E.02.14-D25-CASSIOPEIA-Final Project Report

Document information	
Project Title	CASSIOPIEA
Project Number	E.02.14
Project Manager	The Innaxis Foundation and Research Institute
Deliverable Name	Final Project Report
Deliverable ID	D25 (D0.5 in contract)
Edition	01.00.00
Template Version	03.00.00
Task contributors	
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Abstract

The final report of the CASSIOPEIA project provides a publishable summary of the results. In addition it lists all deliverables, dissemination activities, eligible costs, deviations, bills and lessons learned.

Authoring & Approval

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Rational for rejection
None.

Document History

Edition	Date	Status	Author	Justification
00.00.01	30/10/2013	Submitted	INNAXIS	New Document
00.00.02	14/11/2013	Submitted	INNAXIS	Including ECTL comments
00.00.02	19/11/2013	Submitted	INNAXIS	Including ECTL comments

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

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1 Publishable summary

Objective

The goal of the CASSIOPEIA project is to improve the way future ATM operational concepts are modelled. The solution proposed entails using a single software platform that contains all the elements necessary to model operational scenarios at different scales, allowing the researchers to provide further details to its elements which are saved for future scenarios if needed.

While elements of CASSIOPEIA may serve multiple goals, including the operational scope, the focus of the modelling is to understand how those operational scenarios are to be designed and thus, CASSIOPEIA's methodology and tool-set should be understood as a policy tool rather than an operational piece for those operational concepts to be implemented.

Approach

The main hurdle towards modelling the operational scenarios is designing the complexity of the system. Complexity should be understood here as the interaction of multiple elements which have a non-linear behaviour, driving the ultimate state of the scenario. The complexity of the system cannot be achieved using existing tools in the ATM domain through model design parameters, due to the associated non-linearities and the impossibility of deriving analytical models. The use Agent Based Modelling (ABM) allows us to model the elements interacting, which will create the complex system.

In ABM, the elements capable of making decisions are considered "agents". ABM allows us to design the agents' independent methodologies to reach their objectives and decision-making processes. Each agent executes its computer processes autonomously, depending on its particular observation of the environment. An agent executing a decision will change the environment for other agents, affecting their decisions, which in turn change the environment for the rest. The interactions among the agents result in a changing environment, which is then considered a complex system. These interactions not only depend on the operational concept being studied, but also on the regulatory framework applied.

Designing a platform that can be used to model different scales from a time, spatial and elements perspective is the most challenging demand of CASSIOPEIA. To ensure the validity of the platform for multi-scalar studies, three different operational scenarios were selected to be analysed. The selection of the operational scenarios was carefully carried out, receiving input from European aeronautical stakeholders including airlines and ANSPs. The selection process proposed three operational cases:

1. Local environmental restrictions limiting airport and terminal airspace capacity:

Case Study 1 contains the simulation of different scenarios in which the night curfew for commercial flights between 23:00 and 05:00, presently applied at Frankfurt Main airport, is extended to some or all the top 10 European airports by passenger traffic. A number of different scenarios have been calculated in order to compare the application of this measure to individual airports being hub of Network Carriers, or main base of Low Cost Carriers. Additional scenarios contemplate the effects of modifying the night ban interval for one or more airports, increasing the curfew time at the beginning or at the end of the interval.

2. En-route slot exchanges through CDM:

Case Study 2 uses the agent based modelling capabilities of the CASSIOPEIA's platform to analyse to what extent a collaborative decision making mechanism on en-route regulated slots can help reducing the impact cost for operators. To this end, a collaborative exchange mechanism was developed in which operators are given the chance to negotiate between them and swap slots by an economic compensation in return. The exchange mechanism has been designed following a Game Theory approach. Different strategies were designed for operators to reach particular objectives.

Additionally, we allowed operators to modify their strategy applying self-learning processes. Additional properties, specific to the air traffic domain are also considered, such as no cost revelation, anonymity and feasibility of the solution.

3. Use of variable aircraft speeds to optimise delay cost recovery (dynamic cost indexing):

The objective of Case Study 3 is to demonstrate the usefulness of applying Agent Based Modelling to understanding the impact of an increased use of dynamic cost indexing (DCI) into a major European hub. DCI is the use of variable aircraft airspeeds, employed as an attempt by airlines to better manage delay costs. Increased use of DCI implies improved temporal trajectory flexibility. This flexibility provides utility to the Airline Operators (AOs) and potentially causes ANSP dis-utility. The indicators are thus primarily geared to measuring the cost benefits for AOs and the potential workload increase imposed on ANSPs. Trade-offs will be examined using three scenarios of DCI uptake by airlines, nested by four levels of DCI implementation rules. The temporal scope is from current to medium-term future operations.

