and iv) the operating cost (i.e. Maintenance Cost). The remainder of this section is devoted to elaborating the above cost categories for the Airspace Users.

7.2.1 Pre-Implementation Cost

This category of cost refers to the investment needed for validating the proposed operational concept for airspace users through performing and analysing simulation runs, experiments or/and collecting experts judgements.

7.2.2 On-board Communication Systems Cost

This type of cost relates to the acquisition of any new communication systems (air-ground or air-air) required for the communication of the flight crew with the ground (e.g. SWIM) or any other surrounding aircraft (en-route).

7.2.3 Avionic Systems Cost

This type of investment refers to the new on-board technologies and flight planning applications required for the incorporation of the A^3 concept in the ATM system. Based on the generic equipment requirements presented in D1.1, the airspace users will undertake the following technological costs: i) Acquisition cost for the Airborne Separation Assurance System (ASAS) application, ii) Acquisition cost for the Trajectory Builder (probably integrated in the Flight Management System), and iii) Acquisition cost for the traffic congestion predictor. More details on the relevant equipment will be provided as soon as the functionalities included in the A^3 operational concept will be available.

7.2.4 Interface with the System Wide Information Management (SWIM)

The availability of the airspace constitutes critical information for flight planning and autonomous separation management. Therefore, the airlines will take on the cost of obtaining (or developing) an interface with the SWIM.

7.2.5 System Transition Cost

A management process from the side of the airspace users is required for the efficient transition from the existing ATM to the new ATM emerging from the A^3 operational concept. The cost of this process can be measured by the product of the total person months needed for this project and the average cost per person month.

7.2.6 Training Cost

The implementation of the A^3 operational concept requires the training of the flight crew within the proposed framework of air route planning and navigation. The flight crew training cost could be estimated by multiplying the total training time (number of pilot-hours of training) with the cost per training hour.

7.2.7 Operating Cost

This type of cost refers to the cost of maintaining the above mentioned new (A^3 related) avionics systems and ground systems.

7.2.8 Airspace Users Cost Variables

Table 6 presents the major categories of cost associate to the A3 operational concept, and the corresponding EMOSIA variable taken from the EMOSIA Airlines Model.

Cost Category	**iFly Context Descritpion**	**Function of**	
		EMOSIA Variable	*Variable Category*
Pre-Implementation Cost	Time series of pre-implementation costs.	Pre-Imp_Start_Year	Timing
		Pre-Imp_Duration	Uncertain
		Pre-Imp Cst M-Eu	Uncertain
Implemetnation Capital Cost	Airborne equipment (equipage) plus ground/space equipment: i) Acquisition cost for the Airborne Separation Assurance System (ASAS) application, ii) Acquisition cost for the Trajectory Builder, iii) Acquisition cost for the traffic congestion predictor, iv) Interface with the Information Sharing System	Forward_Fit_Equip_Num	Deterministic
		Equipment_Cst_K_Eu	Uncertain
		Retrofit_Equip_Num	Deterministic
		Retrofit_Install_Cst_K_Eu	Uncertain
		Ground_Space_Imp_Cst_M_Eu	Uncertain
One-off Implementation Cost	Time series of the one-off implementation costs including the Flight Crew Training cost and the cost for system transition.	One_Off_Imp_Cst_M_Eu	Uncertain
		Imp_Duration	Uncertain
		Imp Start Year	Timing
Operating Cost	Cost incurred during the operating life including the Maintenance Cost.	S1_Benefit_%_Achieved_TS	Deterministic
		FOC_Operating_Cst_M_Eu.	Uncertain

Table 6. Cost categories for the Airspace users

The EMOSIA cost model for the airlines will be used for measuring the total costs emerging from the A^3 operational concept. Table 7 presents the EMOSIA deterministic variables needed for the calculation of the airspace users' total cost while Table 8 presents the corresponding EMOSIA uncertain variables needed for measuring the costs for the airspace users. Note that Table 8 also includes the organization that should handle the provision of the estimates needed for each uncertain variable.

Deterministic Cost Variables for Airspace Users			
Name	Units	Description	Function of:
Investment	€ M	Cost of the A^3 investment from the airline perspective	**Capital_Cst_Imp_TS** **Pre_Imp_Cst_M_EU** **Pre_Imp_TS** **Pre_Imp_Duration** **Operating_Cst_TS**
-Operating Cst TS	€ M	Airspace users Costs during the operating life of A^3	S1_Benefit_%_Achieved_TS FOC_Operating_Cst_M_Eu
S1 Benefit % Achieved TS	decimal fraction	Benefits are calculated assuming full equipage and full infrastructure and then adjusted downward for the degree of infrastructure and equipage implementation.	Equippage_Factor Infrastructure_Factor.
Infrastructure Factor	decimal fraction	Benefits are adjusted for the degree that infrastructure is implemented.	Imp Start Year Imp Duration
Percent Equipped	decimal fraction	Percent of the fleet equipped.	Number_of_Aircraft Cum_Equipped.
Cum Equipped	units	Cumulative aircraft equipped through either forward fit or retrofit.	Retrofit_Equip_Num Forward_Fit_Equip_Num
Equipage Factor	decimal fraction	The equipage factor is used to adjust benefits downward for equipage. (There is also an infrastructure factor.) Benefits are zero until a critical mass (minimum equipage required) is met; then benefits are achieved proportional to the percent equipped.	Percent_Equipped Minimum_Equipage_Req'd_%.
-Capital Cst Imp TS	€ M	Airborne and ground/space equipment cost	Forward_Fit_Equip_Num Equipment_Cst_K_Eu Retrofit_Equip_Num Retrofit_Install_Cst_K_Eu Ground_Space_Imp_Cst_M_Eu Ground_Space_TS Imp_Duration.
Forward Fit Equip Num	aircraft	Number of aircraft forward fitted per year.	Annual_Deliveries Forward_Fit_TS.
Forward Fit TS	decimal fraction	Time series used to schedule forward fit costs. Assumption is forward fit occurs to 100% of deliveries after the implementation start year.	Equipage_Start_Year End_Year
Retrofit Equip Num	aircraft	The number of aircraft retrofit per year. This is an "if/then" function, tied to the retrofit time series, which is used to make sure that aircraft are only retrofit during the retrofit period. In addition, the start number of aircraft, at the beginning of the period is adjusted downward for retirements. Finally, the number is divided by the	Retrofit_TS Aircraft_Fleet_in_RF_Start_Yr Ann_Retirement_Rate Retrofit_Duration.