The particular case studies developed modelled potential future operational concepts at current level of traffic (FOC-CTL) to understand the implications that those operational concepts would have if they were implemented today. Only FOC-CTL is within scope of Cassiopeia although the same methodology and even the same coded platform could be used for the simulation of the future operational scenario on future traffic levels (FOC-FTL) and the current operational scenario with future traffic levels (COC-FTL), to achieve a full understanding of changes to the system.

Software architecture

The CASSIOPEIA multi-agent system was implemented with component-based software architecture with the following main components (figure 1):

- *Agent model*. The agent model is formulated using the language ADF, a subset of XML language, which follows a declarative representation that provides comprehension and flexibility to easily make changes in the model.
- *Simulation engine*. The simulation engine is based on JADEX, a general framework for agent-based modelling. The simulation engine uses a continuous simulation clock and provides distributed operation.
- *Working memory database*. A relational database, implemented using MySQL, contains agent instances and environment data. This solution is flexible to easily represent and store the large amounts of data corresponding to specific case studies and to consult data results generated by the simulation process.

In order to facilitate re-usability, the software architecture has been conceived using different levels of generality with two main parts:

- *A general software platform*. A separated common general software platform has been implemented to be reusable across the three case studies defined in the Cassiopeia Project for different ATM problems. This platform contains the general software components that are case independent such as the simulation engine, the working memory database and reusable definitions for agents.
- *Case definition*. Each one of the three case studies has been additionally formulated using specific definitions for the agent model (in ADF language), the behaviour of agents (in Java language) and agent instances and environment (in MySQL database).

Key Results

Regarding the modelling methodology, ABM has been proved adequate for multi-scalar time, spatial, and element-wise dimensions. The operational scenarios chosen and insights on those operational scenarios not reachable through any other simulation platforms (neither generic tools like Matlab or

Excel or specialized airspaces simulators) are reachable through the simulations of the CASSIOPEIA platform due to the complexities of modelling interactions between agents.

Regarding particular case studies, the following key conclusions can be extracted from the simulations performed:

Case Study 1:

Economic impact on airlines

Results show that the restrictions imply a relatively important economic impact on airlines, both for network carriers with a hub at the regulated airport and for the rest of the companies. The same conclusion applies to low cost carriers. The indicators that measure this impact show a small reduction in percentage of the number of flights, but it has to be considered that this percentage affects a very large figure as it is the revenues of the airline and may produce a non-negligible impact on profits.

These indicators are sensitive to the variation of the size of the night ban interval with greater impact at night than in the morning.

Economic impact on airports

Airports' economy is equally affected by the restrictions. Results show that this impact is different depending on the airport, and it can vary appreciably from one airport to another. This fact depends on the number of night flights that each airport has before the night ban implementation, and the possibilities of that airport to accommodate potential re-scheduling of the airlines as a consequence of the restriction.

Results also show how alternate airports, where airlines move the flights that cannot re-schedule in the restricted airport, increase their economic results, in a larger proportion in airports relatively small, compared to the restricted airport.

Socio-economic impact on local communities

Impact on local communities, both in terms of yearly economic losses and jobs affected by having lower traffic is very important. It has to be taken into account that these socio-economic figures measure the full range of effects: direct, indirect, induced and catalytic.

Results for individual airports are consistent with other studies on this subject already published. The different scenarios in Cassiopeia give an economic impact of the night ban at Heathrow from 66 to 2,280 million € and the jobs losses from 1,100 to 38,179 which is in line with similar studies. Cassiopeia results for Paris Charles de Gaulle airport also gives impacts of the night ban on employments in tenths of thousands of Euros.

Environmental impact

Regarding noise, it shifts to the hours adjacent to the ban, and also and more heavily to the alternate airport where an important portion of the flights are moved.
The impact of the restrictions on emissions affecting local air quality in the airport area is almost negligible.

Local environmental restrictions in the form of night curfew may lead to important effects to airline economic results, airport revenues while environmental effects are limited since the noise is obviously reduced in the restricted time band but it is increased in the close time zones and alternative airports.

Case Study 2:

The first important fact to consider is that the average (or total) delay does not change with the CDM slot distribution. It is only the distribution of the delay that changes. After the CDM process, the delay distribution is flattened. Usually the FPFS solution would not assign large delays to any flight, but after the CDM process, some flights might decide to incur in higher delays in exchange of an economic

compensation. Simulations show cost reductions of about 30% after using CDM distribution of ATFM slots without increasing total delay.

There seems to be a critical delay point around the 15 minutes mark. At this point FPFS and CDM delay distributions coincide, exchanges take place mainly between flights below this threshold of delay and flights with delay over the threshold. It may be worth exploring further mechanisms limiting the maximum/minimum amount of delay to be traded around this critical point. Allowing trades only over this threshold may reduce the number of exchanges while probably keeping a fair cost reduction.

The sensibility analysis performed very positive. Even if a relatively large proportion of the agents suddenly decided to change its behaviour, the impact over the overall system was still bounded. As the CDM mechanism self-regulated, no indicator showed abnormal results; the amount of delay exchanged, cost reductions, and economic compensations stayed in a reasonable order of magnitude. As we observed, this was in part due to other agents adapting their behaviour and minimizing the impact of the change. This self-regulation ability is highly desirable in any CDM process, as it reduces the need for external monitoring.

Case Study 3:

Output from multiple scenarios, covering three time frames, have been compared with the baseline situation using predictability, cost-efficiency and environmental impact indicators. The overall results are broadly consistent with expected outcomes, such as arrival delay reduction when DCI is applied and credible cost outputs. DCI usage leads to a change in the cost dynamics: the cost of fuel increases with the additional fuel burn in contrast with passenger, crew and maintenance costs, which decrease as a function of time saved. A dominating effect of the high fuel price scenario was observed, more than counteracting the effect of non-fuel cost savings, resulting in a net loss when DCI was applied. This has important implications under changing fuel price regimes in future.

An informative outcome was the significant average passenger, crew and maintenance (i.e. non-fuel) cost savings per flight under scenario S102. This scenario simulated the medium-term future with six airlines using DCI at Zürich Airport, with a company policy applied of only recovering delay to a residual of 10 minutes. Leaving this residual demonstrated superior results compared with the ‘rule of thumb’ employed by many airlines of recovering all delay above a certain threshold.

Concluding remarks

The achievements of the CASSIOPEIA project includes not only the particular results of each case study, which provides state of the art knowledge of unseen paradigms; but also the main objective was achieved, designing a flexible platform that can be further extended and applied to other scenarios with different scopes. The exploitation of the current results of the simulations of the Case Studies will enrich the existing working groups and scientific activities within their context. A deeper analysis of the operational scenarios covered in CASSIOPEIA is achievable through moderate work allocation through the addition of new case studies that could complement how different technologies could make a breakthrough in terms of cost savings. In this context, CASSIOPEIA would be a powerful tool to complement other CBA techniques. The consortium partners are currently exploring both levels.

Furthermore, the CASSIOPEIA methodology could be used to expand the platform to cover additional operational cases. Agent-based modelling is a powerful modelling technology to be used in operational scenarios where a high number of actors work together to find a global solution that optimises the use of ATM resources. Therefore, the CASSIOPEIA methodology and platform could be used to support such technology demonstrators.

2. Introduction

a. Purpose of the document

The purpose of this document is to:

- Summarise the technical results and conclusions of the project (Publishable Summary);
- Provide a complete overview of all deliverables;
- Provide a complete overview of all dissemination activities (past and in progress). Where appropriate, provide feedback from presentations. Describe exploitation plans.
- Provide a complete overview of the billing status, eligible costs, planned and actual effort (incl. an explanation of the discrepancies).
- Analyse the lessons learnt at project level.

b. Intended readership

This report is written for the professional reader and assumes an understanding of air transport and ATM. Without detriment to appropriate referencing and delineation, the text is not cluttered with explanations of common acronyms or principles.

c. Inputs from other projects

No inputs from other projects have been used.

d. Glossary of terms

Term	Definition
ATC	Air Traffic Control
ATM	Air Traffic Management
ATRS	Air Transport Research Society
DCI	Dynamic Cost Indexing
CBA	Cost-Benefit Analysis
IADIS	International Association for the Development of the Information Society
ICAO	International Civil Aviation Organisation
JATM	Journal of Air Transport Management
PAAMS	Conference on Practical Applications of Agents and Multiagent Systems
TRIP	Transport Research and Innovation portal
UDPP	User-Driven-Prioritisation Process
UPM	Universidad Politécnica de Madrid
UPM-ETSIA	Escuela Tecnica Superior de Ingenieros Aeronauticos of UPM