Deterministic Cost Variables for Airspace Users			
Name	Units	Description	Function of:
		retrofit duration to determine the annual number of aircraft retrofit. The implicit assumption is retrofits occur evenly over the retrofit period.	
Aircraft Fleet in RF Start Yr	aircraft	The number of aircraft in the existing fleet at the start of the retrofit period.	Number_of_Aircraft Imp_Start_Year_Switch Aircraft_Fleet_in_RF_Start_Yr.
Retrofit TS	decimal fraction	Time series used to schedule retrofits and retrofit costs. Assumption is retrofit is spread evenly over the retrofit time period.	Equipage_Start Year Retrofit_Duration
Ground Space TS	decimal fraction	Time series used to schedule ground/space costs. Assumption is costs are spread evenly over implementation time period.	Imp_Start_Year Imp_Duration
Annual Deliveries	aircraft	The number of new aircraft delivered each year.	Number_of_Aircraft Aircraft_Growth_Rate Ann_Retirement_Rate.
Number of Aircraft	aircraft	The number of aircraft in the system for each year of the analysis	Aircraft BL Num Aircraft Growth Rate
Imp Start Year	calendar year	Implementation start year. Used for ground/space equipment.	Pre_Imp_Start_Year Pre_Imp_Duration
Imp Start Year Switch	decimal fraction	This switch determines the year in which the cluster starts implementation. Its used to determine the aircraft population at the beginning of the implementation cycle, for purposes of determining how many aircraft have to be retrofit.	Imp_Start_Year
-Pre-Implementation TS	Decimal fraction	Time series (of decimal fractions) used to schedule on time the total pre-implementation cost, under the assumption that the relevant total cost is spread evenly over the pre-implementation time period.	Pre-Imp_Start_Year Pre-Imp_Duration
-Ann One-Off Imp M-Eu	€ M	One-off implementation costs on an annual basis.	One_Off_Imp_Cst_M_Eu Imp_Duration.

Table 7. Deterministic EMOSIA variables related to airspace users' costs, applicable for the A^3 cost-benefit analysis [23].

Uncertain Cost Variables for Airspace Users		
Name	**Description**	**Potential Estimation Sources**
Equipment Cst K-Eu (€ K)	Cost per aircraft for equipment. This is applied to both forward fit and retrofit aircraft.	iFly Consortium
Retrofit Install Cst K-Eu (€ K)	Cost to install equipment on retrofit aircraft. This cost is incremental to the equipment cost.	iFly Consortium
Pre-Imp Cst M-Eu (€ M)	Costs incurred during the pre-implementation phase under the form of research, prototyping, trials, and simulations. (Number of person hours required for managing validating the new operational procedures)x(Cost of each person hour)	iFly Consortium
Minimum Equipage	The minimum equipage required before benefits are achieved.	iFly Consortium

Req'd %		
FOC Operating Cst M-Eu (€ M)	The annual operating costs when the cluster is fully implemented in terms of equipage and infrastructure.	iFly Consortium
One-Off Imp Cst M-Eu (€ M)	One time implementation costs that don't require replacement. (number of training person hours required for each controller)x(cost per person hour)	iFly Consortium
S1 Ground Space Imp Cst M-Eu (€ M)	Total infrastructure (non-equipage) cost required by the A^3 investment	iFly Consortium

Table 8. Uncertain EMOSIA variables related to airspace users' costs, applicable for the A^3 cost-benefit analysis [23].

8 Major Benefit Categories

The major categories of benefits have been specified by analysing the expected operational improvements emerging from the A^3 operational concept. Based on the A^3 operational concept provided in D1.1 and D1.3, the expected operational improvements of the A^3 concept are the following:

OI-1) Improvement of the en-route situation awareness of the flight crew.

OI-2) Reduction of the ANSP workload, since the tasks of aircraft separation and trajectory management within the airspace covered by A^3 are delegated to the flight crew. Since the ANSPs are relieved from these tasks, their effort is concentrated on other tasks including the management of the traffic outside the A^3 airspace, thus increasing the traffic that they could handle. This last impact implies the increase of the capacity of currently congested airspace.