URL	Uniform Resource Locator
WCTR	World Conference on Transport Research

3. Technical project deliverables

Table 1 List of project deliverables

Number	Title	Short Description	Approval Status
D1.1	High-Level Functional Specification - Model Inputs	This document reports on a survey of ATM stakeholders, executed in order to establish priorities for the selection of future scenarios and case studies to be adopted as part of a new ATM performance model.	Approved
D1.2	High-Level Functional Specification - Model Outputs	This report presents the results of a major stakeholder survey on ATM performance assessment.	Approved
D1.3	Non-Functional Requirements	This document provides the CASSIOPEIA project with a toolset to keep track of the different non-functional requirements.	Approved
D2.1a	Logical Architecture	In this architecture document, the basic elements for the different modelling elements are laid out, presenting the most relevant features of the regulation, network and stakeholders models.	Approved
D2.1	Regulation Models	This document defines the model of the regulations to be applied in the three case studies.	Approved
D2.2	ATM Network Models	This document details the model of the network components of the CASSIOPEIA framework. The network models have been structured in three different modules: Network Management, Arrival/Departure Module and Module. The document details the model chosen for each of the modules.	Approved
D2.3	Agent Models	This document describes an agent-based modelling architecture for the three case studies selected for the project: modelling of local capacity restrictions and their impact across the European air transport network; real-time en route slot trading; and dynamic cost indexing use by a significant number of airspace users.	Approved
D2.4	Exogenous Factors Models	This document reports on the creation of three modules aiming to model the impact of external factors into the ATM system: specifically, the exogenous factors considered are adverse meteorological conditions, network connectivity (in terms of patterns of connecting passengers) and fuel price.	Approved

D5.2	Communication and Dissemination Intermediate Report	This document reports all past and future actions as of end of March 2012 for the CASSIOPEIA project.	Approved
D2.5	Performance Indicators Models	This document defines how the expected outputs will be computed from the actual parameters of the model.	Approved
D2.6	Performance Data Models	This document describes the performance assessment methodology for each of the Case Studies carried out in CASSIOPEIA. The objective of this task is to prepare the scenarios taking into account inputs and outputs expected, as well as define the different strategies and tactics followed by the agents in each Case Study. It also prepares the methodology to analyse the output data.	Pending approval
D2.7	Data Requirements Report	This document will take care of the requirements the data must accomplish to serve the modelling and the constraints the data availability may introduce in the modelling. This will be intimately related to the inputs of stakeholders gathered at working sessions.	Approved
D3.1	Software Requirements Specification	This document is the formal specification of software requirements of the CASSIOPEIA research project.	Approved
D3.2	Software Design Document	This document shows the results of the software design process fed on different functional and non-functional requirements. The document should be useful to understand the overall structure of CASSIPEIA framework and architecture.	Approved
D3.3	Model Dataset	This document reports on the preliminary analyses performed on the sources of information available to the Consortium members, with the aim of ensuring that each one of the requirements was actually supported by data. For each Case Study, its requirements are matched with one or more data sources, with a special focus on *accessibility* and *integrity*.	Approved
D3.4	System Implementation	This document describes the results of the activity developed in Software Programming. In this deliverable, the implementation details of the software system are presented. The document describes the software architecture, explaining how each component has been implemented using programming languages and software tools.	Approved
D3.5	User Manual	This document is the user manual.	Approved

D3.6	System Evaluation Document	In this deliverable, the results of the evaluation of the software system are presented. In particular, the document mainly describes the software validation performed with the help of a specific simulation case for evaluation and the review of the satisfaction of both functional and non-functional software requirements.	Approved
D4.1	Study Report - Case Study 1	This document describes Case Study 1. The purpose of this case is to illustrate the capabilities of the combination of Complex Systems Science and Agent Based Modelling for the study of the impact of regulatory changes on the European Air Traffic System and their environmental and economic consequences.	Approved
D4.2	Study Report - Case Study 2	This document describes Case Study 2. This case uses the agent based modelling capabilities of the Cassiopeia's platform to analyse to what extent a collaborative decision making mechanism on en-route regulated slots can help reducing the impact cost for operators.	Pending approval
D4.3	Study Report - Case Study 3	This document describes Case Study 3.The objective of Case Study 3 is to demonstrate the usefulness of applying ABM to understanding the impact of an increased use of dynamic cost indexing (DCI) into a major European hub.	Pending approval
D5.3	Communication and Dissemination Final Report	This document reports all past and future Communication and Dissemination actions as of 15th September 2013 for the CASSIOPEIA project.	Pending approval