OI-3) Optimization of the flight route planning according to the airspace users routing criteria, e.g., development of 4D Reference Business Trajectories with less flying time.

OI-4) Minimization of flying distance due to efficient aircraft trajectory management.

OI-5) Flight route flexibility improvement within the A^3 airspace, i.e., conflict avoidance/resolution manoeuvres causing minimum ATFM delays.

OI-6) Flight Punctuality Improvement, since specific time windows for entering and exiting the A^3 airspace will be provided for each aircraft. Covering this type of scheduling constraint in A^3 airspace enhances the reliability of the overall schedule of the flights.

Note that this list of operational improvements is based on the A^3 operational concept provided in D1.1 and D1.3.

By further analysing the above operational improvements, the following positive impacts arise: i) possible reduction of the en-route separation minima within A^3 airspace (due to OI1), ii) increase of the ANSPs productivity (due to OI2) which implies either the reduction of resources required for managing traffic for uncongested airspace or the increase of the en-route capacity in congested airspace, iii) reduction of the flying distance (less expected flying distance due to flight planning under airspace users' criteria, i.e., OI-3, iv) reduction of the

ATFM en-route delays (OI-3 & OI-5) in A^3 airspace, and v) reduction of the ATFM ground delays due to improvement of the flight schedule punctuality (OI-6).

Previous relevant economic analyses of ATM investments conclude that the monetary benefits of an ATM investment fall under the following three categories: i) increased revenue due to the potential increase of the en-route or/and ground capacity, ii) cost savings due to potential improvement on the ATM system performance, and iii) cost avoidance basically due to potential reduction of required resources for performing ATM and/or airport operations. Customizing the above categories of benefits for the A^3 operational concept, the following potential A^3 benefits arise [14] :

- Additional revenue to stakeholders. This benefit emerges from the capability of the A^3 operational concept to accommodate the expected traffic growth due to the increased capacity of the (managed and A^3) airspace (ANSP, Airspace users). The increased revenue of the ANSPs is attributed to the corresponding increased charges for the Air Traffic Services provided to the airspace users. The relevant increase in the revenue of the airspace users comes entirely from the charges of the increased annual number of flights.
- Investment expenses savings, e.g., avoidance of replacing equipment not essential by the stakeholders (ANSP, Airspace users) within A^3. This benefit cannot be further specified until the actual technological needs for A^3 operational concept are specified.
- Reduction of the resources needed for Air traffic Control Services provision (applicable in uncongested airspace)
- Reduction of the en-route cost (due to less flying distance) for the airspace users,
- Reduction of the cost emerging from en-route ATFM delays,
- Environmental benefits, which in monetary terms could be expressed by the reduction of the fines paid by airspace users for emissions and noise pollution.

Additional benefits arising from the introduction of the A^3 operational concept relate to: i) safety improvement (reduction of risk bearing incidents and accidents). However, this type of benefit is assumed to have limited direct impact to the ATM economy and therefore they are not incorporated in the economic evaluation of the A^3 operational concept. In what follows, there is an exposition of the above categories of benefits, customised for each of the involved stakeholders.

8.1 ANSPs benefits

The expected benefits for the ANSPs relate to the cost savings due to the delegation air traffic separation and the trajectory management tasks within the A^3 to the flight crew. The ANSPs workload reduction emerges from delegating the en-route traffic separation and trajectory management tasks within the A^3 airspace from the ANSPs to the flight crew. Thus, the actual benefit realised by the ANSPs relates to the reduction of resources required for managing the continuously increasing air traffic. In this context, the ANSPs will achieve to facilitate the control of the maximum possible traffic with the minimum resources. The indicators that measure this type of benefit are: i) the staff reduction due to the expected new role of the ANSP, and ii) the operating cost reduction emerging from delegating the separation task to the flight crew. In principle the estimation of the resources reduction should be performed by experts. The average cost of an ANSP resources will be based on the range of values confronted within the European ANSPs. The EUROCONTROL Central Route Charges Office would be a potential source for this type of information.

Furthermore, an additional potential benefit for the ANSPs relates to the cost savings emerging from the avoidance of rehabilating or maintaining any systems which will become useless due to the delegation of the responsibility of the separation tasks to the flight crew. More detailed description of this type of benefit could be provided when the technological requirements for the A^3 operational concept will be issued. In case that no such savings are possible from the A^3 concept, the above indicator should be disregarded.

Benefit Category	EMOSIA Variable	iFly Context Descritpion	Function of	
			EMOSIA Variable	Variable Category
Reduction of Staff Cost	S1 Staff Cst Svg TS	Staff cost savings from cluster implementation.	S1_BL_Staff_Cst_M_Eu	Baseline
			S1_RB_Staff_Cst_M_Eu.	Deterministic
Operating Cost Avoidance	S1 Operating Cst Avoid TS	Operating cost avoidance over time	S1 Benefit % Achieved	Deterministic
			S1 Operating Cst Avoid %	Uncertain

Table 9. Major Benefit Categories for the ANSPs.

The EMOSIA benefit model for ANSPs will be used for measuring the total benefits emerging from the A^3 operational concept. Table 11 presents the EMOSIA uncertain variables which should be estimated in order to measure the benefits for the ANSPS. Note that Table 10 presents the EMOSIA deterministic variables needed for calculation of the ANSPs benefits.