4. Dissemination activities

a. Presentations/publications at ATM conferences/journals

The following list includes those activities that took place or will take place in ATM conferences or will be published in journals.

i. CASS.CAD.003 ATM Performance Seminar and Workshop

The Air Traffic Management Performance - Seminar and Workshop was held at the University of Westminster in central London on the 10th of January, 2012. Almost 60 attendees (including members of the CASSIOPEIA team) participated in the workshop, with representation from airlines, airports, ANSPs, EUROCONTROL, academia, consultancy, associations, policy makers and regulators.

A series of presentations were made by the Team, including feedback on key results from the earlier stakeholder survey (conducted September - October 2011) and an introduction to the shortlisted case study candidate topics.

A guest speaker from the FAA gave his perspective on the value of performance measurement in strategic planning and joined one of two discussion panels.

The attendees each took part in one of five breakout sessions to discuss the corresponding case study topic and their potential involvement. The second discussion-panel outlined the questions and ideas raised during the breakout sessions.

Attendees have been kept informed, through a series of mail-outs, of progress of the project throughout.

ii. CASS.CAD.007 – Poster presentation at SID 2012

The Second SESAR Innovation Days (SID) were held in Braunschweig, Germany on the 27th - 29th of November, 2012. This conference is considered a key showcase-scenario in the European aeronautical research arena, since the main companies involved are key partners of SESAR. Dissemination of CASSIOPEIA was implemented through the presentation of a poster which explained the programming architecture, provided an introduction to agent-based models, and presented the project's case studies.

iii. CASS.CAD.026 - Case Study 3 presentation at INFORM Airline Forum

The Second INFORM Airline Forum was held on the 18th - 20th September, 2013 at London Heathrow Airport, co-hosted by INFORM and British Airways. The forum focused on the challenges airlines face including: disruption recovery; hub monitoring for situational awareness; effective passenger-transfer management; and delay management and avoidance. CASSIOPEIA tackles all of these matters in Case Study 3. It was therefore a perfect opportunity to share the approach with the industry stakeholders. An outline of Case Study 3 was presented to the audience of airline delegates. Significant interest was shown by these airline delegates, particularly by Finnair. The team plans to follow this up and capitalise on this interest by sharing the results of Case Study 3 with INFORM and Finnair.

iv. CASS.CAD.019, CASS.CAD.023, CASS.CAD.031, CASS-CAD.034 - Journal papers for JATM

The *Journal of Air Transport Management* (JATM) sets out to address, through high quality research articles and authoritative commentary, the major **economic**, **management** and **policy** issues facing the **air transport** industry today. It offers practitioners and academics an international and dynamic forum for analysis and discussion of these issues, linking research and practice and stimulating interaction between the two.

CASSIOPEIA partners plan to publish **four papers** during 2014 in the JATM, with the first three focusing on the results of the three different case studies and the fourth describing the computer infrastructure developed in the project.

v. CASS.CAD.025 - Poster presentation at SID 2013

The third SESAR Innovation Days will be hosted by the KTH Royal Institute of Technology in Stockholm, Sweden from the 26th to the 28th of November, 2013. It will include sessions of the WP-E Research Networks and keynote presentations.

CASSIOPEIA's partners are preparing a poster to present at this event summarizing the developments performed during the last year. Half of the poster will present the agent-based model platform generated for the project, while the other half will present a summary of the results obtained in the different case studies.

vi. CASS.CAD.029 – Presentation of Case Studies 2 and 3 to EUROCONTROL/SESAR Working Group on UDPP

CASSIOPEIA's partner, University of Westminster, is in conversation with EUROCONTROL's Nadine Pilon to present Case Studies 2 and 3 to the SESAR User Driven Prioritisation Process (UDPP) Concept Group (P7.6.4). This group leads the research for the UDPP, for which Case Studies 2 and 3 demonstrate possible alternatives and their effects.

b. Presentations/publications at other conferences/journals

The following list of dissemination activities includes presentations and publications through non-ATM forums.

vii. CASS.CAD.013 – Presentation of paper at IADIS 2012

The International Conference of Intelligent Systems and Agents (IADIS) 2012 was held in Lisbon, Portugal, from the 21st to the 23rd of July, 2012. This conference was part of the Multi-Conference on Computer Science and Information Systems (MCCSIS) 2012, which received a total of 1,036 submissions. The IADIS Intelligent Systems and Agents (ISA) 2012 conference addresses in detail two main aspects: Intelligent Systems; and Agents. The conference aims to make a contribution valuable to academics and practitioners. So, both fundamental and applied research is considered relevant.
CASSIOPEIA's partner, UPM's Faculty of I.T, succeeded in presenting the paper '*Agent-based simulation to assess air traffic management strategies'* in this conference. This paper presents current research work to build an agent-based framework for modelling air traffic flow and management decisions. We are applying this approach to the European air-traffic management system. One of the results of this work is an assessment tool as a software environment able to model and simulate the behaviour of air-traffic management strategies. Each simulation provides performance measures that help to compare the effectiveness of different, alternative strategies.

viii. CASS.CAD.027 - Case Study 1 presentation at Congreso de Ingeniería del Transporte

The 11th Transport Engineering Conference (CIT) 2014 will be held on the 9th to the 10th of June, 2014. Its goal, as with the preceding CIT conferences, is to foster a forum to exchange experiences, knowledge and the latest developments in the field of transport, exploring every mode and area (planning, modelling, management, financing of infrastructures and services, construction and operation of infrastructures, environmental issues, intelligent systems and their implementation on the transport sector, etc.). Therefore, the conference is directed not only towards researchers but also towards planners and other professionals working in the transport sector in their respective areas of focus.
CASSIOPEIA's partner UPM - ETSIA, will make a presentation at this conference detailing the results of Case Study 1.

ix. CASS.CAD.028 - Case Study 1 and/or 3 presentation(s) at the Air Transport Research Society's annual conference

The ATRS annual conference includes participation from all facets of the aviation industry: airlines, airports, ATC, aerospace, government officials, consultants and academics. In addition to paper presentations, the conference will also include invited keynote speakers from industry and a panel session on current and critical issues facing the industry. In the past, in every year, we have published selected papers from the ATRS conferences in the ATRS special issue of the Journal of Air Transport Management, Transportation Research E, the Journal of Air Transportation, and, less frequently, in Transport Policy (the Official Journal of WCTR Society).

CASSIOPEIA partners are planning to again present the results of different case studies to these journals for publication.

x. CASS.CAD.032 - Presentation of paper to the 12th International Conference on PAAMS

The International Conference on Practical Applications of Agents and Multi-agent Systems (PAAMS) provides an international forum to present and discuss the latest scientific developments and their effective applications, to assess the impact of the approach, and to facilitate technology transfer.

PAAMS has become, internationally, the annual platform to present, discuss, and disseminate the latest developments and the most important outcomes related to real-world applications. It provides a unique opportunity to bring together multi-disciplinary experts, academics and practitioners to exchange their experience in the development and deployment of agents and multi-agent systems.

PAAMS aims to bring together researchers and developers from industry and the academic world to report on the latest scientific and technical advances in the application of multi-agent systems, to discuss and debate the major issues, and to showcase the latest systems using agent-based technology. It will promote a forum for discussion on how agent-based techniques, methods, and tools help system designers to accomplish the mapping between available agent technology and application needs.

CASSIOPEIA's partner, the IT faculty of UPM, will present a paper based on the multi-agent architecture of the general software platform.

xi. CASS.CAD.010 - Publication of papers with results through ComplexWorld.eu

At the date of completion of this document there has not been any paper published that included the results of the case studies. Innaxis, managing the website of ComplexWorld.eu, will publish these papers as soon as they are approved for publication.

xii. CASS.CAD.030 - Case Study 3 results circulation

Throughout 2014, the University of Westminster intends to circulate Case Study 3 results to industry and software developers with an interest in the operational assessment of Dynamic Cost Indexing (DCI). Interested parties include PACE for their *Pacelab CI OPS* electronic flight bag tool and Lufthansa Systems' *Lido OC*.

c. Demonstrations

There have been no demonstrations, nor are any expected, in the dissemination activities of CASSIOPEIA.

d. Exploitation plans

The CASSIOPEIA consortium plans several lines of exploitation of the results achieved in the project:

xiii. Results obtained through the operational scenarios and case studies considered during the project