Deterministic Benefit Variables for ANSPs

Name	Units	Description	Function of:
S1 Benefit	€ M	Benefits accruing from the A3 investment during the life span from the ANSPs perspective.	**S1 Staff Cst Svg TS** **S1 Operating Cst Svg TS**
-S1 Staff Cst Svg TS	€ M	Staff cost savings from cluster implementation.	S1_BL_Staff_Cst_M_Eu S1_RB_Staff_Cst_M_Eu.
S1 Staff Cst Avoid % TS	decimal fraction	Staff cost reduction over time.	S1_Staff_Cst_Avoid_% S1_Benefit_%_Achieved.
S1 Benefit % Achieved	decimal fraction	Benefits are calculated assuming full infrastructure and then adjusted downward for the degree of infrastructure implementation.	Benefit_Start_Year Benefit_FOC_Year
Benefits Start Year	calendar year	The year benefits start accruing.	Imp_Start_Year Benefits_Lag
Benefits FOC Year	calendar year	The year benefits are fully achieved.	Imp_Start_Year Benefits_Lag Imp_Duration
Imp Start Year	calendar year	Implementation start year. Used for ground/space equipment.	Pre_Imp_Start_Year Pre_Imp_Duration
S1 RB Staff Cst M-Eu	€ M	Staff costs after cluster implementation.	S1_BL_Staff_Cst_M_Eu S1_Staff_Cst_Avoid_%_TS.
-S1 Operating Cst Svg TS	€ M	Operating cost savings from cluster in PES S1.	S1_BL_Operating_Cst_M_Eu S1_RB_Operating_Cst_M_Eu
S1 RB Operating Cst M-Eu	€ M	Operating costs after cluster implementation	S1 Operating Cst Avoid TS S1 BL Operating Cst M-Eu S1 Operating Cst TS
S1 Operating Cst Avoid TS	decimal fraction	Operating cost avoidance over time.	S1 Benefit % Achieved S1 Operating Cst Avoid %

Table 10. Deterministic EMOSIA variables related to ANSPs benefits, applicable for the A^3 cost-benefit analysis [22].

Uncertain Benefit Variables for ANSPs

Name	Description	Potential Estimation Provider
S1 Staff Cst Avoid%	The proportional reduction in the cost of resources used	iFly Consortium
S1 Operating Cst Avoid %	The proportional reduction in the operating cost due to less excessive delays	iFly Consortium

Table 11. Uncertain EMOSIA variables related to ANSPs benefits, applicable for the A^3 cost-benefit analysis [22].

Baseline Benefit Variables for ANSPs

Name	Description	Potential Estimation Provider
S1 BL Operating Cst M-	Baseline operating (non-staff) costs for segment 1.	iFly Consortium

Eu (€ M)		
S1 BL Staff Cst M-Eu (€ M)	Baseline staff costs for segment 1.	iFly Consortium
S1 BL Service K-Units TS (thousands of units)	Baseline number of service units for segment 1.	iFly Consortium

Table 12. Baseline EMOSIA variables related to ANSPs benefits, applicable for the A^3 cost-benefit analysis [22].

8.2 Airspace Users' benefits

The cost savings from the improvement of flight efficiency and the reduction of the en-route delays, constitute the major benefits for the airspace users. The indicators that express the above benefits are: i) the cost reduction due to the reduction of flying time, ii) the cost reduction due to the decreasing en-route delays per flight, iii) cost savings from ground delays reduction, and iv) the cost savings from the reduction of the Air Navigation Services (ANS) charges. The above indicators will be measured for a specified time horizon and annual traffic growth rate. The traffic projection used in this study will be based on the corresponding values used in similar studies, the most recent traffic performance reports issued from EUROCONTROL [10], [8], and it will be aligned with the outcome of WP7. The cost savings from flight efficiency will be based on the average proportional reduction of the annual flying time. The product of this quantity with the average cost per flying minute and the annual total flying time, constitutes an estimate of the flight efficiency cost savings. The cost savings due to the reduction of the en-route delays is estimated by the product of the average proportional en-route delays reduction per flight with the cost per minute of flight delay and the annual total number of flights in the A^3 airspace.

The increase of punctuality of flights through the A^3 operational concept will potentially reduce the ground delays. The economic impact from the reduction of ground delays is expressed by the product of the average proportion of delay reduction per flight, the average flight ground (off-block) duration and the cost of one unit of ground delay.

Finally, the delegation of the trajectory management and separation tasks from the ANSPs to the flight crew should reduce air traffic services charges for the aircraft using the A^3 airspace. This type of cost savings is expressed by the product of the expected proportion of charges reduction and the annual charges paid to the ANSPs by the airspace users.

The estimation of the reduction of the ground and en-route delays within Europe will be based on experts judgements collected through appropriate interviews. The experts will be asked to estimate the probability distribution of a set of pre-specified levels of proportional reduction of ground and en-route delays per flight given a specific assumption for the annual traffic growth, with and without the A^3 operational concept. Note that the experts should provide this type of judgments for various alternative rates of annual traffic growth thus covering a wide range of possible traffic growth scenarios. The analysis of the experts' judgements will lead to the expected value of the annual reduction of ground and en-route delays with and without the A^3 concept. A similar approach will be used for estimating the reduction of the flying time. The relevant cost units will be taken from the report "Standard Inputs for EUROCONTROL Cost Benefit Analyses" [8].