The Air Transport Group of ETSIA/UPM (the Group) will use the results obtained in the analysis of the local environmental-restrictions at airports for the improvement of the academic and research activities of the Group. The elaboration of PhD theses and the corresponding publication of research work are envisaged. CASSIOPEIA results will also enhance the training material that the Group employs in both graduate and post-graduate programmes. Additionally, the Group participates in related research activities dealing with environmental-related issues in air transport with different air transport stakeholders and the knowledge gained through the simulation of this operational scenario will be used in those activities,

The University of Westminster will maintain an open dialogue with the stakeholder survey respondents and workshop participants. Interested parties will be kept informed of WP-E research developments and invited to future project events. The results obtained from the simulations of the use of dynamic cost indexing will feed planned work with a major European airline and handling agent with regard to their delay-recovery management, and there is similar research potential with a major US airline.

xiv. Exploitation of the current platform and expansion to support additional case studies

The current platform supports the three operational scenarios documented in this report. Those operational scenarios are fully implemented and, although some configuration changes are needed to support additional case studies, the current platform can be expanded to support deeper analysis of those scenarios, including additional airports or different airspace blocks.

Innaxis will look into the exploitation of the results obtained through the simulations of the exchange of en route slots within the current ATM development and deployment programmes (mainly SESAR). The results would help to understand and assess the potential and limitations of such mechanisms and help to build CBA of current technology demonstrators adding new case studies as needed.

xv. Use of the modelling methodology and evolution of the CASSIOPEIA platform to support additional operational scenarios

Innaxis plans to exploit the methodology developed in CASSIOPEIA for the modelling of complex operational scenarios in which the interaction among different actors is key. The methodology used during the project will allow us to drive the development of agent-based models capable of reliably representing those scenarios. The extension of the current CASSIOPEIA platform to cover additional scenarios would allow leverage of the existing infrastructure and methodology. Operational scenarios

that could be considered include UDPP trajectory management, or extended fleet management and schedule recovery with SWIM integration.

xvi. Use of the know-how gained to explore how operational concepts could be implemented

While agent-based modelling as a technology aims to understand complex phenomena rather than to be an operational piece for operational concepts to be implemented, some elements of the technology developed could be used for the development of technology to support such operational concepts. For instance, the application of Collaborative Decision Making (CDM) under different user capabilities, or the application of a new regulatory framework of passenger rights regarding delays.

xvii. Use of results about software architectures for agent-based simulation systems

The research group of the Department of Artificial Intelligence (DAI) at the IT faculty of UPM will use the experience gained in the development of general software architectures for agent-based simulation systems to improve the research and academic activities of the Group. The Group plans to publish the research work for international audiences as well as the results in CASSIOPEIA about agent models for simulation and reusable software architectures. The experience in agent-based models in the CASSIOPEIA project will be also used as part of university programs (both graduate and post-graduate). The Group plans to continue its research activities with new project proposals related to agent-based simulation systems in complex domains as a continuation of the lines of work initiated in the CASSIOPEIA project.

5. Total eligible costs

This section is based on the project-costs breakdown forms of the eligible costs incurred by project participants.

Table 2 Overview of billing

Date	Deliverables on Bill	Contribution for Effort	Contribution for Other Costs (specify)	Status
Dec.2011	0.1, 0.2, 1.1, 1.2, 1.3	60.500,00 €	Travel and subsistence: 3.629,66 €	Paid
Jul.2012	0.3A, 2.1A	78.052,50 €	Travel and subsistence: 1.888,94 €	Paid
Oct.2012	0.3, 2.3, 2.7, 3.3, 5.2	114.099,31 €	Travel and subsistence: 341,09 € Software: 7.500 €	Paid
Jun.2013	0.4, 2.1, 2.2, 2.4, 3.1, 3.2, 3.4, 3.5, 3.6	175.548,75 €	Travel and subsistence: 1.935,22 €	Paid
Nov.2013	0.5, 2.5, 2.6, 4.1, 4.2, 4.3, 5.3,	147.949,44 €	Travel and subsistence: 4.874,32 €	Unpaid
Dec.2013	-	-	Travel and subsistence: 1.580,77 €	Unpaid
GRAND TOTAL		**576.150,00 €**	**Travel and subsistence: 14.250,00 €** **Software: 7.500 €**	