The EMOSIA benefit model for Airspace users will be used for measuring the total benefits emerging from the A^3 operational concept. Table 15 presents the EMOSIA uncertain variables which should be estimated in order to measure the benefits for the airspace users. Note that

Table 16 presents the required EMOSIA baseline variables while Table 14 presents the EMOSIA deterministic variables needed for calculation of the airspace benefits.

Benefit Category	EMOSIA Variable	iFly Context Descritpion	Function of	
			EMOSIA Variable	**Variable Category**
Cost savings from flight efficiency	S1 Efficiency Svg TS	The annual efficiency savings due to more efficient flight path.	S1_Net_Eff_Gain_per_Flt	Deterministic
			Cost_per_Flight_Min	Global Variable
			Avg_Flt_Length_Min_S1	Global Variable
			S1_RB_Annual_Flts_M.	Deterministic
Revenue Increase	S1 Net Revenues TS	The additional revenues (this should be operating profits) realised due to additional capacity.	S1_Net_Flts_Enabled	Deterministic
			Value_of_Addtn'l_Flt.	Global
Cost Savings due to reduced ANS charges	S1 ANS Charges Svg TS	Annual ANS Charge Savings	Service_Cost_Difference	Deterministic
			User_Share	Global
Cost Savings due to reduced en-route delays	S1 Delay Svg TS	Annual delay savings, calculated based on the cost per unpredictable delay minute.	S1_Net_Delay_Red_per_Flt	Deterministic
			S1_RB_Annual_Flts_M	Deterministic
			Cost_per_Unpre_Del_Min	Global
			Structural_Delay_TS	Deterministic
			S1_Net_Delay_Red_per_Flt	Deterministic
			S1_RB_Annual_Flts_M	Deterministic
			Cost_per_Struct_Del_Min	Global
			Structural_Delay_TS	Deterministic

Benefit Category	EMOSIA Variable	iFly Context Descritpion	Function of	
			EMOSIA Variable	**Variable Category**
Savings form Reduction of Structural Delay	S1 Structural Delay Svg TS	Annual structural delay savings, calculated based on the cost per structural delay minute.	S1_Net_Struct_Del_Red_per_Flt	Deterministic
			Cost_per_Struct_Delay_Min	Global
			S1_RB_Annual_Flts_M.	Deterministic

Table 13. Benefits for the Airspace users.

Deterministic Benefit Variables for airspace users			
Name	Units	Description	Function of:
Total Benefits	€ M	Total benefits including delay savings, efficiency savings, ANS charges savings, additional net revenues, and structural delay savings.	S1_Efficiency_Svg_TS S1_Structural_Delay_Svg_TS S1_Delay_Svg_TS S1_ANS_Charges_Svg_TS S1_Net_Revenues_TS
S1 Efficiency Svg TS	€ M	The annual efficiency savings due to more efficient flight path.	S1_Net_Eff_Gain_per_Flt Cost_per_Flight_Min Avg_Flt_Length_Min_S1 S1_RB_Annual_Flts_M.
S1 Net Eff Gain per Flt	decimal fraction	The percentage gain in flight path efficiency on a per flight basis.	S1_RB_Flt_Path_Ineff_%_ S1_BL_Flt_Path_Ineff_%.
S1 RB Flt Path Ineff %	decimal fraction	The rolling baseline for inefficiency in flight path.	S1_BL_Flt_Path_Ineff_% S1_Increm_Eff_Gain_% S1_Benefit_%_Achieved_TS.
S1 BL Annual Flights	Millions of flights	The baseline annual flights in PES 1.	S1_BL_Ann_Flights S1_Ann_Flt_Growth
S1 RB Annual Flts M	€ M	The rolling baseline of annual flights.	S1_BL_Annual_Flts_M S1_Net_Flts_Enabled.
S1 Structural Delay Svg TS	€ M	Annual structural delay savings, calculated based on the cost per structural delay minute.	S1_Net_Struct_Del_Red_per_Flt Cost_per_Struct_Delay_Min S1_RB_Annual_Flts_M.
S1 Net Struct Del Red per Flt	minutes per flight	The net structural delay reduction per flight, from this cluster.	S1_RB_Struct_Delay_per_Flt S1_BL_Struct_Delay_per_Flt.
S1 RB Struct Delay per Flt	minutes per flight	Rolling baseline for structural delay minutes per flight.	S1_BL_Struct_Delay_per_Flt S1_Struct_Delay_Red_% S1_Benefit_%_Achieved_TS
S1 Delay Svg TS	€ M	Annual delay savings, calculated based on the cost per unpredictable delay minute.	S1_Net_Delay_Red_per_Flt S1_RB_Annual_Flts_M Cost_per_Unpre_Del_Min Structural_Delay_TS
S1 Net Delay Red per Flt	minutes per flight	The net delay reduction per flight, from this cluster.	S1_BL_Delay_per_Flt S1_RB_Delay_per_Flt.
S1 RB Delay per Flt	minutes per flight	Rolling baseline for delay minutes per flight.	MAX(S1_BL_Delay_per_Flt*(1-S1_Increm_Delay_Red_%*S1_Benefit_%_Achieved_TS),Optimum_Delay_per_Flight)
Structural Delay TS	decimal fraction	Time series used to determine the percent of unpredictable delay that becomes structural delay.	Benefit_End_Year Final_Year
S1 Net ANS Svg per Flt	€ per flight	The net savings in enroute charges per flight.	S1_RB_ANS_Charge_per_Flt S1_BL_ANS_Charge_per_Flt.
S1 RB ANS Charge per Flt	€ per flight	The user charge per flight after the cluster improvement.	S1_BL_ANS_Charge_per_Flt S1_ANS_Charge_Red_% S1_Benefit_%_Achieved_TS.
S1 Net Revenues TS	€ M	The additional revenues (this should be operating profits) realised due to additional capacity.	S1_Net_Flts_Enabled Value_of_Addtn'l_Flt.
S1 Net Flts Enabled	flights	The annual number of flights enabled by the cluster.	S1_RB_Flts_not_Accom_ S1_BL_Flts_not_Accom.
S1 RB Flts not Accom	flights	The rolling baseline of flights not accommodated.	S1_BL_Flts_not_Accom S1_Flts_Enabled S1_Benefit_%_Achieved_TS.