Table 3 Overview of effort and cost per project participant

Company	Planned man-days	Actual man-days	Total Cost (estimation pre-5th invoice)	Total Contribution (estimation pre-5th invoice)	Reason for Deviation
Innaxis Foundation	620 (as 8 hours/day)	665	320.357 €	239.475 €	
UPM	470 (as 7,5 hours/day)	685	318.525 €	218.550 €	Additional effort required to prepare data and to program specific algorithms for three case studies.
University of Westminster	182 (as 7,5 hours/day)	313	198.769 €	118.125 €	(i) Additional effort required to organise the stakeholder survey and workshops; (ii) considerable data cleaning and preparation required for Case Study 3.
GRAND TOTAL	**1.272**	**1.663**	**837.651 €**	**576.150 €**	

6. Project lessons learnt

Table 4 Project lessons learnt

What worked well?
Stakeholder interaction. The preparation of workshops and surveys allowed the CASSIOPEIA team to understand the stakeholder needs. The results of these dissemination activities allowed the team to decide three case studies which were of great interest to the aeronautical industry while being very different in terms of timeframes, scopes and agent definitions.
Communications between partners through the use of internet-based collaborative documentation services. The participation of all partners in the inGrid system proposed by the coordinator has simplified the communication between partners, reducing the amount of necessary face to face meetings or conferences while maintaining every person involved up to date with the latest developments and to foresee schedule and work plan deviations.
Research community reach out and dissemination through the use of professional social networks. The use of new technologies and professional social networks has allowed us to disseminate the actions and findings to expert groups and keep track of comments and visualization statistics of the project web page by establishing links on the different networks.
It is very difficult to combine research projects with strict project management planning. If the research perform is relevant and really advances the state of the art in one discipline, keeping the project plan as specified years ahead is generally not doable. The Project Officer was supportive and flexible regarding appropriate planning and timescale changes and helped to keep the administrative burden down.
Agent-based modelling methodology is not standardized and the team worked establishing a set of modelling procedures that were agile enough to take the project from requirements to specifications to actual software implementation in a short period of time.
What should be improved?
The management of foreground generated throughout the project is key for these collaborative projects, and its management should be clear to all partners.
It might be useful if WP-E could coordinate the purchase of key external (non-EUROCONTROL) data and licence these for multiple project use, to save unilateral efforts from projects. (The University of Westminster would be willing to support such an initiative, if deemed appropriate and viable.)
Most of the dissemination is planned after project deadline, once results and conclusions are available. This should be considered in the general planning (including budget) and expectations from the SJU.
The coordination with the main SESAR work programme is almost negligible. Gaining the right visibility over the SESAR programme and potential users of the CASSIOPEIA technology would have been ideal but there are no formal mechanisms to do this.
The specific content of each deliverable varies in importance throughout the project, since information is sometimes duplicated, or explained from different perspectives. Under certain conditions, it would be more efficient if it was possible to eliminate a deliverable and switch its effort to other tasks or deliverables.

7. References

1. Air Transport Research Society (1997). *ATRS World Conference*. Extracted in October 2013. Retrieved from http://www.atrsworld.org/conferences.html
2. CIT (2014).*11th Transport Engineering Conference*. Retrieved from http://www.cit2014.unican.es/index.php?lang=en
3. El Sevier. *Journal of air transportation management (JATM)*. Retrieved from http://www.journals.elsevier.com/journal-of-air-transport-management/
4. IADIS (July 2012). IADIS International Conference Intelligent Systems and Agents 2012. Retrieved from http://iadisportal.org/previouseditions/ISA_2012.pdf
5. Innaxis foundation and research centre. *Complex Systems Research in ATM*. Retrieved from http://www.complexworld.eu/
6. Innaxis foundation and research centre & University of Westminster (2012). High Level Functional Specification - Model inputs. *SESAR joint undertaking*. Retrieved from http://www.complexworld.eu/wp-content/uploads/2012/12/E.02.14-CASSIOPEIA-D1.1-High-Level-Functional-Specification-Model-Inputs-V1.1.pdf
7. Innaxis foundation and research centre & University of Westminster (January 2012). Air traffic management performance-seminar and workshop. Retrieved from http://home.wmin.ac.uk/airspace/q/TopicGuideB.pdf
8. Practical Application of Agents and Multi-agent Systems (2014). *12th International Conference on Practical Applications of Agents and Multi-agent System*. Retrieved from http://www.paams.net/
9. SESAR WPE (2012). *SID 2012 SESAR second innovation day*. Retrieved from http://sesarinnovationdays.eu/SID2012
10. SESAR WPE (2013). *SESAR third innovation day*. Retrieved from http://sesarinnovationdays.eu/