Table 14. Deterministic EMOSIA variables related to airspace users' benefits, applicable for the A^3 cost-benefit analysis [23].

Uncertain Benefit Variables for airspace users

Name	Description	Estimation Provider
Cost per Flight Min (€)	Cost per flight minute. Essential input for assessing the incremental cost savings from flight efficiency.	iFly Consortium
Cost per Struct Del Min	Cost per structural delay minute	iFly Consortium Standard Inputs for EUROCONTROL CBA [8]
Cost per Unpre Del Min (€)	Cost per unpredictable delay minute.	iFly Consortium Standard Inputs for EUROCONTROL CBA [8]
S1 Ann Flight Growth (%)	The annual flight growth in European Airspace.	iFly Consortium Standard Inputs for EUROCONTROL CBA [8] Performance Review Report [10]
S1 Flts Enabled (flights per year)	The annual flights enabled by the cluster.	iFly Consortium
Minimum Equipage Req'd %	The minimum equipage required before benefits are achieved.	iFly Consortium
S1 Increm Delay Red %	The % reduction of remaining delay due to the cluster. A value of 1 would eliminate all unpredictable delay.	iFly Consortium
S1 Increm Eff Gain %	The percent of the remaining inefficiency reduced at the end of the cluster implementation.	iFly Consortium
Percent Structural Delay (%)	The final amount of delay incurred in the baseline that becomes structural then unpredictable.	iFly Consortium
S1 Struct Delay Red %	The % reduction of remaining structural delay due to cluster.	iFly Consortium

Table 15. Uncertain EMOSIA variables related to airspace users' benefits, applicable for the A^3 cost-benefit analysis [23].

Baseline Benefit Variables for airspace users

Name	Description	Estimation Provider
S1 BL Flt Path Ineff%	The proportion that expresses the baseline inefficiency	iFly Consortium
S1 BL Flts not Accom (flights)	The baseline annual flights not accommodated due to capacity constraints.	iFly Consortium
S1 BL Delay per Flt (minutes per flight)	The baseline delay minutes per flight.	iFly Consortium
S1 BL Struct Delay per Flt (minutes per flight)	The baseline structural delay minutes per flight.	iFly Consortium

Table 16. Baseline EMOSIA variables related to airspace users' benefits, applicable for the A^3 cost-benefit analysis [23].

9 High Level Experimental Design and Open Issues

The measurement of the cost and benefits elements for each category of stakeholders (i.e., airspace users, ANSPs, and airports) will be performed by calculating the EMOSIA variables presented in the corresponding tables for section 8. A key issue in performing the above calculations relates to the estimation of: i) the Global and Timing variables presented in Tables 1-2, ii) the Uncertain variables presented in Tables 5, 8, 11, 14, 18, 22, and iii) the Baseline Variables presented in Tables 15, 19, and 23.

The changes for the ATM system proposed through iFly project are still at the stage of the definition of the operational concept. Thus, given the time constraints of the projects it is not possible to conduct any shadow mode field trials or simulation runs in order to provide objective observations for the performance of the proposed cluster of improvements. Alternatively, the estimation of the Global, Timing and Baseline variables will be based on values provided by similar ATM cost-benefit analysis studies or subjective estimations provided by experts.

The uncertain variables require the provision of three values (high, medium, and low). Each of the above values will be based on subjective estimations provided by a group of experts. In section 8, an organization (participating in the project) is assigned to each of the above variables, with the task to provide the subjective estimations for the corresponding variable. The collection of the above estimates will be collected through a questionnaire which will be presented in Deliverable D6.3.

In addition, the major prerequisites for the implementation of the proposed cost-benefit analysis and the collection of the required data relate to the following issues:

- Specification of the categories of A^3 technologies and the associated avionic costs. No estimation of the cost and benefits variables can be made unless the functionalities and potential technologies of the A^3 operational concept are specified.
- Specification of the geographical area covered by the A^3 operational concept. Similarly on estimation about the additional operating and capital costs can be made unless the area covered by A^3 is specified.
- Specification of the A^3 airspace, i.e., determine which part of the European airspace (boundaries) will be used in terms of the A3 operational concept.

The above issues will be specified on the basis of the operational scenarios that will be defined within task 6.3 “Data Collection for Cost-Effectiveness Analysis” of WP6.

10 Cost-Benefit Analysis Management Plan

The implementation of the proposed methodological framework includes the following activities:

- Definition of operational scenario. It involves the determination of the geographical scope and the boundaries of the airspace that A^3 will take effect. This is an essential prerequisite in order to estimate other cost benefit analysis variables such as the number of flights, the number of aircraft flying in A^3 airspace etc.
- Development of Data Collection and Analysis tools, i.e. questionnaire for collecting estimates for the uncertain, global, and timing variables.
- Identification of Experts. Each partner involved in the measurement of the cost-benefit analysis variables as indicated in Tables 1-16, should identify a set of experts in their organization for providing the corresponding estimates.
- Data Collection (completion of data collection forms). This process refers to the determination of the values of some cost-benefit analysis variables from existing studies.
- Expert Judgments Collection (completion of questionnaire).
- Deliverable D6.3: "Report on Data Collection".
- Perform the analysis. This process involves the consolidation, processing, and analysis of all the data collected through the data collection process. The analysis of data should include the determination of the Net Present Value (NPV). Moreover, sensitivity analysis and risk analysis will be performed in order to assess the robustness of the estimated NPV.
- Draw Conclusions
- Deliverable D6.4(i) "Interim Cost-Effectiveness Analysis" and Deliverable D6.4 "Cost-Effectiveness Results Presentation".

Figure 4 presents the time-schedule of the above activities. The proposed schedule takes into account the deadlines of the Deliverables D6.3 and D6.4, and the interim report D6.4(i) according to the initial[2] iFly Technical Annex [1].

[2] By the time that this version of the report was issued, the revised description of work time was not officially approved by the EC. Upon EC approval, the time plan presented in the section will be revised accordingly.

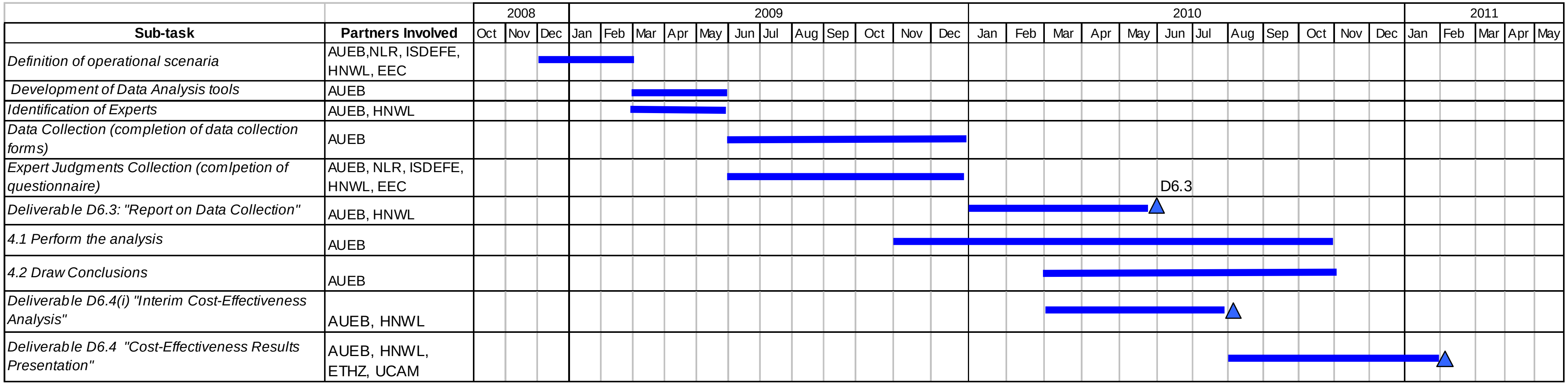

Figure 4. Time schedule of the cost-benefit analysis activities[3].

[3] This time plan was based on the Project Schedule and Work plan included in the Initial Description of Work of the iFly Project. By the time that this version of the report was issued, the revised description of work time was not officially approved by the EC. Upon EC approval, the time plan presented in the section will be revised accordingly.

11 Concluding Remarks

The economic assessment of the A^3 operational concept is achieved through the cost-benefit analysis of the associated positive and negative impacts to each stakeholder category affected by the proposed concept. The objective of this report is to present the methodological framework for performing the above stated cost-benefit analysis.

The proposed methodological framework aims to identify the major cost and benefits indicators and metrics for each category of stakeholders by utilising standard ATM operational concept validation methodologies like the E-OCVM and the EMOSIA. Each of the cost and benefit indicators is associated with its counterpart variable in EMOSIA cost and benefits models. In this context the measurement of each indicator is achieved by utilising the corresponding EMOSIA cost and benefit models per stakeholders category. In addition any EMOSIA variable needed for the calculation of the above cost and benefit indicators is presented in order to clarify the input required for performing the cost benefit analysis.

The determination of the values needed for measuring the cost benefit analysis variables constitutes the next step in applying the proposed methodology, and will be addressed in WP6.3 “Data Collection for Cost-Effectiveness Analysis”. The associated values along with the data collection tools will be provided in D6.3 “Report on Data Collection”.

12 References

[1] iFly Consortium (2007). Contract for Specific Targeted Research or Innovation Project, Annex I: Technical Work. EC project iFly (TREN/07/FP6AE/S07.71574/037180 IFLY), Project for EC-DG-TREN.

[2] iFly Consortium (2008). Deliverable D1.1 “A^3 High Level ConOps”. EC project iFly (TREN/07/FP6AE/S07.71574/037180 IFLY), Project for EC-DG-TREN.

[3] iFly Consortium (2008). Deliverable D1.2 “A3 Airline Strategy”. EC project iFly (TREN/07/FP6AE/S07.71574/037180 IFLY), Project for EC-DG-TREN.

[4] iFly Consortium (2008). Deliverable D1.3 “A3 ConOps”. EC project iFly (TREN/07/FP6AE/S07.71574/037180 IFLY), Project for EC-DG-TREN.

[5] iFly Consortium (2008). Deliverable D7.1a “Scoping and Safety Target Report”. EC project iFly (TREN/07/FP6AE/S07.71574/037180 IFLY), Project for EC-DG-TREN.

[6] iFly Consortium (2008). Deliverable D10.1i “Overall Validation Strategy/Plan”. EC project iFly (TREN/07/FP6AE/S07.71574/037180 IFLY), Project for EC-DG-TREN.

[7] EMMA2 Consortium(2007). D6.1.1a: EMMA2 Validation Plan. Project EMMA2 Contract no. TREN/04/FP6AE/SI2.374991/503192.

[8] EUROCONTROL (2007). Standard Inputs for EUROCONTROL Cost Benefits Analyses. (http: //www.eurocontrol.int / ecosoc/ public/ standard_page/ documents.html_)

[9] EUROCONTROL (2007). http: //www.eurocontrol.int / ecosoc / public / standard_page/ emosia.html

[10] EUROCONTROL (2007). Performance Review Report: An Assessment of the Air Traffic Management in Europe during the Calendar Year 2006. Performance Review Commission. ‘

[11] EUROCONTROL (2006). Final Report on the Generic Cost Benefit Analysis of A-SMGCS. European Air Traffic Management Programme.

[12] EUROCONTROL (2005). EMOSIA User’s Guide. European Air Traffic Management Programme.

[13] EUROCONTROL (2005). European Operational Concept Validation Methodology. European Air Traffic Management Programme.

[14] EUROCONTROL (2003). Approach to Assess the Benefits and Costs of ATM Investments. ESC/STRAT/SPF_ECONOMICS/DOC/20.

[15] Helios Technology (2002). Cost Benefit Analysis of Free Route Airspace. Eurocontrol P562.2D001.

[16] Helios Technology (2005). Cost Benefit Analysis of Chain including the implementation of E-DIT. EUROCONTROL P147.D012.

[17] ICAO (2005). Global Air Traffic Management Operational Concept. Doc 9854 AN/458.

[18] SESAR Consortium (2006). Review of existing Tools and preparation of the CBA model. T1.4.1/D2, DLT-0607-141-00-07.

[19] SESAR Consortium (2006). "Cost Benefit Modelling Review and assess existing Cost Benefit methodologies and tools and capture lessons learnt and expectations", WP1.4.1/D1, DLT-0507-141-00-10.

[20] White, J.A., K.E. Case, D.B. Pratt, M.H. Agee (1998). Principles of Engineering Economic Analysis, 4th Edition, Wiley, New York.

[21] iFly Consortium (2008). Deliverable D1.1: Autonomous Aircraft Advanced High Level ConsOps. EC project iFly (TREN/07/FP6AE/S07.71574/037180 IFLY), Project for EC-DG-TREN.

[22] EUROCONTROL (2005). EMOSIA, Air Navigation Service Provider Model. EMOSIA II/ DOC/ 3.4

[23] EUROCONTROL (2005). EMOSIA, Airline Model. EMOSIA II/ DOC/ 3.1.

[24] EUROCONTROL (2005). EMOSIA, Airport Model. EMOSIA II/ DOC/ 3.5.

13 Appendix 1: E-OCVM steps and activities

Step	Activity	Description
Step 0 "State Concept and Assumptions"	0.1	Understand the problem
	0.2	Understand the proposed solution(s)
Step 1 "Set Validation Strategy"	1.1	Identify the stakeholders, their needs, issues, and involvement in the validation
	1.2	Identify the level of maturity to ensure that expectations are realistic
	1.3	Describe the expected outcome of the validation process
	1.4	Identify high level performance objectives
	1.5	Establish initial validation needs, potential scope and draft plan
	1.6	Select validation tools or techniques
	1.7	Define validation strategy and plan
Step 2 "Determine the Experimental Needs"	2.1	Identify stakeholder acceptance criteria and performance requirements
	2.2	Identify low level validation objectives
	2.3	Refine validation strategy
	2.4	Identify indicators and metrics
	2.5	Specify scenarios
	2.6	Produce experimental plan
	2.7	Produce analysis plan
	2.8	Produce detailed experimental design
	2.9	Identify assessment requirements
	2.10	Prepare the platform or facility
	2.11	Conduct pre-exercise testing
Step 3 "Conduct the Experiment"	3.1	Conduct validation experiment
	3.2	Assess for unexpected effects or behaviors
Step 4 "Determine the Results"	4.1	Perform analysis specified in the analysis plan
	4.2	Prepare analysis contributions
	4.3	Prepare validation report
Step 5 "Information for Dissemination"	5.1	Disseminate information to stakeholders and decision makers
	5.2	Draw conclusions and decide on actions feedback to validation strategy.